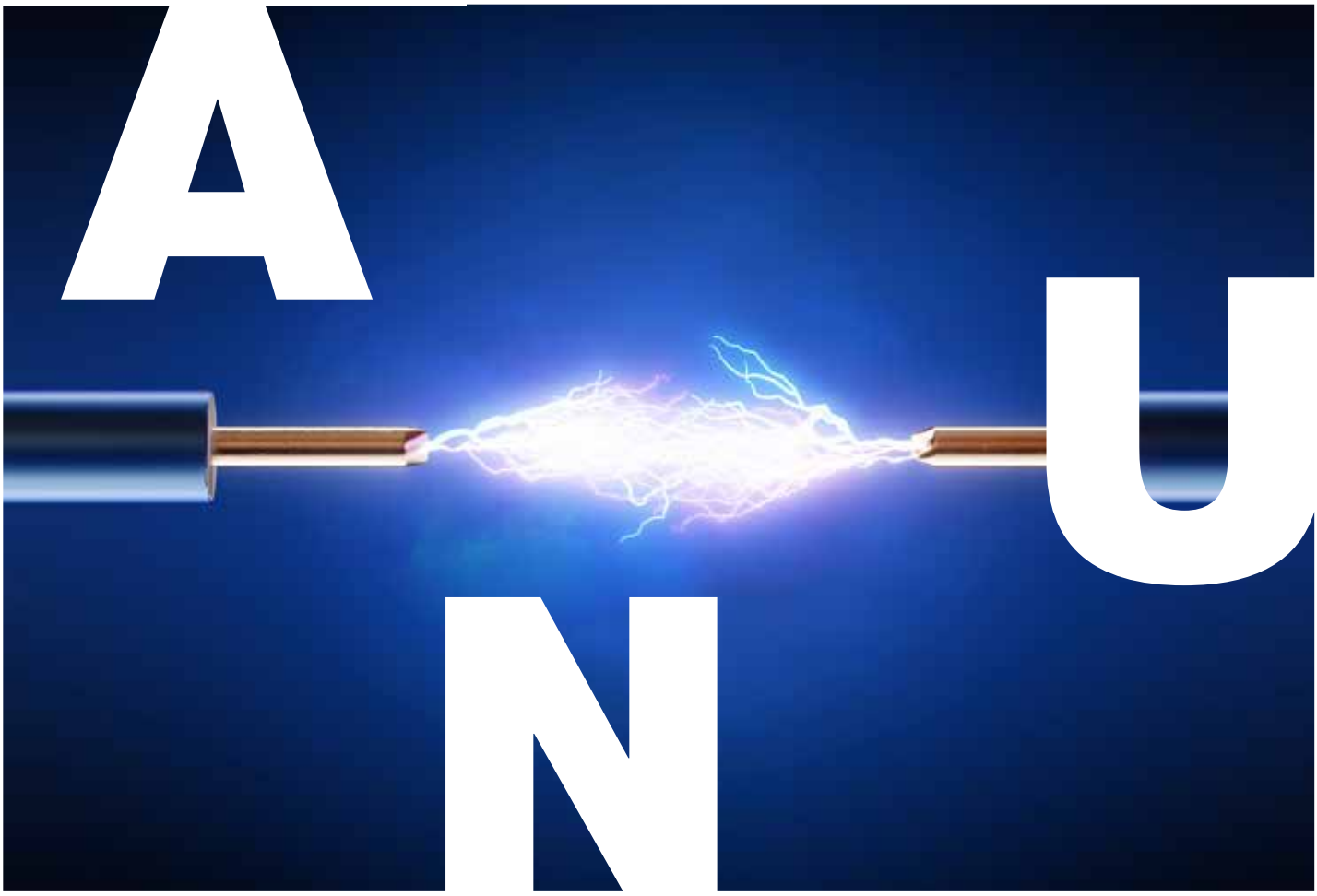
Australian National University



ANNUAL REPORT 2014

THE ANU ENERGY CHANGE INSTITUTE

CONTENTS

MESSAGE FROM THE DIRECTOR

Professor Ken Baldwin
ECI Director

2014 was an important year for the ANU Energy Change Institute, with many highlights as the ECI continues to expand its profile and research base. The ECI has more than 200 researchers and a broad portfolio across all seven ANU Colleges. The Research spans the spectrum of energy research from science, engineering, energy efficiency and technology to implementation expertise in economic, legal, sociological and policy areas.

