



ANU ENERGY CHANGE INSTITUTE ANNUAL REPORT

2016

CONTENTS

| Message from the Director | 1 |
|--|----|
| Highlights | 2 |
| Mission | 5 |
| Governance | 6 |
| Education | 7 |
| Research | 10 |
| The ANU Energy Master Plan | 29 |
| The Australia-Indonesia Centre Cluster | 30 |
| Public Policy | 31 |
| Events | 34 |
| Outreach | 36 |
| Media and Communications | 37 |
| Awards | 38 |
| Outlook | 39 |
| Appendix | |
| Advisory Board Membership | 40 |
| Executive Membership | 41 |
| ECI Participants | 42 |

MESSAGE FROM THE DIRECTOR



2016 was a landmark year for the ANU Energy Change Institute. In partnership with the ACT government we announced a new \$8 million research program in Battery Storage and Integration, seeded by an initial \$4 million grant from the ACT Renewable Energy Innovation Fund. This is a successful outcome of the ACT renewable energy reverse auction process, and will see the appointment of a worldclass research leader to establish a new ECI research program in this field.

In another successful outcome of the ACT renewable energy reverse auction, in 2016 we commenced the new course in Wind Energy delivered by Windlab Ltd (one of the reverse auction winners), with 27 students in the commencing cohort. We will also introduce a new course in 2017 on Integration of Renewable Energy into Power Systems and Microgrids with the assistance of CWP Renewables, another reverse auction winner. Other partnerships with winners Union Fenosa and Neoen are currently being developed for future research activities.

The ECI is also entering into a new partnership with our local energy provider ActewAGL who will engage in a number of areas. Their \$2 million ANU endowment program with ICON Water will be restructured to provide new research opportunities for ECI researchers. In addition, further collaborative research programs are being developed, some in partnership with renewable energy companies. As the ANU Energy Master Plan develops, ActewAGL will be involved with consultations in key areas of the plan informed by their expertise. And we are delighted to announce that ActewAGL is the very first principal sponsor of the ECI annual flagship event - Energy Update 2016.

The ECI has also expanded its educational portfolio through the delivery of professional short courses to a range of organisations. In 2016 this included the Department of Defence, the Department of Environment and Energy, the Indonesian Leadership program (through the Australia-Indonesia Centre - AIC) and the Centre for Defence and Strategic Studies.

The ECI is the lead organisation for the Energy Cluster of the AIC, and I chair the Cluster program. We are engaged with the Indonesian Ministry of Energy and Mineral Resources via a Memorandum of Understanding established following several collaborative visits from both parties. Through a \$100,000 AIC grant, we will develop an Indonesian energy technology assessment to inform the 35 GW expansion of their electricity sector by 2025. In three other projects focusing on the key AIC energy theme of micro-grids, ECI researchers have received over \$0.5 million in collaborative research funding with our Indonesian partners. This is in addition to almost \$6 million in external funding won by individual ECI researchers from other agencies, principally ARENA.

In the public policy arena the ECI has continued to be a leader nationally, with significant contributions to the South Australian Nuclear Fuel Cycle Royal commission, the COAG Energy Ministers consultations on reforming the National Electricity Market, and through the holding of a national forum on Energy Security in partnership with Engineers Australia. And as always, Energy Update continues to be a major national focus for discussions on energy policy.

Administratively 2016 has been an important year, with the ECI and the ANU Climate Change Institute receiving separate operating budgets for the first time, while sharing the Communications Manager position held by Clare de Castella. Dr Igor Skryabin continues to expand the research and education funding portfolio of the ECI as Business Development Manager. The ECI has received administrative support from the Research School of Physics and Engineering, as well as resources from the College of Engineering and Computer Science. The ECI Secretariat staff have done a fantastic job in helping to deliver these excellent outcomes in 2016.

As our interactions with industry, government and the wider community continue to expand, we hope that our engagement with you helps advance the prospects for Energy Change.

Professor Ken Baldwin ECI Director

HIGHLIGHTS

From ECI Open Day 7th December 2015 to Energy Update 29th November 2016

ECI Open Day 7 December 2015

The Energy Change Institute Open Day provides a platform for exchanging ideas for ANU based researchers and stakeholders working in the field of energy change. 2015 highlights included a live update from the CoP 21 UNFCCC Paris Climate Conference by Associate Professor Frank Jotzo, the announcement of two new energy research clusters - Energy & Security and Wind Energy - and tours of the world-leading energy change research facilities at ANU.



From left: Associate Professor Llewelyn Hughes (Crawford School, ANU), Nicole Thomas (Department of Industry, Innovation and Science), Professor John Williams (Crawford School, ANU), Damian Dwyer (Australian Petroleum Production and Exploration Association) and Tony Wood (Grattan Institute) take part in panel discussion at Energy Update 2015.

ANU Energy Update 8 December 2015

The annual ECI flagship event Energy Update brought together Australian researchers, policymakers, industry and members of the public to provide news on the latest world energy trends. The event was opened by Professor Brian Schmidt (now ANU Vice Chancellor).

Ian Cronshaw of the International Energy Agency presented the IEA's perspective on the World Energy Outlook (WEO) 2015, followed by a keynote address by Mr Byron Washom on *UC San Diego's Microgrid: The World's Largest, Most Diversified Portfolio of Distributed Energy Resources.* Panels of expert speakers also presented their perspectives on two key WEO themes: Renewables & Energy Efficiency, and Unconventional Gas.

Creating Energy Efficient Cities in Switzerland and Australia 22 February 2016

A panel of experts from Switzerland and Australia discussed, compared and contrasted opportunities for energy innovation across various urban centres. Swiss energy efficiency experts, Roland Stultz, Martina Blum and Andreas Luzzi, outlined how the vision of a "2000 Watt Society" can be achieved using efficiency and sufficiency with co-ordinated planning at regional, town, neighbourhood and building level. The event highlighted the contrasting approaches of the two countries, notably Australia's primary focus on increasing renewables and Switzerland's primary focus on reducing energy consumption.



From left: Mr Roland Stulz (2000 Watt Society), Martina Blum (City of Zurich), Megan Ward (ACT Government), Dr Andreas Luzzi (Laros Technologies), Dr Mike Smith (ANU) and Dr Igor Skryabin (ANU) participate in panel discussion on Creating Energy Efficient Cities in Switzerland and Australia.

Energy Conversations – Integrating Renewables and Storage into the grid 3 May 2016

In this joint series with the Australian Energy Institute (ACT Branch), a panel of energy researchers and industry representatives gave their perspectives on integrating renewables into the grid.

This event provides a forum for conversations between different parts of the local energy sector about emerging research and technology.

The Vote: 2016 Federal Election Series – Climate Change, Energy and the Environment 21 June 2016

Four speakers discussed climate and energy policy in the context of the Federal Election and responded to audience questions. Key themes were the ability of different policies to meet Australia's greenhouse gas reduction targets and the commitments made in the Paris Climate Change Agreement.



Mark Kenny (Sydney Morning Herald), Lily Dempster, Dr Paul Burke (Crawford School, ANU), Professor Ken Baldwin (ECI) and Professor Mark Howden (Climate Change Institute). Image credit: Katharine Pierce, ANU.

Announcement of new Battery Storage and Integration Research Program 7 September 2016

ACT Environment Minister, Simon Corbell, announced a new international research program at ANU to improve ways to store renewable energy that can be integrated into the electricity grid. The program is part of an \$8 million partnership between ANU and ACT Government.

As the proportion of renewables in the grid grows, battery storage and its integration are becoming increasingly important to address intermittency in renewable energy supply. This research program will feed into existing cutting-edge energy research at ANU and in the ACT, facilitating the transition to a broader low-carbon electricity system.



From left: Professor Brian Schmidt (ANU Vice Chancellor), Simon Corbell (ACT Environment Minister) and Professor Ken Baldwin (Director, Energy Change Institute) at the announcement of the new Battery Storage and Integration Research Program. Image credit: James Walsh, ANU.

"Energy, and understanding how to provide the world's people with abundant and inexpensive energy, is the key factor that is going to make or break society's ability to deal with the challenge of living sustainably on planet earth."

Professor Brian Schmidt ANU Vice Chancellor

Energy Security Forum 13 October 2016

This forum, presented by the ECI and Engineers Australia, was attended by a diverse audience including policy makers from a range of government departments, industry, researchers and NGOs. Speakers focused on two dialogues: *A Resilient Energy Future: How should Australia manage its energy supply and infrastructure? and Energy and Global Risks: How should Australia contribute to ensuring regional and global public goods?*

The forum found that Australia's energy security needs to be reviewed in the face of new threats from climate change, cyber attacks and greater complexity in the energy system.



From left: Michelle Price (Department of Prime Minister & Cabinet and on secondment to ANU National Security College), Dr Paul Barnes (ASPI Director of Risk & Resilience) and Dr Robert Care (Arup Australia) at the Energy Security Forum organised by the ECI and Engineers Australia.

The Importance of Innovation to Global Clean Energy Deployment – past and future 20 October 2016

Dr Julio Friedmann, Senior Fellow, Lawrence Livermore National Laboratory, California and former Principal Deputy Assistant Secretary for the Office of Fossil Energy at the US Department of Energy, presented an ECI public lecture on recommendations that will have the most impact in bringing innovations forward across the breadth of clean energy deployment.

HIGHLIGHTS

The Energy Change Institute is all about what universities are meant to do – they're meant to take knowledge, they're meant to teach people, they're meant to learn stuff and they're meant to work with the rest of society to take that knowledge and to disperse it.

Professor Brian Schmidt ANU Vice Chancellor



Coming Up

ECI Open Day 28 November 2016

ECI Open Day showcases ANU energy research. Highlights of the program this year include the latest state-of-the-art energy research, with a focus on the work of new Energy Change Institute members, new company research programs and new ActewAGL / ICON research grant opportunities for researchers. The formal presentations are followed by tours of the world-class ANU energy laboratories.

ANU Energy Update 29 November 2016

Highlights of the upcoming Energy Update include an opening address by the Honorable Josh Frydenberg, Minister for the Environment and Energy, the 2016 World Energy Outlook presented by Ian Cronshaw from the International Energy Agency in Paris, progress in thermonuclear energy by Dr Jean Jacquinot (senior advisor to the ITER director) and panel discussions on two of the WEO 2016 themes: Climate Change Response Post-Paris and Dominantly Renewable Energy Futures. This year, Energy Update is sponsored by ActewAGL.

ACT Government / ANU annual Solar Oration: The Carbon War – a dispatch from the front lines 29 November 2016

Energy in society can be thought of as being in a state of global civil war, with a light side and a dark side and many sideless people caught in the crossfire. Jeremy Leggett, who is presenting this year's Solar Oration, is a social entrepreneur and author of The Carbon War and Half Gone. He is founder and chairman of Solarcentury, an international solar solutions company, and founder and Chairman of SolarAid.

MISSION



Image Credit: James Prest, ANU.

A key solution to the challenge of climate change is a world-wide shift to lowcarbon forms of energy. Energy change that drives this transformation to a clean economy in response to climate change will also offer wider benefits to society by increasing economic productivity, and by improving energy access and security.

The ECI provides authoritative leadership in energy research, education and public policy through a broad portfolio ranging from the science and engineering of energy generation and energy efficiency, to energy economics, regulation, security, sociology and policy.

A defining feature of the ECI is that we are both technology and policy neutral. That is, we undertake research and education in key areas of energy technology and energy policy without favouring one particular area over another. This can and should create an open forum for good ideas leading to energy change.

GOVERNANCE

EDUCATION



ECI Executive team and staff. Back row from left to right: Professor Ken Baldwin, Professor Andrew Blakers, Andrea Butler, Associate Professor Llewelyn Hughes, Dr James Prest, Dr Igor Skryabin. Front row from left to right: Professor Elmars Krautz, Professor Sylvie Thiebaux, Associate Professor Kylie Catchpole, Clare de Castella. Image credit: Jack Fox, ANU

The ECI comprises more than 150 academic staff and their postgraduate research students, bringing the total complement to over 300 researchers.

The wider ECI membership meets twice a year: at the Annual Business Meeting (ABM), which establishes the activity for the coming year; and at the ECI Open Day which presents research highlights to the ECI stakeholder community.

Operationally, the ECI is governed by an Executive comprising representatives from ANU Colleges:

ECI Executive

Professor Ken Baldwin – Director ANU College of Physical & Mathematical Sciences

Professor Andrew Blakers ANU College of Engineering & Computer Science

Associate Professor Kylie Catchpole Education Convenor, ANU College of Engineering & Computer Science

Associate Professor Llewelyn Hughes (vice Dr Paul Burke) ANU College of Asia & the Pacific

Professor Elmars Krausz (vice Associate Professor Colin Jackson)

ANU College of Physical & Mathematical Sciences **Dr James Prest** (vice Professor Tom Faunce)

ANU College of Law Dr Igor Skryabin

Business Development Manager, ANU College of Physical and Mathematical Science

Professor Sylvie Thiebaux (vice Dr Evan Franklin) ANU College of Engineering and Computer Science

The Executive meets regularly throughout the year as required.