This year ECI researchers were the recipients of $9M of funding from the Australian Renewable Energy Agency (ARENA). This will boost facilities in the solar photovoltaics and solar thermal themes, and will enable ECI researchers to continue their world-leading research in these areas.

The ECI's international profile has also strengthened our relationship with the US National Renewable Energy Agency (NREL). Following my visit to NREL late last year, the ECI hosted a delegation from NREL in July, and followed an announcement by President Obama for enhanced collaboration in solar research between the US and Australia – specifically ANU and UNSW. As a result of these closer ties, a memorandum of understanding is currently being developed between NREL and the ECI.

This first year of the new Federal Government generated numerous contributions by the ECI in response to government programs and reviews including:

- Emissions abatement options for Australia: assessments against criteria of magnitude, cost and quality
- Review of the Renewable Energy Target
- Review of the Energy Efficiency Opportunities (Repeal) Bill 2014

In addition, the ECI made a submission to the recently released Energy Green Paper. All these reports are available on the ECI website.

Locally, the ACT Government called for tenders for 200MW of wind-generated electricity in a reverse auction process which mandated local engagement with research and higher education. As the dominant energy higher education institution in the region, the ECI signed letters of intent to develop collaborative programs with a dozen companies, at least two of which will contribute to generating the required 200MW. The outcome will be known at the end of this year.

Further energy research and education opportunities will arise from ECI involvement as a founding member of the Australia-Indonesia Centre (AIC). This multi-million dollar Federal program will see an enhanced level of collaboration in the energy sector between the two countries, and it is my privilege to chair the AIC Energy Cluster.

Finally, the ECI is about to host the Optical Society (OSA) Congress on Light, Energy and the Environment featuring Professor Steven Chu, Nobel Prize winner and former Energy Secretary to President Obama. This will lead in to the ECI 's annual Energy Update, at which Steve Chu will speak alongside Ian Cronshaw from the International Energy Agency who will present the 2014 World Energy Outlook.

These new opportunities hold great promise for the future of the ECI, and I look forward to working with you towards these goals in 2015.

HIGHLIGHTS

Events from ECI Open Day 11 November, 2013 to ECI Open Day 1 December, 2014

Photo: Energy Economics panel at the ANU Energy Update 2013 (left to right): Bruce Wilson (BREE), Paul Burke (ANU), Quentin Grafton (ANU) (ECI/Adhityani Putri)

December 2013: Energy Update 2013

Mr Ian Cronshaw from the International Energy Agency (IEA) presented the latest in international energy trends as captured by the World Energy Outlook 2013, at the ANU Energy Update.

Mr Cronshaw was joined by an array of national and international presenters from government, universities and the private sector, discussing a range of issues include global and regional energy outlook, sustainable energy technologies, energy security and energy poverty. The participating speakers were at the cutting edge of politics, economics and trade, and each session focused on opportunities and challenges in these fields.

The ANU Energy Update provides Australian researchers, policymakers, industry and members of the public with the latest state of play in the world's energy markets. The inaugural event had a particular focus on Asia, where energy demand is growing faster than anywhere else in the world.

March 2014: Defence Road Map

After co-hosting the meetings that led to the release of the Defence Energy Integration Framework last year, the ECI continues its strong engagement with the Department of Defence. The ECI is part of the Defence Land Power and Energy Roadmap, and is still involved with the Defence Science and Technology Organisation DSTO) through Capability and Technology Demonstrator (CTD) programs.

The ECI was the sole tertiary research institution (along with DSTO) to be invited to participate in the Defence Energy Symposium. The aim was to expose the wider Defence community to energy technology and innovation through interaction of the symposium audience with ANU researchers. The ECI was afterwards invited to participate in a closed workshop to contribute to Defence energy planning that took place in two seperate sessions in March.

March 2014: Science Meets Parliament

The ECI joined with the ANU Climate Change Institute (CCI) and the College of Science, Health and Medicine (CPMS-CMBE) to sponsor this year's "Science meets Parliament" (SmP).

SmP is run by Science and Technology Australia (STA) and is an annual gathering of more than 200 scientists representing scientific societies across Australia, who engage with policymakers through briefings, workshops and face to face meetings.

The ECI, CCI and CPMS-CMBE sponsored the SmP Press Club lunch, which featured an address by Chief Scientist, Professor Ian Chubb, who was introduced by CCI Director Mike Raupach. ECI researcher Colin Jackson participated in SmP as part of the ECI sponsorship.

May 2014: ANU appoints new Public Policy Fellows from ECI

The ECI welcomes the new appointments of Associate Professor Karen Hussey (from the ECI research area Energy-Water Nexus), Associate Professor Frank Jotzo (from Energy Economics & Policy) and ECI Advisory Board member Professor Mike Raupach as ANU Public Policy Fellows.

They join three ECI researchers that were selected amongst the nine inaugural Public Policy Fellows, namely ECI Director Professor Ken Baldwin, Professor Andrew Blakers and Professor Warwick McKibbin, in addition to the more recently appointed Professor Quentin Grafton.

There are now seven ECI Public Policy Fellows. The Fellows contribute to the new Crawford School of Public Policy - the ANU gateway for public policy.

Photo: A workshop on Defence Energy Integration Framework organised by the ECI and the Department of Defence (ECI/Adhityani Putri)

June 2014: Australia-Indonesia Research Summit

The ECI has been invited to participate in the new Australia Indonesia Centre (AIC) jointly with Monash University, the University of Sydney, the University of Melbourne and CSIRO. The Federal Government has provided $15M funding for this program over 4 years, and the ANU has contributed $1M matched by the other partners.

The inaugural Research Summit was held in Jakarta on 22-23 May, and the ECI was represented by Dr Igor Skryabin (ECI Business Development Manager) in the Energy section of the summit, with general facilitation provided by Adhityani "Dhitri" Putri (ECI Communications Manager).

June 2014: Obama announces ECI links with NREL

US President Barack Obama announced a deeper collaboration between the US and Australia in clean energy technology research, which includes an ECI-led initiative to forge stronger links between the ANU and the United States National Renewable Energy Laboratory (NREL). This announcement followed Prime Minister Tony Abbott's White House meeting with US President Barack Obama on June 13.

The NREL collaboration also includes the University of New South Wales. NREL is the United States Department of Energy's primary national laboratory for renewable energy and energy efficiency research and development.

In a White House statement after their meeting, President Obama said that "NREL, The U.S. National Renewable Energy Laboratory, together with ANU and UNSW, plan to enhance their collaboration by sharing knowledge and best practices on photovoltaics in our ongoing efforts to meet an increased energy demand with a focus on clean energy."

Photo: PM Tony Abbott and President Barack Obama at the bilateral talks (News Corp)

Photo: Senator Zed Seselja takes a close look at the MagPIE materials testing experiment at the Opening of the Fusion Facility Upgrade (ANU/D. Paterson)

July: Opening of the $7.6M Fusion Facility Upgrade

Fusion energy research has received a major boost with the launch of the Australian Plasma Fusion Research Facility (APFRF) at the ANU.The facility includes Australia's largest fusion experiment, the newly upgraded H1, which will now be able to heat fusion experiments to temperatures hotter than the core of the sun.

The facility also includes a new machine, MagPIE, which will accelerate research into extreme materials to be used in future experiments involving even higher temperatures. Senator Zed Seselja pressed the button to initiate a 30,000 degrees Celsius fusion experiment in H1 to conclude the launch.

August: ANU received $9M in energy research funding from ARENA

ANU will enhance its position as a leader in clean energy research after receiving $9 million in new funding for five major research and development projects. The Solar Photovoltaics and Solar Thermal groups at the ECI were primary beneficiaries of the funding. The Australian Renewable Energy Agency (ARENA) has announced details of the research funding, designed to help make renewable energy more affordable and to boost the amount of clean energy produced in Australia.

September: ACT Government 200MW Wind Reverse Auction closed

In April, the ACT Government commenced its reverse auction process for 200MW of wind energy feed-in tariff by calling for companies to submit proposals for new wind farm projects. The process mandates local engagement with research and higher education. It closed in September and the winner is expected to be announced before the end of this year.

As the dominant energy higher education institution in the region, the ANU ECI signed letters of intent to develop collaborative programs with a dozen companies, at least two of which will contribute to generating the required 200MW.