The strategic directions of the ECI are reviewed each year when the Executive meets with the ECI Advisory Board.

ECI Advisory Board

Professor Armin Aberle, CEO Solar Energy Research Institute of Singapore

Ms Glenys Beauchamp PSM, Secretary Department of Industry, Innovation and Science

Mr Stephen Devlin, General Manager Assets Division ActewAGL

Ms Dorte Ekelund, Director General of Environment and Sustainable Development

ACT Government

Mr Ian Farrar, Board Member

Centre for Sustainable Energy Systems (former Chair and CEO of the Joint Coal Board)

Professor John Poate Colorado School of Mines (Member of the US National Renewable Energy Laboratory Advisory Board)

Professor Mark Howden, Director ANU Climate Change Institute



The ACT Wind Auction helped support the development of Coonooer Bridge Wind Farm, which commenced operations in February 2016. Windlab, who operate Coonooer Bridge, contributed the new ECI course in Wind Energy as part of their reverse auction commitment. Image credit: Windlab Ltd

Master of Energy Change

A key to addressing climate change is a world-wide change to carbon-free forms of energy.

Energy change also offers a number of other benefits to society: it not only facilitates the transition to a sustainable economy, but also improves energy access and security, and increases energy productivity for the benefit of the wider economy.

Currently there are relatively few practitioners with a broad understanding of the many issues involved, or the skills needed to contribute to, this complex growth area.

The Master of Energy Change (MEnCh) equips the next generation of energy decision makers with the knowledge and skills to help drive and lead the energy revolution.

Addressing the challenges of energy change requires innovative, interdisciplinary approaches. The Master of Energy Change provides a strong basis in the fundamentals of economics, governance, policy, sociology and technology related to energy change, whilst also giving students the flexibility to focus on areas of energy innovation most relevant to their professional needs, interests and skills.

As the need for energy change grows, demand for these skills will only increase.

The degree includes two foundation courses and the option of 41 elective courses.

The foundation courses are:

> Principles of Energy Generation and Transformation

> World Energy Resources and Renewable Technologies

These courses are aimed at providing students who do not have a technical background with an understanding of the principles underpinning energy technologies. The course "Principles of Energy Generation and Transformation" was specifically developed for this degree. The program now involves almost all ANU Colleges.

The remaining subjects are grouped into the key discipline areas of:

- > Energy regulation and governance
- > Energy economics
- > Climate change
- > Environmental sustainability
- > Specific energy technologies (solar, wind, nuclear etc.)
- > Energy sociology and risk

In addition to the formal coursework, MEnCh students can participate in the wider activities of the ECI, which include seminars presented at the ANU, conferences and workshops engaging with government and industry, and other outreach programs with the wider community. Carefully targeted promotion of the Master of Energy Change remains the key to advancing this program.



Students from the wind energy course at Gunning Wind Farm. Site visit courtesy of Acciona Energy.

EDUCATION



Sovia Sara, Master of Energy Change graduate.

Alumni Profile: Tackling energy issues from every perspective

Sovia Sara works in the energy sector of the Indonesian Government. She has just completed the Master of Energy Change (MEnCh) at ANU.

Sovia was looking for energy related education that involved not just science and engineering, but also policy. She believes she found the ideal combination in the MEnCh because it's a genuinely multi-disciplinary program.

I've studied not just science and engineering related energy issues but also many other aspects of energy which will be very useful for my career, including policy, economics, environment and law.

She feels it's vital to understand a wide range of issues and their relationship with energy, particularly for those working in government.

"Energy problems in society impact a combination of many different sectors. As the program is so multidisciplinary, I've been able to meet, discuss, and connect with people from different backgrounds who are all experts in their field."

Sovia says she would highly recommend the program to others, both from within and outside government. "This degree provides graduates with vital knowledge, great experience and networks which are critical in dealing with energy related problems."

Wind Energy

The first edition of the Wind Energy course was successfully developed and delivered to ANU students in 2016 and was considered a roaring success. The course covered a broad range of topics relevant to wind energy and wind farm development with a focus on technical aspects and the physics of wind energy. Lecturers included Professor Andy Hogg (Atmospheric Structure and Global Scale Circulation), Dr Keith Ayotte (Mesoscale and Microscale Meteorology and Modelling),

Dr Horst Punzmann (Wind Measurement and Remote Sensing), Dr Nathan Steggel (Wind Development), Dr David Osmond (Wind Energy Assessment Processes), Dr Elizabeth Hanna (Health Impacts of Wind Farms) and Dr James Prest (Legal Aspects of Wind Development).

New course in 2017

In 2017, a new course will be introduced:

Integration of Renewable Energy into Power Systems and Microgrids

This course aims to provide a thorough understanding of power systems, their operation and control and particularly issues related to the integration of distributed renewable generation into the network. The content focuses on technical aspects of traditional and renewable electrical power generation, power transmission and distribution, power network stability, management and control, electricity market operations and smart grid technologies with particular emphasis on the integration of renewable generation into the network at both transmission and distribution level and the challenges and opportunities associated with that.

Professional Short Courses

The Energy Change Institute regularly runs short courses and briefings for government departments, companies and NGOs. Short courses are designed to provide updates on recent advances in the science & technology of energy generation, and the social, policy, economic and governance aspects of energy change for policy makers and professionals. They can be tailored to meet the needs of a specific audience, and scheduled over consecutive days or spread over weeks. For example:

- In June 2016, the ECI delivered a comprehensive 3-day short course on "Defence Energy" for the Department of Defence, which included sessions on Energy Fundamentals, Science of Climate Change and Climate Change Adaptation, Energy Futures, Energy Efficiency Opportunities - Land, Sea and Air, Solar PV, Solar Thermal, Wind and Nuclear Energy Technologies, Electricity Grids, Energy Systems, Energy and Economic Growth, and Energy Security.
- In September 2016, ECI delivered a one-day intensive course titled "Renewable Energy and Energy Technologies". This course was commissioned by the Department of the Environment and Energy (DEE) and attended by more than 20 training participants from DEE, the Department of Industry and the Clean Energy Regulator.



Student Profile: Bridging the gap between energy technologies and advocacy

With a background combining law and advocacy, MEnCh student Lily Dempster was drawn to the degree because of its multidisciplinary nature, flexibility and large range of electives.

multidisciplinary nature, flexibility and large range of electives. "I've been passionate about climate change mitigation and sustainability for a long time. I chose this Master's because I believe I'll be a better advocate if I have a decent technical overview of different renewable energy technologies and greater scientific literacy." After completing an undergraduate I aw degree at ANUL Liv

After completing an undergraduate Law degree at ANU, Lily worked at the Department of Prime Minister and Cabinet, before being employed by online community advocacy group GetUp on a range of campaigns, including on clean energy and coal seam gas.

I searched everywhere for a Master's degree within Australia that would help bridge the gap between energy technology and advocacy and this was the only one I could find that didn't require you to have a background in science or engineering.

Find out more about the Master of Energy Change degree:

Associate Professor Kylie Catchpole (MEnCh Program Convenor) T +61 2 6125 0874

- E kylie.catchpole@anu.edu.au
- W energy.anu.edu/education/master-energy-change

Lily Dempster, current Master of Energy Change student.

This program provides you with the physics and engineering knowledge you need up-front.

Doing this course has also reaffirmed in my mind that ANU really is a worldclass university. You get great access to academics and practitioners, as well as being close to the policy community as a whole.

Lily said a wide range of people could benefit from the program, from those who are interested in renewables, environment and sustainability but don't have a technology background, to those with deep technical knowledge who want to learn how to effectively communicate and impact policy and behaviour.

RESEARCH

The expanded ECI research program covers a broad spectrum from energy science, engineering, efficiency and technology, to implementation expertise in the economic, legal, security, sociological and policy issues surrounding Energy Change. This broad portfolio of research activity is unique in the country.

The ECI continues to add new researchers to its portfolio. The number of staff members now exceeds 150, which together with PhD students yields close to a total of around 300 researchers in total.



Last year two new research clusters – Wind Energy and Energy and Security – were added to the ECI portfolio, bringing the total number of clusters to 18:

- > Artificial Photosynthesis
- > Biofuels
- > Carbon Capture & Storage
- > Energy & Security
- > Energy Economics & Policy
- > Energy Productivity, Energy Efficiency & Demand Management
- > Energy Regulation & Governance
- > Energy Sociology & Risk
- > Energy Storage & Recovery
- > Energy-Water Nexus
- > Enhanced Oil & Gas Extraction
- > Fusion Power
- > Nanostructure Photovoltaics
- > Nuclear Science
- > Smart Grid
- > Solar Photovoltaics
- > Solar Thermal
- > Wind Energy

The Energy Storage and Recovery cluster will be boosted by the new \$8 million research program in Battery Storage and Integration, funded in a partnership with the ACT Government Renewable Energy Innovation Fund. This was a result of the investments realised by the ACT Government renewable energy reverse auction process, which has also created collaborative research projects with a number of companies, including Windlab, Neoen, Union Fenosa and CWP Renewables.

Researchers in the ECI were also the recipients of numerous research grants, including:

- A total of more than \$5 million from ARENA for residential battery storage, robotic inspections of PV and solar thermal plants, solar forecasting and pumped hydro storage
- More than \$0.5 million from the Australia-Indonesia Centre for microgrids and energy technology assessment,
- > A further \$0.5 million from the AutoCRC to investigate sustainable transport.

With the continuation of ARENA funding from 2016 (albeit at a reduced level), the ECI will be looking to continue its success in Energy Change research.

To find out more about ECI research, go to energy.anu.edu.au/research

Artificial Photosynthesis

The ANU Artificial Photosynthesis research cluster involves individual and collaborative efforts of four ARC funded research groups and 25 staff. Key studies are on the mechanism of water-splitting, the fundamental processes and efficiencies of biological photo-energy conversion and the design and properties of biomimetic molecular assemblies. Research into and development of a range of effective biomimetic catalyst systems, in particular splitting of water into hydrogen and oxygen, is a main focus.

Recent breakthroughs include the successful replication of crucial photosynthesis steps which use biological systems powered by sunlight to manufacture hydrogen as a fuel, as well as details of fundamental charge separation processes and the oxygen evolution in photosynthesis.

Such advances help pave the way for affordable fuel alternatives, particularly in developing countries.

Professor Ron Pace and Professor Rob Stranger have received a Discovery Transfer Fund Grant from the ANU for research into the development of cheaper and more efficient catalysts. These catalysts will make electrolysis cost competitive with fossil fuel based methods currently used for hydrogen production.

Dr Cox, an ARC future fellow and new faculty member at the Research School of Chemistry, is helping to establish Australia's first high-field electron paramagnetic resonance facility to conduct new chemistry, structural biology and materials science applications. He received the Robin Hill Award from the International Society of Photosynthetic Research for his work, helping to develop new methods to investigate the mechanism of biological water oxidation.

Professor Tom Faunce continues to work on drawing attention to the regulatory and policy needs of the artificial photosynthesis as emerging technologies. In September 2016 he organised the Global Artificial Photosynthesis conference in Canberra and Lord Howe Island on 'Breakthroughs for the Sustainocene'. This international conference was dedicated to developing the scientific breakthroughs and governance structures for globalising artificial photosynthesis and promoting its role in environmental and social sustainability.



Cluster Members: Professor Tom Faunce Dr Jeremy Hall Professor Elmars Krausz Professor David Ollis Dr Ron Pace Professor Robert Stranger

Biofuels

Biofuels research at ANU takes place at both the Research School of Chemistry and the Research School of Biology.

At the Research School of Biology, the research has a strong focus on plant science. Research is conducted by world leading researchers in photosynthesis, plant physiology and biochemistry, biotechnology and high throughput analysis.

A recent highlight in the area of biofuels is the discovery of eucalyptus as a potential source of terpenes that could serve as jet fuel. The world aviation sector produces about two per cent of all human-caused carbon dioxide emissions.

Eucalyptus plantations globally produce up to 200kg of oil per hectare per year, but by selecting the best genetic stock they could produce more than 500kg of oil per hectare. Jet fuel derived from eucalyptus oils would be close to carbon neutral. These trees can be planted on marginal lands that have low rainfall, and we can also plant them in agricultural systems that have salinity problems and help them defeat that problem.

Scientists are a step closer to using Australia's iconic gum trees to develop low-carbon renewable jet fuel.

Further research is focused on developing high lipid producing microalgal strains for large scale cultivation.

At the Research School of Chemistry, the research focuses on harnessing the catalytic power of enzymes to enhance biodiesel production. Biodiesel can replace fossil fuels as a renewable energy source, yet its use is limited by our reliance on free fatty acids (FFAs) from plant sources and excessive water consumption.