The 200MW wind auction is expected to provide about 24% of the ACT's electricity consumption in 2020 and will deliver about 40% of the large-scale investments required to achieve the capital's 90% renewable energy target.

September: Energy Green Paper Forum

The ANU Energy Green Paper Forum convened a panel of experts from industry, government and academia to discuss key topics vital to Australia's resilient and sustainable energy future amid the imminent release of the Federal Government Energy Green Paper. The event provided a platform for experts and members of the public to interact with the Energy White Paper Taskforce, who were present to take note of comments made throughout the event.

September: Launch of the UN Deep Decarbonisation Pathways Project

The United Nations global "Deep Decarbonisation Pathways Project" (UNDDPP) was launched at the UN Headquarters in New York and presented to the UN Secretary General Ban Ki-Moon at the UN Climate Summit. The project will eventually provide an illustrated model of a deep decarbonisation pathway that enables the world to reach net zero emissions by 2050.

Associate Professor Frank Jotzo is a co-author of Australia's contribution to the global report together with ClimateWorks Australia, with insights from ECI Director Professor Ken Baldwin and CCI Director Mike Raupach. The interim report showed Australia could achieve net zero emissions by 2050 without major structural changes to the economy or lifestyle with the biggest opportunities in the energy sector and in carbon forestry

October: ECI signs book contract with Cambridge University Press

In partnership with the Climate Change Institute (CCI), the ECI will produce an edited book on the topic of 'Low Carbon, Resilient and Prosperous Economies' starting in late 2014. The book contract with Cambridge University Press promises to be an opportunity to strengthen collaboration among the CCI and ECI research communities. The project will be coordinated by Dr Michael Smith from the ECI.

Photo: ARENA Chair Greg Bourne speaking at the ANU Solar Oration 2014 (ECI/Adam Edwards)

November: Solar Oration 2014: ARENA Chair Greg Bourne

Chair of the Australian Renewable Energy Agency (ARENA) Greg Bourne shared his views on the future of renewables from both a technological and commercial perspective. The ANU Solar Oration is an annual public lecture on the future of renewable energy technologies in the global and Australian energy landscape. It is jointly held by the ANU and the ACT Government.

The event, attended by more than 250 people, discussed the creative disruption that renewable energy brings to the energy sector and the types of responses expected from incumbent players. Greg spoke from a global and local perspective and covered some of the short-term challenges and the longer-term opportunities and threats. The talk was opened by ACT Minister for Environment & Sustainable Development, Simon Corbell MLA, who discussed Canberra's renewable energy progress towards the target of 90% by 2020.

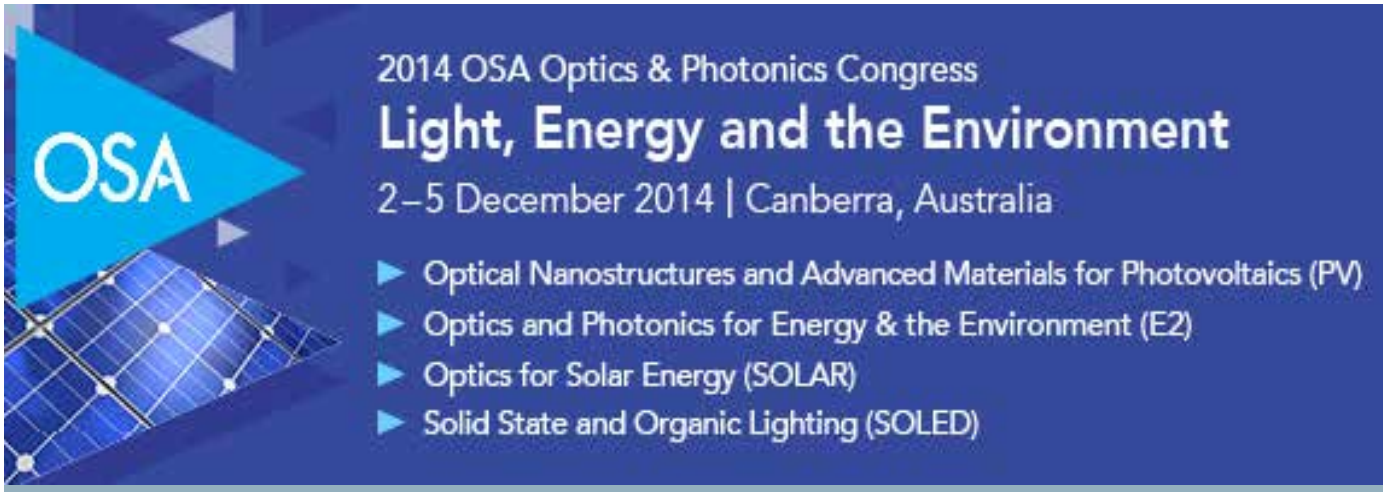
November: Kylie Catchpole named winner of John Booker award winner

ECI Executive member Associate Professor Kylie Catchpole received one of the nation's most prestigious science prizes, presented by the Australian Academy of Science. The inaugural John Booker award, named after engineer Professor John Booker, recognises the achievements of early- and mid-career researchers.

Kylie's research focuses on using nanotechnology to make solar cells cheaper and more efficient. Her major achievements include showing that the efficiency of thin solar cells can be improved using tiny metal particles, which act like antennas to direct light into the solar cell. This has opened up a range of new possibilities for reducing the cost of solar electricity.

UPCOMING HIGHLIGHTS

to be reported in the 2015 Annual Report



The ECI is proud to host the Optical Society (OSA) "Light, Energy and the Environment Congress" on optical technologies for use in energy and the environment (2-5 December). This presents a unique opportunity for all ECI researchers to showcase their research to an international audience. The Congress examines the frontiers in the development of optical technologies for energy production, transport, and use. It also examines the use of optical and photonic approaches to monitor energy usage and the effects energy production has on the environment.

It is designed to bring together researchers, engineers, and managers and foster timely information exchange between several of the disciplines involved in energy production, usage, cost and environmental and efficiency management. The Congress will be hearing from a number of eminent speakers such as Steven Chu, James G. Anderson, Martin Green, Toshihiko Iwasaki and Roland Winston.

The ECI has organised a series of events over two weeks (2-12 December) featuring Steven Chu, Nobel Laureate and Former US Energy Secretary. Professor Chu is the William R. Kenan, Jr., Professor of Humanities and Sciences and Professor of Physics and Molecular & Cellular Physiology at Stanford University. His research program encompasses atomic physics, quantum electronics, energy and energy economics, and biophysics and biomedicine that tests fundamental theories in physics, the development of methods to laser cool and trap atoms, atom interferometry, and the study of polymers and biological systems at the single molecule level.

During his visit, the ANU will be presenting Professor Steven Chu with an Honorary Doctorate. Professor Chu will be speaking at a number of forums including the OSA Congress, the ECI Energy Update and the National Press Club.

MISSION

A key to addressing the many challenges the world is facing today is a world-wide change to carbon-free forms of energy production. Energy change will offer broader benefits to society by:

- driving the transformation to a clean economy in response to climate change
- increasing economic productivity to help ensure long-term growth
- improving energy access and security.