The research aims to address both of these obstacles. It proposes a waterless alternative to traditional methods of biodiesel production, where we harness the catalytic power of enzymes. It also proposes using sewage sludge from wastewater plants as a low cost and local source of FFAs. The research aims to repurpose a recently discovered enzyme from the Australian blowfly to survive in the extreme environments of a biodiesel reactor.

The ANU hosts major facilities for structural detection and quantification of molecules (mass spectrometry, NMR) as well as providing world class facilities for the controlled growth of plant and algal materials. Our researchers collaborate with leading European, Japanese and United States groups and the ANU supports the Plant Energy Biology ARC Centre of Excellence.



Cluster Members: Associate Professor Michael Djordjevic Professor Graham Farquhar Associate Professor Colin Jackson Dr Carsten Kulheim Dr Ron Pace Dr Dean Price

Above: David Kainer and Dr Carsten Kulheim holding biofuels produced from eucalypts. Image courtesy of Stuart Hay, ANU

Carbon Capture & Storage

One way to reduce greenhouse emissions, while minimising disruption to high-carbon industries, is to capture the emitted carbon dioxide before it enters the atmosphere, then store it deep underground at high pressure, inside porous rocks. The Carbon Capture & Storage (CCS) node of the ECI examines efficient and effective CO₂ capture and storage.

Endex thermoreactive principles underpin new high efficiency systems for separating carbon from fuels and flue gases. In collaboration with Imperial College London, the University of Leeds, CanMet Energy, and an industry partner, Calix Ltd, ANU researchers are developing a suite of Endex carbon capture technologies.

CO₂ Storage

Demonstrating the long-term security of CO₂ storage is an essential first step in CCS. Research into supercritical CO₂ and water flow at the micron-to-centimetre scale has been conducted with support of Australian National Low Emissions Coal (ANLEC) R&D focusing on rocks from the CCS flagship site in Queensland's Surat basin. This research has demonstrated that strong water-wetting conditions will prevail, enabling pore-scale CO₂ trapping and thus greatly reducing uncertainty in CO₂ storage at this site. Also, a new type of pore-network model was developed, the first to accurately capture the capillary trapping of CO₂ that occurs at the trailing edge of a migrating CO₂ plume. The model revealed that high levels of CO₂ trapping occur in ideal flow scenarios through the laminated (layered) Surat basin sandstone, although more investigation is required to quantify the implications of layering for trapping at larger scales.

This research has demonstrated that strong water-wetting conditions will enable pore-scale CO₂ trapping and thus greatly reduce uncertainty in CO₂ storage in Queensland's Surat basin.

The ANU X-ray CTLab is central to the research and will officially open in November 2016. CTLab houses a range of custom 3D X-ray microscopes and other analytical and core-flooding equipment used to help determine the security of CO₂ storage within aquifers at Australia's CCS flagship sites. Funding was primarily from the Department of Education's 'Education Investment Fund' (EIF), in association with the Cooperative Research Centre for Greenhouse Gas Technologies (CO₂CRC), \$5 million grant.



Ground-breaking findings on the origin of life more than 3.8 billion years ago have helped advance Endex CO_2 capture systems via very applied, industry-driven research.

Carbon dioxide capture at the dawn of life on Earth

The research uses entropy generation analysis to optimize the efficiency of the Endex calcium looping process. By applying thermodynamic optimization to a process, certain subprocesses are revealed as more imperfect than others. Detailed entropy accounting can identify and quantify these imperfections, or irreversibilities. Since the entropy generated in a process is linearly proportional to the cost of the fuel used to drive it, the classic tradeoff between operating and capital costs can be made rigorously when sound thermodynamic analysis is carried out at the design stage.

Energy and Security

The Energy and Security Research Cluster at the Energy Change Institute was established in 2015 to lead the conversation on the complex interactions between energy supply and demand and security in Australia, and in the Asia-Pacific region.

The relationship between energy and security has its origins in supply chain risks in the delivery of energy services. It now incorporates a broad set of issues, including the security and resilience of electricity supply systems, the implications of climate change for environmental and human security, the nexus between decarbonisation of the electricity grid and security of energy supplies, and the relationship between geopolitics, energy and national security. Australia is at the centre of many of these policy issues given its position as a major energy supplier to the Asia-Pacific region.

In October 2016, the research cluster partnered with Engineers Australia to host an Energy and Security Forum for government agencies, industry and researchers. The forum included dialogues on, "A Resilient Energy Future: How should Australia manage its energy supply and infrastructure?" and "Energy and Global Risks: How should Australia contribute to ensuring regional and global public goods?".

The forum found that both energy networks and the internet are critical services that are heavily interconnected and extremely vulnerable to a range of threats.

Australia's energy security thus needs to be reviewed in the face of new threats from climate change, cyber hacking and greater complexity in the energy system.

Such risks to our energy security can be minimized, on the other hand, through a systemic approach that emphasizes collaborative engagement across institutional barriers.



Cluster Members: Adjunct Professor Chris Barrie Dr Roger Bradbury Professor Quentin Grafton Associate Professor Llewelyn Hughe Dr Jennifer Hunt Professor Rory Medcalf Dr Brendan Taylor

Energy Economics and Policy

A market mechanism proposal for regulated exit of highly emissions intensive power stations could help Australia reduce its emissions from electricity generation.

Expertise in energy economics and policy at ANU is centred in the Crawford School of Public Policy and the Research School of Economics. The research cluster draws on disciplinary strengths in economics, governance, and political science. The Centre for Climate Economics and Policy (CCEP), directed by Associate Professor Frank Jotzo, anchors a network of Australian and international researchers providing insights on the economics of climate change and its implications for public policy. The Climate and Energy Program of the Centre for Applied Macroeconomic Analysis (CAMA), directed by Professor Warwick McKibbin, is an international network of scholars working in climate and energy.

Associate Professor Frank Jotzo has developed a market mechanism to achieve early closure of brown coal-fired power stations. The proposal recommended that plants bid competitively for exit payments and the remaining plant operators would pay. The scheme could save significant amounts of carbon dioxide emissions and also overcome difficulties that plague alternative schemes for payments or regulation for power plant closure. The idea found strong interest across a wide spectrum in industry and policy circles and was published in Economic Analysis and Policy.

In 2016, Dr Paul Burke released a paper on additionality challenges faced by the Emission Reduction Fund, including for energy-sector projects. The paper concluded that the Direct Action program often leads to inefficient spending on projects that would go ahead even without government support, and that the emissions reductions achieved by the scheme are likely being overstated. The paper was published in Economic Papers and received wide media coverage.

This year, Professor David Stern was elected Fellow of the Academy of the Social Sciences in Australia. He also commenced an ARC Discovery Project on energy efficiency innovation and diffusion (2016–2018) which saw Dr Zsuzsanna Csereklyei join the ANU to work on the project. Professor Stern is also Team Leader for an international project on energy and economic growth funded by the UK Department for International Development, and Dr Paul Burke is a team member for this project. Dr Burke commenced an Australian Research Council Discovery Early Career Researcher Award (DECRA) to study the effects of energy subsidy reform in Indonesia (2016–2018).



Cluster Members: Dr Imran Habib Ahmad Professor Robert Breunig Dr Paul Burke Professor Bruce Chapman Professor Robert Costanza Dr Zsuzsanna Csereklyei Dr Matthew Dornan Professor Quentin Grafton Associate Professor Carolyn Hendriks Honorary Professor Carolyn Hendriks Honorary Professor John Hewson Associate Professor Llewelyn Hughes Associate Professor Frank Jotzo Professor Kaliappa Kalirajan Dr Andrew Kennedy Dr Ida Kubiszewski Professor Warwick McKibbin Adjunct Professor Robert McMullan Dr Maria Racionero Professor Martin Richardson Honorary Associate Professor Hugh Saddle Professor David Stern

Energy Productivity, Energy Efficiency & Demand Management

Researching energy efficiency methods and management strategies to reduce greenhouse gas emissions and keep Australian businesses globally competitive.

Energy efficiency and demand management strategies are central to reducing energy demand growth. Investing in energy efficiency and demand management is also the lowest cost strategy to reduce greenhouse gas emissions. A range of ANU academics across three colleges undertake research in the fields of energy efficiency and demand management.

According to the International Energy Agency, between now and 2030, 55 percent of greenhouse gas mitigation potential lies in identifying and implementing energy efficiency opportunities.

Energy efficiency, design and business competitive advantage

Improving energy efficiency in the design of buildings, industrial processes and equipment, manufactured products, and transportation vehicles is critical to helping businesses remain competitive by reducing operational costs and strategically positioning them for growing global markets. ANU staff have contributed to a range of research projects over the last decade to better understand how to improve the energy efficiency of the design of engineered systems. For instance the ANU Research School of Engineering is a partner of the AutoCRC, which is researching how to achieve a step change in the fuel efficiency of transportation vehicles. The ANU Business School, through its Undergraduate Corporate Sustainability major, teaches the next generation of business leaders the potential of energy efficiency strategies to improve business competitive advantage.

IT and energy efficiency

IT products and services represent one of the fastest areas of energy demand and greenhouse gas emission growth, of any sector, nationally and internationally. ANU offers research opportunities and undergraduate and postgraduate courses in ICT and Sustainability, which focus on energy efficiency. ANU work in this area shows how, through energy efficiency, energy demand and greenhouse gas emissions can be significantly reduced over time.

Energy management systems

ANU also has expertise in research, design and implementation of effective energy management systems. For instance, the ANU has implemented and managed its own energy management system and energy efficiency strategy for close to a decade now. This has resulted in ANU achieving significant reductions in energy usage.



Cluster Members: Ms Christine Allard Mr David Glavas Mr John Sullivan Professor Xuemei Bai Dr Mike Dennis Professor Denis Evans Professor Denis Evans Professor Saman Halgamuge Professor Weifa Liang Dr Adrian Lowe Mr Bartholomew Meehan Dr Digby Race Honorary Associate Professor Hugh Saddle Dr Michael Smith Dr Idris F. Sulaiman Dr Shane West Mr Tom Worthington

Energy Regulation and Governance

The Regulation and Governance cluster brings together researchers concerned with questions of how the law can encourage, or impede, a rapid transition to a cleaner energy future.

A large body of literature states that poorly designed and/ or administered frameworks of institutions, regulation and governance can represent a barrier to a rapid transition to clean energy. This group's research involves examining options for law reform, the record of implementation of various laws, as well as the interaction of different levels of law, policy and governance. The researchers approach these vital questions on a number of different scales - international, comparative and by examining Australian issues of law and policy at federal and state levels. This cluster seeks to contribute to the debate by researching and publishing on various aspects of the best international models for energy transition.

Summary of current and recent research projects

One area of particular focus involves questions of the regulation of competition between firms in various sectors of the electricity market. Our research into electricity market governance draws upon competition law and market regulation frameworks to consider barriers to market entry of renewable energy and the attainment of renewable electricity targets.

Another theme concerns the influence of regulatory frameworks on the level of impact of disruptive technological innovations. Projects under this heading examine regulatory and policy transformation for micro-grid enablement, and study the legal and regulatory implications of energy storage technologies in various contexts.

Internationally comparative case studies

A further body of research involves a series of international and/or local industry based case study approaches including a comparative review of law and policy for concentrating solar thermal electricity generation, an examination of legal and governance barriers to geothermal and solar PV energy in Indonesia, and examination of the energy change in Japan in terms of climate and energy law developments post-Fukushima.

Solar and wind litigation

Researchers in the energy cluster are also involved in critical analysis of legislative models in the field of domestic energy law affecting particular energy sectors: for example, considering the design of optimal planning law regimes and the patterns of litigation over wind energy, and the role of solar photovoltaic generation capacity within electricity networks.

Fossil Fuel Divestment

One research area of particular focus is the role of the fossil fuel divestment movement as an agent of social change and non-state climate governance. This has been investigated via questions about the feasibility of non-state climate governance, the divestment movement's targets, tactics and strategies, and factors that are likely to shape the movement's influence in the longer term. The research also considers whether



Cluster Members: Dr Tim Bonyhady Professor Peter Drahos Professor Tom Faunce Professor Neil Gunningham Associate Professor Llewelyn Hughes Associate Professor Andrew Macintosh Dr James Prest

initiatives will be rebuffed by a coordinated and well-resourced industry counter-movement with roots that extend deep into the institutionalised political system.

We must consider the notion of 'carbon lock-in' if we are to understand Australian policy inertia in making the energy transition. Legal frameworks for the energy shift must overcome carbon lock-in to incumbent electricity generation technologies.

Additional research projects:

- Examining the national-level regulatory implications of the UN Minamata Convention on Mercury in combination with the Paris Agreement on Climate Change;
- Comparative analysis of regulation of the coal industry in Australia and the United States and analysis of the impact on investment of proposed air quality regulation;
- Geopolitical analysis of international energy governance issues, with a focus on regulatory unilateralism, including arguments for going it alone on climate change;
- > A governance framework for a shift towards the Sustainocene with Global Artificial Photosynthesis.