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

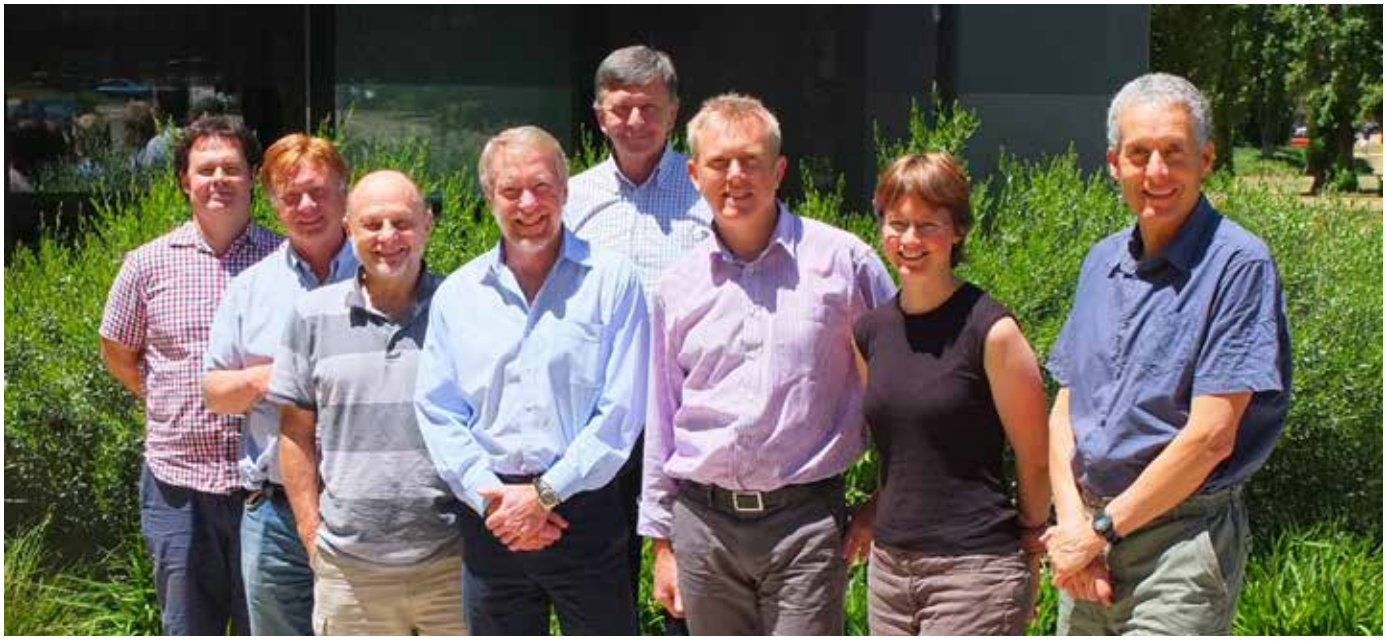
A defining feature of the ECI is that we are *technology and policy neutral*. The ECI undertakes research and education in critical areas of energy technology and energy policy without favouring one particular area over another. This can and should create an open forum for effective ideas leading to energy change.

GOVERNANCE

The ECI comprises more than 100 academic staff and their postgraduate research students, bringing the total complement to over 200 researchers.

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

Photo: Members of the ECI Executive Adam Edwards/ECI)



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)

Professor Elmars Krausz (ANU College of Physical & Mathematical Sciences)

Professor David Stern *vice Professor Warwick McKibbin* (ANU College of Asia and The Pacific)

Dr Kylie Catchpole - Education Convenor (ANU College of Engineering and Computer Science)

Dr James Prest *vice Professor Tom Faunce* (ANU College of Law)

Dr Igor Skryabin - Business Development Manager (ANU College of Engineering & Computer Science)

Dr Michael Smith (ANU College of Medicine, Biology & Environment)

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

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 Michael Raupach, Director, The ANU Climate Change Institute

EDUCATION

Master of Energy Change

Master of Energy Change (Advanced)

The need for changes in global energy generation and usage is well established. However, at present, too few professionals have an effective overview of the many factors involved in energy change. The Master of Energy Change degree is structured to meet the needs and aspirations of professionals, and equips them to engage with the broad spectrum of challenges in energy change.

In 2014, the ECI continues the delivery of its flagship educational program – The Master of Energy Change. Associate Professor Kylie Catchpole has been the convenor of the program in 2014, and that role will be taken on by Professor Ken Baldwin, the Director of the ECI, in 2015.

The program commenced in the first semester of 2012 and now includes 15 enrolled students from Australia and overseas (part time and full time). Since its launch, the program has produced 6 graduates, currently pursuing a career in research, industry and the public sector.

The ANU Master of Energy Change is a multi-disciplinary postgraduate degree, available as a coursework-only option or as a coursework plus research dissertation (advanced) degree. The duration of the degree offered in 2014 was 1 year (full time) for coursework and 1.5 years for those pursuing a research degree. However, starting in 2015, both degrees will be offered as a 2-year program (full time). These changes have been introduced university-wide to enhance the quality of Master programs at the ANU.

The program continues to bring together the wide-ranging energy expertise present at ANU. It covers policy, legal, economic, sociological, environmental and regulatory aspects of energy change, and is underpinned by fundamental scientific and technical training. The degree comprises two foundation courses and starting next year will expand the range of electives from 25 to 38 courses.

The foundation courses are:

- Principles of Energy Generation & Transformation
- 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” was specifically developed for this degree.