Energy Sociology and Risk

Energy change raises a host of social and political issues. How are risks associated with existing energy systems, and their alternatives, distributed? Why do some risks capture our collective attention more than others? How best can transformation in the consumption of energy be facilitated?

The ANU School of Sociology hosts a range of projects concerned with the social dimensions of risk and disasters.

A particular research focus in 2016 has been the proposal by BP to drill in the Great Australian Bight. There was concern that publicly available documentation for the proposal did not demonstrate that BP had learnt the lessons from its 2010 blowout in the Gulf of Mexico. This led to a submission to the Senate Standing Committees on Environment and Communications Inquiry into Oil or Gas Production in the Great Australian Bight.

Research is also on-going on the question of what the gas industry can do to combat climate change that is also in its own economic interest.

For example, at this juncture, it would appear to be in the interests of the gas industry to support the carbon pricing proposals of the Climate Change Authority.

Another project has focused on exploring sustainable transport from a number of different perspectives. Ongoing research into the social impacts of commuting in Sydney has resulted in a a submission to the Senate inquiry on Aspects of Road Safety, from which Dr David Bissell was invited to present evidence in parliament. This work will be extended by the awarding of a new Discovery Project to Dr Bissell and collaborators, which is looking at the bodily and social sustainability dimensions of long distance commuting.



Cluster Members:

Energy Storage and Recoverv

Short-term energy storage is increasingly important to smooth out peaks of high energy demand and low energy supply. This cluster is made up of five main research themes:

Materials Research for Energy Storage

Materials chemistry research for energy conversion and storage is carried out at the Research School of Chemistry. Professor Yun Liu has achieved a major research breakthrough in the development of a new material that can store large amounts of energy with very little energy loss. Applications include renewable energy storage, electric cars and defence and space technologies. The new material outperforms current capacitors in many aspects, is cheaper to manufacture than current components, and could be transformative for wind and solar power. There is additional research on functionality characterisation and device fabrication, which is likely to be critical in the practical application of renewable energy generation systems and smart grids and in electric vehicles.

Pumped hydro energy storage (PHES)

A new ANU energy research program is investigating offriver pumped hydro energy storage to stabilise renewables contribution to the electricity system. PHES constitutes 99% of all existing energy storage around the world, primarily using conventional hydro-electric dams that are cheaper than alternatives such as batteries. Professor Andrew Blakers, Dr Matthew Stocks and their team are investigating the potential of energy storage via off-river PHES which are easier and cheaper to construct than large hydro-electric dams. Nearly all new generation capacity in Australia is photovoltaics and wind energy making storage highly relevant for policy makers and the electricity industry.

Energy storage is now a major focus for ANU. In addition to the research Above: PhD Candidates Mac Mao (left) and Xiaozhou Wang (right) programs outlined here, a new \$8 million of electroceramics for energy applications by creating novel partnership with the ACT government nanostructured ceramics with high functionality in terms of high will see the establishment of a new surface areas and quantum confinement effects. Energy storage battery storage and integration research work has focused on the use of nanostructured vanadium program from 2017. oxides as cathode materials in rechargeable Li-ion batteries. An extensive equipment portfolio includes battery processing Fuel cell research stations and a state-of-the-art electrochemical test facility. New directions include developing nanostructured electrode material. Fuel cell research focuses firstly on the development of new Positive results would be a significant leap for storage technology of cheap systems that store huge amounts of energy and charge/ discharge it very quickly.

plasma processing techniques (similar to those used for microelectronics) to make fuel cell components and secondly on the electrical testing of fuel cell assemblies. Research areas include electrode development using platinum coated carbon nano-tubes and testing of integrated manufacturing systems using commercially available membranes to separate electrons and protons. Fuel cell research is carried out in the Space Plasma, Power and Propulsion laboratory, Research School of Physics and Engineering.

Energy nanomaterials

This research concentrates on the liquid-state processing



Cluster Members: Professor Rod Boswe Dr Evan Franklin Professor Weifa Liang Professor Yun Liu Dr Matthew Stocks

Solar thermal energy storage

Energy storage technologies based on sensible, latent and chemical reaction heat are being developed by Professor Wojciech Lipinski's team in College of Engineering and Computer Science for low- and high-temperature solar energy applications. These include high-temperature metal-oxide, carbonate, ammonia and sodium based energy storage systems as well as clathrate hydrate systems for low-temperature energy storage.

Energy Water Nexus

Responding to climate change, meeting expanding energy demand and sustaining freshwater resources are three of the greatest challenges facing society. There are crucial and often unacknowledged linkages between policies intended to achieve each of these objectives.

All forms of energy, to differing degrees, draw on water in their production, and so climate change policy choices between energy sources have considerable implications for water resources.

Similarly, climate mitigation policies such as carbon sequestration often have implications for water, depending on how, where and when trees are planted and soil is prepared for greater carbon uptake.

Working closely in collaboration with colleagues from the United States, Europe and around the world, the Energy-Water Nexus group is an integrative and interdisciplinary endeavour, incorporating scholars, policymakers and industry.

ANU researchers from the ECI Energy-Water Nexus research theme are now hosting the secretariat for the global Food, Energy, Environment and Water Network (FE2W network), which was launched in 2014.

The FE2W Network works with decision-makers to improve the understanding of systemic risks and how to manage shocks across these systems. The approach is founded on collaboration and an emphasis on poverty reduction, sustainable livelihoods, and the need to maintain critical ecosystem services. The network engages with the people who make the decisions, from farmers to policy makers to consumers, and enabling actions that result in improved long-term outcomes.

The Network organised a meeting, sponsored by the Rockefeller Foundation, on food and water security at the Rockefeller Foundation Facilities at Bellagio, Italy in February 2016. The meeting included network members and decision makers. Following the February meeting, the Network has been actively working on food, water energy security challenges in Lam Dong Province in Vietnam and in terms of resilience and nexus security in South Asia. In both places, the Network is applying the Risks and Options Assessment for Decision making (ROAD) it developed, which combines participatory methods with causal risk analysis (http://onlinelibrary.wiley.com/doi/10.1002/app5.128/ full). This approach has been featured in a recent compendium entitled 'The Water, Food, Energy and Climate Nexus: Challenges and an agenda for action' edited by Felix Dodds and Jamie Bartram (Routledge, 2016).



Cluster Members: Professor Stephen Dovers Professor Quentin Grafton Dr Barry Newell Associate Professor James Pittock Dr Michael Smith

Enhanced Oil and Gas Extraction

While the world, and Australia, now seems committed to a shift towards renewable and other low-carbon forms of electricity, this transition will take decades. In addition, some sectors, most notably aviation, are likely to continue to consume petroleum for the foreseeable future. It is the goal of this cluster to help ensure that hydrocarbon-based energy is pursued in the most sustainable manner possible.

Research aims to find the most efficient and cleanest methods for the extraction of oil and gas, both to reduce the emissions associated with this industry, but also to reduce costs to allow cleaner alternatives, such as gas, to displace coal-fired electricity.

Researchers are doing this by learning more about the physics of fluid flows at the sub-millimetre scale between grains in sedimentary rocks, then upscaling these results to explain larger scale phenomena. They are also working to better understand the fundamental processes underpinning shale gas extraction, as hydraulic fracturing ("fracking") remains remarkably poorly understood despite having grown into a multi-billion dollar industry.

Improved understanding of shale gas extraction can avoid unnecessary drilling but, more importantly, can help quantify the risks of environmental damage and fugitive methane and CO₂ emissions.

The Department of Applied Mathematics, Research School of Physics and Engineering, at ANU has been working for over a decade with many of the largest petroleum companies in the world to better understand the underlying science and help in the development of new techniques for enhancing the efficiency and effectiveness of oil and gas extraction. Much of the science and technology in this area is in common with that required for geologic storage of CO_2 and therefore research in this area overlaps with work done as part of ECI's Carbon Capture and Storage research cluster.



Cluster Members: Professor Mark Knackstedt Professor Tim Senden Associate Professor Adrian Sheppard

Fusion Power

Fusion has the potential to deliver effectively limitless, clean, base-load power for future generations.

Fusion is the process that powers the sun and stars. ANU researchers, technologies and expertise are strongly linked into the international fusion program.

Two departments in the ANU Research School of Physics and Engineering conduct fusion research, the Centre for Plasmas and Fluids and the Plasma Research Laboratory. There is significant international collaboration with the W7-X superconducting stellarator (Germany), the KSTAR superconducting tokamak (Korea), the DIII-D National Facility (USA), and the MAST tokamak (UKAEA) groups. In a major development, ANU scientists now engage directly in the research activities of the international fusion experiment, ITER, with the next step fusion experiment under construction.

The Centre for Plasmas and Fluids

The Centre for Plasmas and Fluids hosts the Plasma Theory and Modelling Group, who develop theory and models describing high performance toroidally confined burning plasmas as well as stellarators. Fields of research include equilibrium physics, wave-particle and MHD stability, Bayesian inference, and toroidal magnetic confinement experiments. The Centre provides support to local experiments and collaborates actively with other centres including JET tokamak (Euratom), Princeton Plasma Physics Laboratory (USA), and the University of Texas, Austin (USA). Staff also engage in ITER research through the International Tokamak Physics Activity (ITPA), which conducts R&D activities in fusion physics in support of ITER.

The Plasma Research Laboratory (PRL)

PRL performs research across a multitude of activities including plasma-material interactions, the study of 3D magnetic confinement systems, atomic and molecular physics, and the development of advanced remote sensing systems.

It is home to the Australian Positron Beamline Facility (APBF) and the Australian Plasma Fusion Research Facility (APFRF). This research will help maintain a frontline in Australian research capability in edge plasma fusion physics, plasma physics, diagnostics, nanotechnology, materials science, and atomic and molecular physics.

The Laboratory collaborates actively with ITER and a number of national and international institutions. Significant developments include highly prized port space on ITER reserved for a novel optical imaging system conceived and developed at the APFRF. Staff also engage in ITER research through the International Tokamak Physics Activity (ITPA), which conducts R&D activities in fusion physics in support of ITER.



Cluster Members: Emeritus Associate Professor Boyd Blackwell Dr Cormac Corr Emeritus Professor Bob Dewar Associate Professor Matthew Hole Emeritus Professor John Howard

Above: Schematic of the German Max Planck Institute for Plasma Physics €1bn Wendelstein 7-X (W7-X) stellarator, which came online in 2016.

International collaborations

The 2015/16 international fusion research program consolidated large-scale high-performance toroidal confinement experiments designed to demonstrate the scientific and technological feasibility of fusion power. The \$20+ billion international ITER tokamak saw new management and accelerated construction. A major development was the €1bn Wendelstein 7-X (W7-X) stellarator (Figure 1) in Germany commissioned by the Max Planck Institute of Plasma Physics. Constructed over 20 years, the W7-X functions to evaluate the main components of a future fusion reactor built using stellarator technology

The Australian ITER Forum co-released a five year strategic plan in 2014. The first step of this plan was realised in September 2016: an agreement between the Australian Nuclear Science and Technology Organisation (ANSTO) and the ITER Organisation that enables the provision and exchange of research, data and scientific cooperation. This agreement is the first of a kind to any nation outside the ITER members. The agreement enables participation of Australian scientists in ITER research and the International Tokamak Physics Activity (ITPA).

Nanostructure Photovoltaics

Nanostructure Photovoltaics is leading the way in developing innovative clean and sustainable energy resources.

Nanostructured Photovoltaics research is carried out in the Department of Electronic Materials Engineering of the Research School of Physics and Engineering. Research is focused on developing novel concepts and technologies for high efficiency nanostructured solar cells. This is achieved by combining the excellent properties of III-V semiconductors as photovoltaic materials with unique properties of nanostructures such as quantum dots and nanowires.

Nanowires provide a paradigm shift in photovoltaics by decoupling light absorption from carrier collection paths, which lead to more efficient charge extraction. Quantum dots are predicted to form an intermediate band within the bandgap to absorb lower energy photons and also lead to multi-exciton generation.

2016 Research Highlights include:

Nanostructured Solar Cells

Research on techniques in 'selective-area metal organic vapor phase epitaxy' (SA-MOVPE) and 'plasma-enhanced chemical vapor deposition' (PECVD) have resulted in increased power conversion efficiency. This outcome indicates that a promisingly simple approach can achieve high performance results. Research continues on optimization of device design, material growth, device fabrication and improved efficiency and device performance.

Solar cells with carrier selective contacts

Carrier selective contacts lead to solar cells with high performance and also with reduced fabrication costs as it eliminates the need for differently doped structures present in the homojunction solar cells. Ta2O5 has been investigated as an electron selective and hole blocking material for InP heterojunction solar cell. The resulting solar cell device exhibited a very high power conversion efficiency of 18.6%.

Nanostructured solar water splitting:

This research team have developed a top-down fabrication method to obtain GaN nanopillars from the epilayers grown using MOVPE towards solar water splitting application. The nanopillars based photoelectrodes were further modified with flame-spray deposited Co3O4 nano-islands as an oxidation co-catalyst. This has enhanced the solar-to-hydrogen conversion efficiency compared to the bare GaN nanopillars photoelectrode. The results have been published in 2016 Advanced Energy Materials.



Cluster Members: Associate Professor Lan Fu Dr Qiang (Michael) Gao Professor Chennupati Jagadish Dr Siva Karuturi Dr Ziyuan Li Dr Sudha Mokkapati Dr H. Hoe Tan

Above: From Left, PhD students Mr Ahmed Alabadla and Ms Qian Gao, A/Prof Lan Fu (EME) and Dr Lily Li (ANFF Staff)

Ongoing research efforts include the demonstration of efficient, stand-alone water splitting devices. Highly efficient stand-alone devices for solar water splitting are critical for the practical implementation of solar hydrogen production. Tandem photovoltaic and photoelectrochemical devices based on materials with complementary light absorptions, such as CdS and organohalide lead perovskite, have been developed with close to 10% solar to chemical conversion efficiency.

Nuclear Science

Nuclear Science at ANU operates the premier laboratory in Australia for accelerator-based research in nuclear physics, providing and developing experimental facilities for local staff and external users.

The Heavy Ion Accelerator Facility is used for educational training over a wide range of basic and applied research. The research draws on a suite of techniques and instruments, and on the flexibility of the Heavy Ion Accelerator itself.

Research areas include fundamental nuclear and quantum physics as well as applications of accelerator-based techniques. Applications focus particularly on accelerator mass spectrometry methods, and range from extending our understanding of the properties of advanced fuels for Generation IV nuclear reactors, to climate change monitoring, the determination of groundwater flows, and environmental tracing of nuclear discharges via ultrasensitive measurement of rare isotope abundances.

The Heavy Ion Accelerator Facility supports many active national and international research collaborations. It is operated as a National Facility, with merit-based access via collaborative agreements.

A recent graduate of the Master of Nuclear Science program, Robert (Rob) Parker, is President of the Australian Nuclear Association. As well as teaching secondary students about nuclear science, Rob leads community nuclear issues and the potential role of nuclear power in reducing greenhouse gas emissions.

ECI researchers in the area contributed to the South Australian Royal Commission - Professor Quentin Grafton and Professor Ken Baldwin were appointed as members of the Socio-Economic Modelling Advisory Committee - and made commentary to the media on its outcome.



Cluster Members: Professor Keith Fifield Professor David Hinde Dr Greg Lane Professor Andrew Stuchbe

Smart Grids

The future electricity grid calls for a fundamental paradigm shift in the way power systems are planned and operated, underpinned by a new generation of communication, control, data analytics, and optimisation technologies.

In the future, the electricity grid will feature millions of intermittent and distributed generation sources, support many electric vehicles, and give greater incentives and control to consumers to optimise energy usage. It will require an unprecedented level of automation, to self-manage, self-reconfigure and self-heal. This vision challenges the human-controlled, top down management style of the current grid which relies on the existence of a few predictable and adjustable fossil fuel generators.

The ECI Smart Grid Group conducts research into the use of Information Communications Technology (ICT) to support future energy systems, in areas such as grid integration of renewables and storage, microgrids, energy price and solar forecasting, demand response, and home and building energy management. This research applies ICT disciplines such as optimisation, simulation, machine learning, and planning and scheduling.

In 2016, group members, working in collaboration with a range of partners, were awarded \$5 million funding for 4 new projects under the Australian Renewable Energy Agency (ARENA) R&D Industry-Researcher Collaboration program, and the Australia-Indonesia Centre (AIC) Energy Cluster Research Grants Program:

ARENA: A robotic vision system for automatic inspection and evaluation of solar plants

The project will develop a cost-effective automated inspection system for monitoring concentrating solar and solar PV power plants, based on the use of ground-mounted cameras and drones. Building on ANU expertise in computer vision, machine learning, PV and solar thermal technologies, this project is a collaboration with FRV Services Australia, Vast Solar, 4D Surveying and Data 61. The system will accurately measure dust on the panels, and will diagnose defects, to determine efficient maintenance and cleaning procedures.

ARENA: Consumer energy systems providing costeffective grid support

This project will develop algorithms to automatically coordinate consumer-owned PV-battery systems to simultaneously provide network support and consumer value. The team will implement these algorithms on Bruny Island, Tasmania, to reduce the use of diesel during peak demand, and to assess the network and household responses. The algorithms build on ANU expertise in optimisation and scheduling for smart grids. This project is a collaboration with Tasmanian Networks, Reposit Power, the University of Sydney and the University of Tasmania.



Cluster Members: Dr Lachlan Blackhall Dr Nicholas Engerer Dr Evan Franklin Dr Dan Gordon Dr Alban Grastien Professor Saman Halgamuge Dr Hassan Hijazi Professor Weifa Liang Dr John Pye Dr Igor Skryabin Professor Sylvie Thiebaux

ARENA: Real-time operational PV simulations for distribution network service providers

This project collaborates with distributed service network providers (DNSPs) and other industry partners to deliver real-time forecasts of photovoltaic power. By quantifying PV power ahead of time, these predictions will help DNSPs to manage solar PV integration challenges using solutions such as energy storage and demand management. The work builds on ANU expertise in simulation, numerical weather prediction and machine learning. The technologies will be deployed by Solcast, a startup company established by project lead, Dr Nicholas Engerer.

AIC: Optimal Microgrid Design and Operations

This project collaborates with CWP renewables and the Institut Teknologi Bandung to develop reliable decision support tools for the design and operations of microgrids, with the aim of providing low cost electrification solutions to remote areas of Australia and Indonesia. Building on ANU expertise in modelling and optimisation of energy systems, the project will develop a holistic tool that takes into account the strong coupling constraints linking key problems of finding the optimal technology mix, sizing and operations.

Solar Photovoltaics

Photovoltaics research at ANU is at the cutting edge globally, spanning the entire spectrum of solar electricity technologies—from solar forecasting, to fabricating high-efficiency PV cells, to integrating renewables with storage capacity into the grid.

Solar energy research at ANU aims to increase the uptake of environmentally benign solar energy solutions through the use of photovoltaic (PV) and solar thermal energy conversion technology. Activities range from basic R&D to commercialisation. The Research School of Engineering has sophisticated laboratories, state-of-the-art processing equipment with specialised characterisation tools, accelerated lifetime equipment, solar thermal research facilities, and outdoors testing facilities. The 80 research staff, students, support staff and funding partners have 20 research projects exceeding \$30M in value. The past year's research highlights include:

100% renewable electricity futures

With global energy markets shifting, recent research finds that the Australian electricity grid can transition smoothly to 100% renewable energy while retaining stability. Wind and PV can contribute 90% of Australia's annual electricity, while existing hydro, biomass and other sources could contribute the remaining 10%, with no fossil or nuclear energy required. In this scenario there are no heroic assumptions about technology development: the research considers technology that has been deployed in quantities greater than 100 Gigawatts, namely PV, wind, pumped hydro energy storage (PHES) and high voltage DC (HVDC) transmission. The levelised cost of electricity is less than \$100/MWh based on 2016 prices, and this is only likely to decline in future.

Passivated contacts

Most photovoltaic systems are based on crystalline silicon solar cells, which keep getting cheaper and better. "Passivating contacts" selectively transport electrons and holes towards the cell's electrical terminals. For example, researchers have developed 22% efficient cells with a rear passivating contact. In an alternative pathway, researchers are investigating a wide range of materials, many of them transparent, that can be deposited at low temperatures, thus simplifying the manufacturing of high efficiency silicon solar cells.

Solar silicon

Reducing the cost of silicon is critical to achieve cost-reductions of PV modules. New low-cost "solar grade" silicon feedstocks are a potential alternative to conventional high purity silicon. However, solar-grade feedstocks often contain greater concentrations of impurities, to the detriment of the cell efficiency. This research fabricated a 21.1% efficient silicon solar cell using solar-grade silicon. This represents a world efficiency record for solar grade silicon and is comparable to the efficiency of high purity silicon.



Cluster Members: Dr Fiona Beck Professor Andrew Blakers Dr Kate Booker Associate Professor Kylie Catchpole Professor Andres Cuevas Dr Mike Dennis Professor Rob Elliman Dr Nicholas Engerer Dr Marco Ernst Mr Kean Chern Fong Dr Evan Franklin Dr Niraj Lal Dr Daniel Macdonald Dr Sudha Mokkapati Dr Fiacre Rougieux Dr Igor Skryabin Dr Gerskryabin Dr Matthew Stocks Dr Sachin Surve Dr Andrew Thomson Dr Yimao Wan Associate Professor Klaus Weber Dr Thomas White Dr Xinbo Yang Dr Soe Zin

Perovskite solar cells

Perovskites, a promising new class of materials, have increased efficiency and reduced solar cell costs by processing easily and absorbing different parts of the solar spectrum. Researchers recently developed a new way to increase efficiency of perovskite solar cells by using a titanium dioxide layer with improved conductivity. Overall, they achieved an efficiency of 24.5%, one of the highest efficiencies that has been reported for a perovskite/ silicon tandem solar cell. They also achieved an efficiency of 23% in a novel reflective tandem structure, which has the potential to improve the efficiency of tracking solar systems.

Solar Thermal

The Solar Thermal Group, in the Research School of Engineering, conducts research and education in solar thermal energy conversion and related basic and applied disciplines. Formed 40 years ago they have a long history of development in remote-area solar thermal power stations, thermochemical energy storage, and dish and trough solar concentrators. The current work encompasses applied research themes such as concentrating solar technologies for power generation and production of fuels and commodity materials, solar heating and cooling, thermal and thermochemical energy storage, hybrid renewable energy technologies, and system integration.

The experimental work in the Solar Thermal Group is supported by a cutting-edge infrastructure including the SG4 Big Dish (a 500 m² dish concentrator, the largest solar parabolic dish in the world), and the recently commissioned 45 kWe high-flux solar simulator (see photo). The dish is a valuable tool for research into high-temperature receiver and engine design, sun-tracking algorithms, and thermochemical systems. The high-flux solar simulator has been developed to evaluate solar receivers and reactors, materials and other technology-critical components including space radiation shields and ceramic coatings under controlled broad-band and high-flux irradiation in an in-door laboratory environment.

Professor Wojciech Lipinski leads the Group, which currently includes 11 academic staff, 3 adjuncts, 16 higher degree research students, and 2 research officers. Research projects are supported by grants from the Australian Research Council (ARC), the Australian Renewable Energy Agency (ARENA) including the Australian Solar Thermal Research Initiative (ASTRI) collaborative agreement and industry. The Group has strong national and international presence and collaborations.

The Solar Thermal Group have set an efficiency world record for steam generation using a novel solar receiver evaluated on the ANU Big Dish, halving losses and achieving a 97% conversion of sunlight into steam.

Research Highlights include:

Solar fuels via redox-based thermochemical cycling (ARC, ASTRI)

Production of synthesis gas and liquid hydrocarbon fuels is investigated for improved process efficiency and lower fuel cost.

Solar-driven carbonate-based chemical looping (ASTRI)

Carbonate-based chemical looping processes are investigated for thermochemical energy storage and CO₂ capture applications.

High-temperature energy storage via redox cycling (ARENA)

In collaboration with University of Colorado Boulder and IT Power Australia, a new approach to efficient and dispatchable power production from concentrated solar radiation is investigated.



Cluster Members: Dr Joe Coventry Dr Mike Dennis Dr Graham Hughes Dr Peter Kreider Professor Wojciech Lipinski Dr Adrian Lowe Dr John Pye Associate Professor Antonio Tricoli Dr Mahesh Brahmadesham Venkataramar Adjunct Professor Alan Weimer Dr Vincent Wheeler Dr Jose Zapata Fuentealba

Above: Dr Peter Kreider (left), Ms Lindsey Yue and Professor Wojciech Lipinski (Right) in front of the ANU 45 kWe high-flux solar simulator. Image Credit: ACT Government

Sodium-based solar energy collection and storage (ASTRI, ARC and industry)

The group investigates thermal transport phenomena in single and two-phase sodium.

High-temperature receivers for dish concentrators (ARENA)

The Solar Thermal Group have set an efficiency world record for steam generation using a novel solar receiver integrated with the ANU Big Dish, halving losses and achieving a 97% conversion of sunlight into steam.

Design, fabrication and characterisation of solar concentrators (ASTRI, ARENA, Vast Solar)

The recent advances span from development of new, costeffective heliostat designs to design of high-flux solar simulators and secondary optics tuning.

Low-temperature solar thermal and energy storage technologies

Solar cooling research focusses on thermally driven ejector cycles to produce low cost cooling solutions using solar or waste heat and the development of energy storage technology for air conditioning.