The program has expanded over the year and currently involves all ANU Colleges. Considering the strong inter-

Photo: Master of Energy Change 2013 graduates Carla Douglas and Zeba Anjum (Adam Edwards/ECI)

OUR STUDENTS

disciplinary nature of this degree, our primary requirement is that candidates possess an undergraduate degree from an accredited institution. No other formal prerequisites are required apart from appropriate numeracy skills and an accredited ability in English.

The subjects are grouped into the following key areas:

- Energy regulation and governance
- Energy economics
- Climate change
- Environmental sustainability
- Specific energy technologies
- Energy sociology and risk

In addition to the formal coursework, MEnCh students have an opportunity to participate in the wider activities of the ANU Energy Change Institute, which includes seminars presented by ANU and other world leaders in the field, conferences and workshops engaging with government and industry, and other outreach programs with the wider community.

This year, two students have completed a research component as part of their program, carried out under the close supervision of an ECI academic. Both projects presented a unique opportunity to integrate knowledge and experience from various academic disciplines, whilst enabling the students to interact closely with experts inside and outside of the university.

The ECI is proud to mention that both projects have received positive comments from academic reviewers and practitioners. Glory Chidubem's research that critically examines climate change adaptation strategies drew high praise from a UN official in charge of climate change. Similarly, Eshan Ahuja's investigation into waste-to-fuel options for the ACT was deemed by the ACT government to be "of remarkable quality and a valuable contribution to future planning processes".

"The interdisciplinary nature of the program is what really attracted me. While I already had a good understanding of energy generation technologies, the worlds of economics, international and domestic politics and law were essentially foreign to me. The problem of moving to a clean energy future is a complex one, and in solving complex problems it helps to see things from many different perspectives. "

Dr. David Pretty, Visiting Fellow at the ANU Research School of Physics and Engineering. David has a PhD in Physics (ANU). He is currently enrolled as a part time student in the Master of Energy Change program.

"When you come from a developing country, to a developed country like Australia, you see key differences in policies, standards and issues related to government and decision making that are supportive of energy change. The research project with the ACT government gave me the opportunity to learn from the people who are experts and those directly involved in the process of expanding sustainable energy in Australia"

Eshan Ahuja completed a research paper for the Master of Energy Change program that investigated waste-to-fuel options in the ACT, a project that received support by the ACT Government.