Wind Energy

The inaugural 2016 ANU Wind Energy course was a great success, with 27 students in its first enrolment.

Research in the Wind Energy research cluster at the ANU covers a wide range of wind assessment, wind development and renewables integration topics. Examples include legal aspects of wind energy development, community concerns and health impacts of wind farms, international wind prospecting and renewables integration of hybrid wind, solar and storage projects. Research is complemented by a new course in Wind Energy, available to students in the Master of Energy Change and Climate Change degrees, and Physics, Engineering and other ANU undergraduates.

Several interesting research projects were completed or initiated during 2016, including turbulence generation and propagation from complex topographic features. The work was supported by Coonooer Bridge Wind Farm and Ararat Wind Farm.

One highlight was the development of a Hybrid Deterministic Statistical Model (HDSM) for wind energy assessment including CFD modelling for stratified flows in complex terrain and the use of high-resolution mesoscale modelling. This research is ongoing and is undertaken by the WindScape Institute, an ECI partner. It is expected to be applied to two wind farms which will commence construction during 2017, including Windlab's Kennedy Energy Park. Another highlight was research on renewables integration of hybrid wind, solar and storage projects by the WindScape Institute.

Over the past twelve months the Wind Energy research cluster completed a number of education and research firsts. The first edition of the Wind Energy course was successfully developed and delivered to ANU students and was considered a roaring success. The course covered a broad range of topics relevant to wind energy and wind farm development with a focus on technical aspects and the physics of wind energy.



Cluster Members: Dr Elizabeth Hanna Associate Professor Andy Hogg Dr Frank Mills Dr James Prest Dr Horst Punzmann Professor Michael Shats Dr Igor Skryabin Dr Nathan Steggel Dr Hua Xia

Above: Dr Nathan Steggel (Windlab) at Coonooer Bridge Wind Farm during commissioning. Windlab are the major collaborator delivering the new wind energy course with ECI..

THE ANU ENERGY MASTER PLAN



A 39kWp solar panel installation on the rooftop of the ANU School of Art.

The ANU Energy Master Plan (EMP) has been kicked off by a \$40,000 grant from the Vice-Chancellor, Professor Brian Schmidt, to create the business case.

This will involve a Master Planning team comprising key people from the Facilities and Services Division and relevant experts from the ECI. In early 2017, if the business case is compelling, design of the EMP will start in earnest.

The EMP will examine all facets of the University's energy use and generation – including campus energy systems modelling developed by ECI researchers in CECS to design strategies for our electricity, gas and water networks and to optimize their usage.

The EMP will focus on a range of energy saving/generating opportunities:

- > Analysing data sets from a large array of energy network sensors
- Demand management through the Building Management Systems
- > Lighting efficiency including LEDs
- > Insulation and other forms of energy efficiency
- > A mandatory energy efficiency building code
- > Plant and equipment selection
- > Energy generation for retail substitution, including rooftop PV
- Energy generation for the wholesale market, including off-campus, ground-mounted PV
- > Energy storage using heat and batteries
- > Thermal load management (including NCI)
- > Electric vehicle charging and storage
- Provision of demand management capability to our energy provider.

Why do an EMP?

There are numerous parallel benefits which aim to:

- 1. Coordinate with other master planning procedures
- 2. Prevent ad-hoc decision making
- 3. Provide planning certainty and lower the finance costs of investment
- 4. Reduce carbon emissions
- 5. Create a positive profile for the university
- 6. Attract staff and students
- 7. Provide leadership and collaboration in the university system
- 8. Develop a prototype for other organisations eg. defence bases
- 9. Create ongoing research and education outcomes from the planning process
- 10. Provide an economic return over the long term (up to 10 years).

The ECI would like to congratulate the team at ANU Facilities and Services led by Christine Allard, and strongly supported in particular by David Glavas, John Sullivan and Michael Wright. Their work in developing the EMP has been a true partnership with ECI academic staff.

The ECI is contributing a team of experts in solar PV, electricity network design, energy efficiency and other areas – and in particular would like to acknowledge the conrtributions of Andrew Blakers, Evan Franklin, Hassan Hijazi, Igor Skryabin, Michael Smith and Sylvie Thiebaux.

If you would like to join this team then please contact the ECI at: energy.change@anu.edu.au

AUSTRALIA-INDONESIA CENTRE ENERGY CLUSTER



Meeting with government officials in Jakarta. From left: Dhita Rachmadini, Ken Baldwin (ECI), William Sabandar, Agung Wicaksono, Igor Skrvabin (ECI), Ariel Liebman (AIC), Adhityani Putri, Max Richter, Rajab Khalilpour.

The Australia-Indonesia Centre is a joint research venture between the two countries, with the ECI co-leading the Energy research cluster.

This year saw the first allocation of AIC Strategic Research Project funding to the four Australian universities and their seven Indonesian partners:

Australia: ANU, University of Melbourne, Monash University and University of Sydney

Indonesia: Institut Teknologi Bandung, Institut Pertanian Bogor, Universitas Gadjah Mada, Universitas Indonesia, Institut Teknologi Sepuluh Nopember, Universitas Airlangga and Universitas Hasanuddin

The funded projects and their principal investigators were as follows:

Optimal Microgrid design and operations

Dr Hassan Hijazi, Australian National University (ECI) Dr Tri Desmana Rachmildha, Institut Teknologi Bandung

Microgrids as enablers of sustainable power system investment and decarbonisation pathways in Australia and Indonesia

Dr Ariel Liebman, Monash University Dr Armansyah Tambunan, Institut Pertanian Bogor

Indonesian Energy Technology and Resource Assessments

Professor Ken Baldwin, Australian National University (ECI) Dr Retno Dewi Gumilang Institut Teknologi Bandung

In all, more than \$500,000 in research funding was allocated to ECI researchers.

To enable flexibility in developing new research opportunities, a series of smaller Tactical Research Project grants were also allocated:

Control the grid or be controlled: Near off-grid solutions using renewable energy technologies and demand side prediction

Professor Saman Halgamuge, The University of Melbourne (now at ANU, ECI)

Associate Professor Deendarlianto, Universitas Gadjah Mada

Building coalitions and processes to support community empowerment through renewable energy and livelihood solutions

Dr Sebastian Thomas, The University of Melbourne Dr Yudo Anggoro, Institut Teknologi Bandung

Operational security support for power and energy systems: Networked microgrids as the solution

Dr Yan Xu, The University Of Sydney Dr Ardyono Priyadi, Institut Teknologi Sepuluh Nopember

Inter-island multi-terminal high-voltage direct current (HVDC) transmission system for renewable energy integration

Dr Ke Meng, The University Of Sydney Dr Tridesmana Rachmildha,

In August, the ECI held its annual research meeting in Surabaya, East Java where the collaborative research programs were advanced through presentations and discussions. Following that meeting, the AIC Energy cluster leads Dr Ariel Liebman (Monash), Dr Igor Skryabin (ECI) and ECI Director Prof Ken Bladwin (Energy cluster chair) travelled to Jakarta to meet with key government and private sector partners to advance the research porgrams.

This included meetings with the Ministry of Energy and Mineral Resources (MEMR) to progress the Indonesian Energy Technology Assessment (IETA), and with the national electricity provider (PLN) to develop partnerships with the microgrid research program. In addition, MEMR officials visited the ECI in Canberra in June and November to progress the IETA project.

The ECI also contributed to educational projects, with the engagement of Australian and Indonesian students at the Surabaya workshop, and in Canberra around Energy Update. A cohort of young Indonesian officials were recipients of an ECI short course in Canberra as part of the Indonesia Future Leaders program.

In order to facilitate its engagement with Indonesia. The AIC Energy Cluster has employed former ECI Communications Manager, Adhityani Putri, to represent its interests in Jakarta.

PUBLIC POLICY



The ACT's 2.3MW Mount Maiura Solar Farm opened on 6 October 2016, Image credit; James Prest, ANU

The ECI continues to engage in the development of public policy through its extensive relationships with government departments and agencies.

This year's public policy highlights included:

International

- > The ECI supported the 51st APEC Energy Working group and associated meetings held in Canberra. This APEC meeting program included a visit to the ECI, associated discussions and tours of ANU renewable energy facilities. In addition, Professor Ken Baldwin spoke at the official Energy Working Group reception and Dr Skryabin hosted a visit to ECI by the Asia-Pacific Sustainable Energy Centre. 9-13 May 2016.
- > In May 2016 ECI held a one day Energy Futures course as a key part of Australia-Indonesia Leaders Program. The program brought together future policy leaders from Australia and Indonesia
- > In August and in October 2016 Professor Ken Baldwin and Dr Igor Skryabin met with Indonesian Government officials to advance the AIC research projects, in particular the Indonesian Energy Technology Assessment (IETA).
- > Dr Igor Skryabin participated in a meeting of APEC energy storage experts in China and delivered an invited presentation on the financial benefits of energy storage in APEC countries.



APEC delegates from the 51st APEC Energy Working Group visited the ECI to learn about ANU energy change research



APEC delegates toured ANU renewable energy facilities, including the ANU Solar Thermal Big Dish.

PUBLIC POLICY



Meeting with Indonesian Ministry of Energy and Mineral Resources. From left: Bintan, Igor Skryabin (ECI), Retno Gumilang Dewi, Ken Baldwin (ECI), Ir Adhi Wibowo, Max Richter, Ariel Liebman (AIC), R&D staff member, Rajab Khalilpour, Agus Nurhudoyo

Federal Government

- ECI members of the fusion research cluster made submissions in response to the Tentative Findings of Nuclear Fuel Cycle Royal Commission, as part of the Australian ITER Forum – 18 March 2016
- ECI members including Professor Ken Baldwin, Professor Andrew Blakers and Dr Igor Skryabin participated in an ARENA visit to discuss ARENA investment Strategy – 16 June 2016
- In partnership with the Australian Renewable Energy Agency (ARENA), the ECI hosted a roundtable forum on Concentrated Solar Thermal energy at ANU bringing together research, industry and government – 22 July 2016
- The ECI (Professor Ken Baldwin, Professor Mark Howden and Professor Frank Jotzo) contributed to an ANU / Chifley Research Centre future leaders program, holding briefing discussions on energy with eight Australian Labor parliamentarians – 29 July 2016
- The ECI contributed submissions to the COAG Energy Ministers consultation papers on Energy Storage Registration and on Consumer Protection – September and October 2016
- The ECI partnered with Engineers Australia in holding a forum on Energy Security at the National Gallery of Australia. Over 60 delegates from key stakeholder groups attended two sessions on grid security and fuel supply chains, with a lunchtime address by Air Vice-Marshall (retired) John Blackburn – 13 October 2016
- ECI members made submissions to the National Research Infrastructure Roadmap Issues Paper, as part of the Australian Plasma Fusion Research Facility – 9 September 2016



Margaret Sewell (Department of Environment and Energy) presenting at the Energy Security Forum.

ACT Government

Locally, the ECI plays an important role in the ACT Government energy plan as a founding partner in the Renewable Energy Industry Development Strategy (REIDS). The ECI was strongly involved in the ACT Government Next Generation Energy Storage and reverse auction for 200MW wind energy announced this year, engaging with dozens of corporate bids which undertake to invest in renewable energy research and education.

The new 2016 undergraduate/postgraduate course in Wind Energy, developed in collaboration between the ECI and Windlab Ltd, is a result of the first 200MW wind reverse auction, as is the partnership with CWP Renewables to develop a new course for 2017 in Integration of Renewable Energy into Power Systems and Microgrids.

The University and the ACT Government have also established a Renewable Energy Precinct at the interface of Civic and the ANU campus which includes a number of renewable energy companies and related government agencies.



From left: Daulet Taimagambet (Kazakh Bolashak Scholarship Student at ANU), Mr Murat Smagulov (Consul General of Kazakhstan in Sydney), His Excellency Rapil Zhoshybaev (Deputy Foreign Minister of Kazakhstan and Commissioner of Expo 2017), Dr Igor Skryabin (ECI), Lachlan James (ACT Govt) at the ANU Big Solar Dish.

Individual contributions

Many ECI researchers contribute to public policy development through their individual research expertise as part of their everyday activities – particularly in the disciplines of economics, law, sociology and policy. Amongst many individual achievements throughout the year, ECI researchers contributed to the following areas of public policy:

Decarbonisation of the economy

- The ECI (represented by Dr Michael Smith and Professor Ken Baldwin) have partnered with Alliance to Save Energy on the COAG National Energy Productivity Plan.
- Professor Ken Baldwin attended the August 19th COAG Energy Ministers meeting.
- > Associate Professor Andrew Macintosh is Chair of the Emissions Reduction Assurance Committee.
- Associate Professor Frank Jotzo is co-lead of the Australian component of the global Deep Decarbonisation Pathways Projects. He is a member of the ACT Climate Change Council and of South Australia's low carbon economy expert committee. His recent proposal for a market mechanism to achieve early closure of brown coal-fired power stations has found strong interest amongst policy makers.

SA Electricity Crisis

The South Australian Government invited Professor Ken Baldwin, Dr John Hewson and Honorary Associate Professor Hugh Saddler to participate in a discussion roundtable on October 6th following the SA "black start" event.

Australian Renewable Energy Agency (ARENA)

- Professor Andrew Blakers initiated and organised a range of activities which ultimately resulted in the retention of \$800 million of funding for ARENA, including a submission to the Senate inquiry into the proposed "Omnibus bill" in relation to ARENA (with Richard Corkish), open letters and engagement with various MPs – July - September 2016
- Professor Andrew Blakers participated in the ARENA ACAP Review meeting – 6-7 July 2016 D
- Professor Andrew Blakers made a submission to ARENA on its R&D and investment strategy (jointly with Richard Corkish)
 16 June 2016

Nuclear

- Professor Quentin Grafton and Professor Ken Baldwin served as members of the Socio-Economic Modelling Advisory Committee, one of three Expert Advisory Committees for the South Australia Royal Commission into the Nuclear Fuel Cycle.
- Professor Andrew Stuchbery participated in a meeting of the Nuclear Energy Experts Group in Singapore. The meeting brought together specialists from countries throughout the Asia-Pacific and beyond. It included discussions on nuclear governance, the role of the Nuclear Security Summit (NSS) process, technical approaches to improving management of civilian nuclear activities, and regional approaches to improving nuclear safety and security governance.

Oil and gas

 Emeritus Professor Andrew Hopkins made a submission to the Senate Standing Committees on Environment and Communications Inquiry into Oil or Gas Production in the Great Australian Bight.

Sustainable transport

Ongoing research by Dr David Bissell into the social impacts of commuting in Sydney resulted in a submission to the Senate inquiry on Aspects of Road Safety, from which Dr Bissell was invited to present evidence in parliament.

ANU Public Policy

> The University is currently reviewing its Public Policy program and the ECI has made key contributions to this process. The new program will be unveiled for commencement in 2017.

Public Policy Fellows

The University has a major role in providing expertise to government and the wider community through its Public Policy Fellows program in which the ECI is a major player, contributing 5 Public Policy Fellows:



Professor Ken Baldwin ECI Director Research School of Physics and Engineering



Professor Andrew Blakers ECI Solar Photovoltaics College of Engineering and Computer Science



Professor Quentin Grafton ECI Energy Economics and Policy Crawford School of Public Policy



Associate Professor Frank Jotzo ECI Energy Economics and Policy Crawford School of Public Policy



Professor Warwick McKibbin ECI Energy Economics and Policy Crawford School of Public Policy

EVENTS



Participants tour ANU renewable energy facilities as part of ECI Open Day 2015.

The ECI organised and hosted many public events in 2015 and 2016, ranging from public lectures by eminent speakers of global standing, to seminars and discussions of a technical nature, engaging experts and practitioners in the field of energy change in discussions around science, technology and policy. More information about these events can be found at energy.anu.edu.au/news-events.

Flagship Events

2015 ANU Energy Update 8 December 2015

The Annual ANU ECI Energy Update brought together Australian researchers, policymakers, industry and members of the public to provide an update on the latest world energy trends from the IEA World Energy Outlook. Byron Washom, University of California San Diego, was a keynote speaker.

ECI Open Day

7 December 2015

ECI Open Day showcased the latest in energy change research at ANU to key stakeholders, with ECI participants giving oral and poster presentations on their work.

2015 ACT / ANU Solar Oration: Solar PV – Changing the Energy Landscape – Dr Pierre Verlinden 7 December 2015

Dr Pierre Verlinden, Vice President and Chief Scientist at Trina Solar, shared his views on renewable energy evolution and trends from technological and commercial perspectives.

Meetings

ECI Annual Business Meeting 26 May 2015

The ECI Annual Business Meeting is an opportunity for ECI members to participate in setting the directions of the ECI over the coming year. This year, incoming ANU Vice-Chancellor, Professor Brian Schmidt, provided the keynote address, and emphasised the key role that the ECI plays in enhancing the University's profile.



A sell out crowd at Creating Energy Efficient Cities in Switzerland and Australia.

ECI Public Lectures and Seminars

Creating Energy Efficient Cities in Switzerland and Australia Hosted by ECI and the Embassy of Switzerland

A panel of experts from Switzerland and Australia discussed, compared and contrasted opportunities for energy innovation across various urban centres, 22 February 2016

Energy Conversations: Integrating Renewables and Storage into the grid

Hosted by ANU ECI & the Australian Institute of Energy (Canberra Branch), 3 May 2016

Renewables in the Post COP21 Era – A Global Perspective Hosted by ECI & Australian Solar Thermal Research Initiative Cédric Philibert, International Energy Agency, 5 May 2016

Three shifts in US energy policy: Implications for the globe

Dr Christian Downie, Vice Chancellor's Postdoctoral Fellow, UNSW and Visiting Fellow, ANU, 31 May 2016

The Vote: 2016 Federal Election Series - Climate Change, Energy and the Environment

Professor Ken Baldwin (ECI), Professor Mark Howden (Climate Change Institute), Dr Paul Burke (Crawford School, ANU), Lily Dempster (Master of Energy Change student), 21 June 2016

Solar Energy R&D and Materials by Design

Dr William Tumas, National Renewable Energy Laboratory, USA, 7 July 2016

What the petroleum industry can do about climate change Professor Andrew Hopkins, Research School of Sociology, ANU, 2 August 2016

The Importance of Innovation to Global Clean Energy Deployment – past and future

Hosted by the ECI and the US Embassy Dr Julio Friedmann, Lawrence Livermore National Laboratory, USA, 20 October 2016



From left: Dr Evan Franklin, Dr Nick Engerer, Bin Lu and Professor Ken Baldwin at the Energy Conversations event.



From left: Jon Sibley (ACT Government), Lesley Dowling (Department of the Environment & Energy) and Dr Julio Friedmann (Lawrence Livermore National Laboratory, USA) at the innovation and clean energy public lecture.



Professor Ken Baldwin (ECI Director) thanking Professor Shuji Nakamura, 2014 Nobel Prize Winner in Physics, for his plenary speech at the 2016 OSA Energy Congress in Leipzig, Germany

OUTREACH



The ANU Solar Thermal Big Dish is part of the recently launched Renewable Energy Trail, developed by the South East Region of Renewable Energy Excellence (SEREEE). Image credit: Stuart Hay, ANU.

Part of ECI's mission is to disseminate information on energy change through outreach activities. The following list gives a sample of many of the types of activities ECI members have been involved in.

Community Engagement

ECI exhibited at the ACTSmart Business Sustainability Expo, 1 September 2016

Public Fora

Professor Andrew Blakers and **Professor Robert Dewar** participated in a panel discussion after the film *Atomic: Living in Dread and Promise*, as part of the 2016 Environmental Film Festival, 15 October 2016

Professor Andrew Stuchbery and **Professor Ken Baldwin** appeared in a discussion panel on Nuclear Energy organised by the Burton and Garran residents association.

Industry engagement

Professor Ken Baldwin is a Board member of the South East Region of Renewable Energy Excellence (SERREE) including the ACT and surrounding areas.

Dr Igor Skryabin is a Board member of the Australian Photovoltaic Institute, an Advisory Board member of the APEC Asia-Pacific Solar Energy Centre in China, a member of the NSW Energy and Resource Knowledge Hub, and a member of the organizing committee of 2016 Asia-Pacific Solar Research Conference as well as leader of the "Energy in the Asia-Pacific" research stream of the conference.

Professor Quentin Grafton is a member of FE2W (Food Energy Environment Water), an international, non-profit association with 40 members from universities, multilateral organisations and non-government organisations committed to addressing the world's food, energy, environment and water challenges.

Professional contributions

Professor Yun Liu hosted the Australia-China Joint Symposium on Colossal Permittivity Materials and Application in Energy Storage, 26-30 January 2016

Professor Tom Faunce organised conferences in Canberra and Lord Howe island, Global Artificial Photosynthesis - Breakthroughs for the Sustainocene, 9-10 September 2016

Professor Rob Elliman and **Dr Cormac Coor** were coorganisers (with Associate Professor Patrick Kluth) of the International workshop on Radiation Effects under Extreme Conditions at ANU, 26–28 October 2016

NSW Energy and Resources Knowledge Hub – Energy Technologies Initiative: Centre for Sustainable Energy

Systems, ANU, which includes ECI members Dr Igor Skryabin and Professor Yun Liu, is collaborating with Newcastle Institute for Energy and Resources, University of Sydney, The University of Technology Sydney and the Australian Energy Storage Alliance, to showcase new energy technology and service solutions for the energy industry. Professor Yun Liu is research team leader of the project *Development of Devices for Energy Conversion and Storage Based on Novel Functional Materials*.

Professor Ken Baldwin was General Chair of the OSA Congress on Light, Energy and the Environment held in Leipzig, Germany, 13 – 17 November 2016

MEDIA AND COMMUNICATIONS

The media is a key partner helping the ECI to engage and educate the wider community on topics relevant to energy change.

ECI participants regularly provide expert commentaries on news relevant to energy technology and energy policy. This is often done via an "ANU experts alert" issued as news breaks. For example, media coverage generated by ANU on Australia's emissions reductions targets reached an audience of over 2 million people.

Here are some of many examples of coverage listed by theme:

Decarbonisation of energy

Central Telegraph, QLD, 20 May 2016, "Canavan defends carbon scheme", commentary by Dr Paul Burke

Canberra Times, 25 May 2016, "How Australia can eliminate coalfired power by 2030", Professor Andrew Blakers

Scope television show channel 11, 9 July 2016, "Concentrating solar power" interview with Dr John Pye about Solar Generator 4

The Conversation, 13 July 2016, "Can Malcolm Turnbull do climate and energy policy now?" Associate Professor Frank Jotzo

IFL Science, 24 July 2015, "Hair bleach may have powered the origins of life" Comments by Associate Professor Rowena Ball

The Conversation, 26 July 2016, "South Australia's electricity price woes are more due to gas than wind", Dr Hugh Saddler

The Conversation, 25 October 2016, "The gas industry need a carbon price to compete with coal", Emeritus Professor Andrew Hopkins

The Daily Telegraph, 3 November 2016, "Big changes looming across the world but Australians could be left behind", commentary by Professor Ken Baldwin

Energy Security

SBS World News, 7 October 2016, "Political Storm over SA blackout intensifies at COAG", commentary by Professor Ken Baldwin

Energy Storage

ABC 666 Breakfast show, 19 May 2016, Interview on battery storage and Bruny project with Dr Evan Franklin

ReNew Edition, 15 July 2016, Feature Article "Agents of change. Making Batteries Go the Extra Mile" Dr Evan Franklin

The Science Show, 20 August 2016, "Pumped hydro for the cloudy windless days and nights", Professor Andrew Blakers was guest speaker

ARENA

The Sydney Morning Herald, 30 August 2016, "The sun will set on solar if the Australian Renewable Energy Agency is Gutted", Andrew Blakers

Nuclear energy

SBS, 6 Dec 2015, "Nuclear fusion in the shadows of clean energy debate", includes commentary by Professor John Howard

The Sydney Morning Herald, 11 May 2016, "What role will Australia have on the nuclear world stage?", Professor Ken Baldwin

Sustainable Transport

Canberra Times, 11 June 2016, "Electric car components a good fit for Australian manufacturers, experts say" Dr Evan Franklin

The Conversation, 6 July 2016, "Renewable jet fuel could be growing on Australia's iconic gum trees", David Kainer and Dr Carsten Kulheim

ABC, PM, 7 July 2016, "Solar plane completes first round-theworld-flight", commentary by Professor Andrew Blakers



Media Type Breakdown (Volume)

Media generated by ECI Executive and Public Policy Fellows for the 6 months to 3 November 2016 reached an audience of nearly 6 million people (isentia Media Monitoring)

Communications

ECI communications in 2016 have been focussed on promotion of ECI research and events, building and supporting ECI membership, strengthening partnerships and connections between ECI members and external stakeholders in government, industry, NGOs and the community and promoting the Master of Energy Change degree.

Our main communication channels have been events, media relations and digital communications, including ANU websites, a regular e-marketing programme to our database of almost 3,000 people and social media (including Twitter: @ANUEnergyChange, and a new Facebook page: ANU Energy Change).

AWARDS

OUTLOOK



Professor Ken Baldwin, Professor Mark Howden, Dr Paul Burke, Lily Dempster Vice Chancellor's Award for Public Policy and Outreach

The team behind The Vote: 2016 Federal Election Series, including the ECI members listed above, have been awarded a Vice Chancellor's Award for Staff Excellence.

Professor Andrew Blakers 2016 Admission to the Australian Solar Council Hall of Fame

Professor Blakers has been inducted into the Australian Solar Council Hall of Fame for his contribution to the development of the solar energy industry in Australia. He was recognised for his outstanding contribution to solar research and effective communication to the public of complex scientific issues.

Dr Nicholas Cox Robin Hill Award, International Society of Photosynthetic Research

ANU Future Fellow Dr Nicholas Cox received his award in recognition of his work on mechanisms of biological water oxidation, a major step in photosynthesis research. He is a member of the Artificial Photosynthesis research cluster.



Professor Andres Cuevas Becquerel Prize for Outstanding Merits in Photovoltaics

Professor Cuevas's award recognises his scientific merits in the development and characterisation of silicon solar cells, the most common type of solar cell technology. His work in the field spans 40 years and he is one of the pioneers in the development of bifacial silicon solar cells. He has also contributed significantly to the development of highefficiency silicon solar cells.



Dr Hassan Hijazi 2015 "Rising Star" award, Australian Society of Operations Research

Dr Hassan Hijazi from the Research School of Computer Science has recently been awarded the 2015 "Rising Star" award from the Australian Society of Operations Research (ASOR). The award recognises an early career researcher who has made a significant contribution to the field of optimisation and planning. Dr Hijazi is in the Smart Grid research cluster.

Associate Professor Colin Jackson 2015 Royal Australian Chemical Institute Rennie Memorial Medal

Associate Professor Colin Jackson received the Royal Australian Chemical Institute Rennie Memorial Medal for his work in chemical science research. His research focusses on understanding the fundamental chemistry that underlies biological function, using chemical techniques to manipulate biological systems. He is in the Biofuels research cluster.













Professor Chennupati Jagadish AC Companion to the Order of Australia

Distinguished Professor Chennupati Jagadish was appointed a Companion of the Order of Australia (AC) for eminent service to physics and engineering, particularly nanotechnology. In a career spanning over 25 years at the ANU, Professor Jagadish was recognised for receiving Australia's highest honour during the 2016 Australia Day Honours. He is a member of the Nanostructure Photovoltaics research cluster.

Professor Warwick McKibbin AO Officer of the Order of Australia

Professor McKibbin was awarded the Officer of the Order of the Australia (AO) for distinguished service to education as an economist, particularly in the area of global climate policy, and to financial institutions and international organisations.

Professor David Stern Academy Awards

In September 2016, Professor Stern was elected into the Academy of Social Sciences in Australia and was installed as a Fellow at the Academy's Annual Symposium and General Meeting in November 2016. He is considered a highly influential energy and environmental economist focussing on resource use and economic growth and development.

Mr Tom Worthington Gold Award winner for ICT Higher Educator of the Year

Mr Worthington received his Gold award from the Australian Computer Society on 17 November 2015, for the design of an open access on-line ICT Sustainability course used to train industry personnel in energy reduction in Australia and North America. Mr Worthington is in the Energy Productivity, Energy Efficiency and Demand Management research cluster.

Shannon Wang

Australian Institute of Refrigeration, Air Conditioning and Heating Student of the Year

This prestigious award is well deserved credit for the depth, scope and relevance of Shannon's PhD at ANU. This is the second year running that a student from ANU Research School of Engineering has taken out the top award.

Mr Thomas Allen and Mr Mohsen Goodarzi

2016 European Union PV Solar Exhibition & Conference Student Awards

Mr Allen and Mr Goodarzi were each awarded the EU PVSEC Student Awards in recognition of their remarkable and outstanding work in the field of photovoltaics. Mr Allen (pictured left) for his calcium contacts to n-Type Crystalline Silicon Solar Cells, and Mr Goodarzi for modelling and characterization of multicrystalline silicone blocks by quasisteady-state photoconductance.



Taralga Wind Farm Image credit: Dr James Prest, ANU

With the international ratification of the 2015 Paris Climate Change Agreement at CoP22 in Marakesh in November 2015, the imperative for energy change will increase apace. The ECI looks forward to contributing to this, as well as to advancing the parallel objectives of energy access, energy security and energy productivity.

Nationally, 2017 will see a review of Federal Government policies on climate change, which will also inform and hopefully support the review of the National Electricity Market by Chief Scientist, Alan Finkel. These policy developments will no doubt provide opportunities for the ECI over the next few years.

Locally, with the return of the ACT Government in the 2016 election, we can look forward to continuity in the leadup to achieving 100% renewable electricity by 2020. The ECI has played a key role in engaging with the ACT Government and industry in this process, and will continue to contribute to these partnerships which have been delivering significant research and education outcomes. With all these challenges and opportunities, the ECI will continue to expand as we have during the past year through the addition of new researchers. The ECI will represent this expanded membership not only by enhancing their research and education activities, but also through a major role in the University's new public policy program to be unveiled in 2017. This will further enhance our ability to engage more broadly with industry, government and the wider community.

Please visit our website (energy.anu.edu.au), follow us on Twitter (@ANUEnergyChange), like us on Facebook (www.facebook.com/ ANUEnergyChange), and keep in touch through our mailing list for the latest developments. Subscribe at energy.anu.edu.au

ADVISORY BOARD MEMBERSHIP

EXECUTIVE MEMBERSHIP



Professor Armin Aberle – Solar Energy Research Institute of Singapore

Armin Aberle is the CEO of the Solar Energy Research Institute of Singapore (SERIS) at the National University of Singapore (NUS) and a professor in the university's Department of Electrical and Computer Engineering. His research focus is on reducing the cost of solar electricity generated with silicon solar cens, both wafer based and thin-film based. His work has covered the full spectrum from fundamental materials research to the industrial evaluation of novel PV technologies at the pilot line level, including the development of novel solar cells, their fabrication in the laboratory, their characterisation, and their computer modeling. He has published extensively and his work has a high impact on the field.



Ms Glenys Beauchamp PSM - Secretary, Department of Industry, Innovation and Science

On September 18 2013, Glenys Beauchamp was appointed Secretary of the Federal Department of Industry. Prior to this, she was appointed Secretary, Department of Regional Australia, Regional Development and Local Government in 2010 after acting in the position since the Department was created on September 2010. She has also worked as Deputy Secretary in the Department of the Prime Minister and Cabinet.



Mr Stephen Devlin – General Manager, Energy Networks, ActewAGL

Stephen Devlin is responsible for ActewAGL's energy networks asset strategy and planning functions. He is also responsible for the gas networks business, technical regulatory standards, major customer connections and smart networks developments. He has a breadth of experience in the energy, water and waste sectors, having worked across many facets of the electricity, water, gas and waste industries for 30 years. Stephen holds a Bachelor of Engineering (Electrical), a Master of Business Administration and a Master of Commercial Law.



Ms Dorte Ekelund - Director General of Environment and Sustainable **Development, ACT Government**

Dorte Ekelund is an urban planner and the Director- General of the Environment and Sustainable Development Directorate of the ACT Government. She was formely the head of the Major Cities Unit, the Australian Government's think tank on urban policy issues. Prior to that, she held roles as the Deputy Lirector General, WA Department for Planning and Infrastructure, and Deputy Chief Planning Executive, ACT Planning and Land Authority. Dorte is experienced in urban development coordination, infrastructure planning, statutory planning, planning system reform and governance reform.



Mr Ian Farrar - Board Member, Centre for Sustainable Energy Systems; former Chair and CEO of the Joint Coal Board

Ian Farrar has a distinguished career in senior management in CSIRO and the coal industry. He has a Bachelor of Commerce from ANU. From 2002 until his retirement in 2005 he was Managing Director/CEO of Coal Services Pty Limited (CSPL), Coal Mines Insurance Pty Limited (CMI) and Mines Rescue Pty Limited, as well as Chairman of Coal Services Health and Safety Trust and Injury Prevention and Control Australia Limited. From 1964 to 1992 he held a range of senior management position within CSIRO, including General Manager (Corporate Resources) and Senior Principal Advisor (Special Projects).



Professor Mark Howden - Director, ANU Climate Change Institute

Mark is also an Honorary Professor at Melbourne University, School of Land and Food. Mark has worked on climate variability, climate change, innovation and adoption issues for over 27 years in partnership with farmers, farmer groups, catchment groups, industry bodies, agribusiness, urban utilities and various policy agencies via both research and science-policy roles. He has over 390 publications of different types. Mark has been a major contributor to past Intergovernmental Panel on Climate Change (IPCC) reports and is a Vice Chair of the IPCC Working Group 2, which addresses Climate Impacts and Adaptation. Recently Mark sat on the US Federal Advisory Committee for the 3rd National Climate Assessment and he participates in several other international science and policy advisory bodies.



Professor John Poate - Colorado School of Mines; Member of the National Renewable Energy Laboratory(US) Advisory Board

John M. Poate is Vice-President for Research and Technology Transfer at the Colorado School of Mines. He previously served as a Harwell Fellow of the UKAEA, Head of the Silicon Processing and Interface Physics Research Departments at Bell Laboratories, Dean of the New Jersey Institute of Technology and CTO of Axcelis Technologies. John has published extensively in several areas of nuclear physics, solid state physics, materials science and engineering. He is a Fellow of the American Physical Society and Materials Research Society, MRS Past-President and the John Bardeen award winner of the The Minerals, Metals and Materials Society (TMS)



Professor Ken Baldwin - ANU College of Physical & Mathematical Sciences

Ken Baldwin is the Director of the Energy Change Institute at ANU, and Deputy Director of the Research School of Physics and Engineering. From 2011-13 he was a member of the Project Steering Committee for the Australian Energy Technology Assessment, and in 2015/16 was a member of the Socioeconomic Modelling Advisory Committee to the South Australian Royal Commission into the Nuclear Fuel Cycle. Ken is an ANU Public Policy Fellow, and is a Fellow of the American Physical Society, the Institute of Physics (UK), the Optical Society of America and the Australian Institute of Physics.

Professor Andrew Blakers – ANU College of Engineering & Computer Science



Andrew Blakers is the Director of the Centre for Sustainable Energy Systems, ANU. He was a Humboldt Fellow and has held Australian Research Council QEII and Senior Research Fellowships. He is a Fellow of the Academy of Technological Sciences & Engineering, the Australian Institute of Energy and the Institute of Physics. He has published 200 papers and patents with research interests in the areas of photovoltaic and solar energy systems. He is also interested in sustainable energy policy, and is an ANU Public Policy Fellow.

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Kylie Catchpole is the education convenor of the Master of Energy Change program. Her research interests are in novel materials for solar cells and solar fuels. She has a physics degree from the ANU, winning a University Medal, and a PhD from the ANU. She was a Post-doctoral Fellow at UNSW and the FOM Institute for Atomic and Molecular Physics, Amsterdam. She has published over 90 papers, and was awarded the John Booker medal from the Academy of Science in 2015.

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Llewelvn Hughes is an Associate Professor in the Crawford School of Public Policy, and research director at GR Japan, a public affairs consultancy based in Tokyo. His academic work focuses on the regulation of natural resource markets, and the political economy of climate change. Dr Hughes joined the ANU in 2014 from the Elliott School of International Affairs at George Washington University. He received his Ph.D. from the Massachusetts Institute of Technology, and holds a Master's degree from the Graduate School of Law and Politics at the University of Tokyo.

Professor Elmars Krausz – ANU College of Physical & Mathematical Sciences Elmars Krausz graduated with a PhD from the University of Sydney. He has since held research positions at The Australian National University, Oxford University, the University of Virginia, and the University of Sydney before being appointed as Research Fellow at the Research School of Chemistry. He was awarded fellow of the Royal



Dr James Prest – ANU College of Law Dr Prest lectures in law at the ANU specialising in environmental law. He is a Member of the IUCN Commission on Environmental Law and works on renewable energy law and major projects legislation. After graduating from the AU and the ANU and gaining admission to practise in the Supreme Court of the ACT in 1995 he worked many years as a legal policy officer at the Department of Prime Minister and Cabinet. He has also worked as a Research Officer at the Law and Bills Digest Group of the Parliamentary Library in Canberra and as an adviser at Parliament House.

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Igor Skryabin's career has spanned both industry and academia. His major technical contribution has been in the development and commercialisation of solar technologies. Igor has published more than 100 research papers and is an inventor of more than 30 patents and industrial designs, granted in Australia and overseas. Igor is a co-lead/coordinator of the Australia-Indonesia Energy Cluster, Board Member of the Australian Photovoltaic Institute and of the Asia-Pacific Sustainable Energy Centre in China.

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Sylvie's research interests are Artificial Intelligence (AI), its optimisation and application to smart grids. She leads the CONSORT project in developing and trialling methods enabling consumer-owned battery systems to provide owner value while supporting the grid, with ANU, USyd, UTAS, TasNetworks, Reposit Power, and ARENA. She is an associate editor of the Artificial Intelligence journal, an AAAI Councillor, former President of the board of directors of International Conference on ICAPS, and a former Director of the Canberra Laboratory of NICTA.

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