Artificial Photosynthesis

Biofuels

Carbon Capture and Storage

Energy Economics and Policy

Energy Efficiency and Demand Management

Energy Regulation and Governance

Energy Sociology and Risk

Energy Storage and Recovery

Energy-Water Nexus

Enhanced Oil and Gas Extraction

Fusion Power

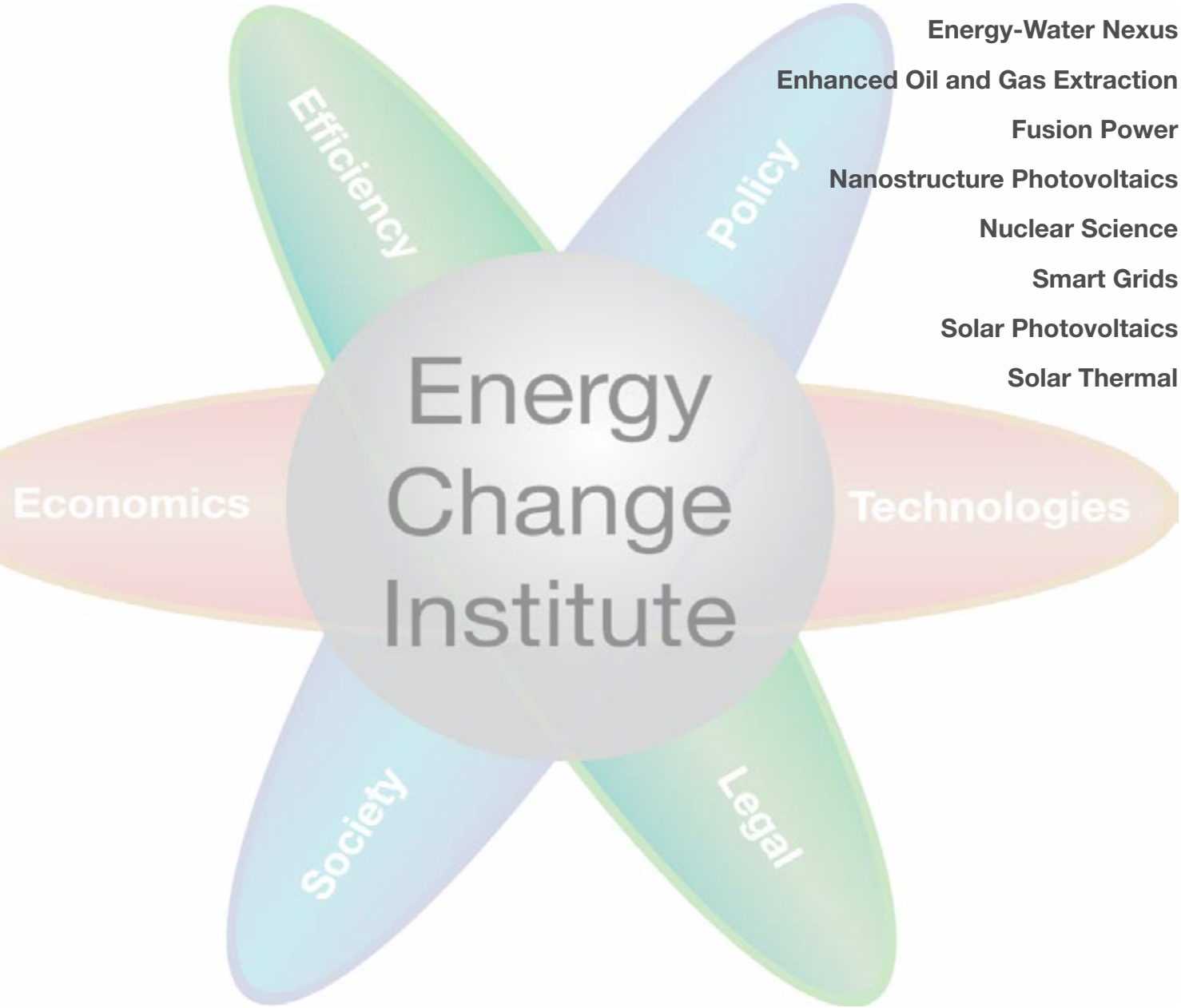
Nanostructure Photovoltaics

Nuclear Science

Smart Grids

Solar Photovoltaics

Solar Thermal



RESEARCH: INTRODUCTION

The ECI has the broadest spectrum of energy research in the country, and continues to add new researchers to its portfolio. The number of staff members now well exceeds one hundred (112), which together with PhD students yields a total of around 200 researchers in total.

The research capabilities of the ECI were enhanced this year with some key funding announcements. Principal amongst these was the $9M for research in solar energy from the Australian Renewable Energy Agency (ARENA). With the continuation of ARENA in the Federal sphere, more ECI funding applications are currently under consideration.

New research opportunities have arisen through the establishment of the Australia-Indonesia Centre (AIC) –- a multi-institutional enterprise funded by the respective Governments of the two countries. The ANU, Monash, University of Melbourne, University of Sydney and the CSIRO are the Australian contributors, who join seven research institutions in Indonesia. The Federal funding component of $15M over 4 years is matched by funding of at least $1M from each of the universities. A similar level of support is being provided by Indonesia, and all funding will leverage substantial private and other non-government contributions.

The AIC have four areas of research focus: energy, food and agriculture, health and infrastructure. ANU is co-leading (through the ECI) the Energy research cluster which is chaired by the ECI Director. ECI researchers have already received funding from the opening small grants program, having been successful with three of four energy proposals, out of 20 funded projects across all clusters and all institutions. More opportunities will soon arise through rapid start projects, and eventually though the allocation of up to $2.5M in research program funding in the energy cluster, and a further $2M for interdisciplinary projects. This represents an enormous opportunity to develop collaborative energy programs with Indonesia in areas of ECI research.

Further research opportunities will develop from the ACT Government's 200MW wind generation reverse auction process. The ANU has signed letters of intent with a dozen bidders who are required to fulfill the criteria for local investment in research and higher education, with the ECI being the major partner in the ACT and surrounding regions. This will bring substantial ongoing funding for ECI research and education programs, further strengthening links with the renewable energy industry.

The research summaries and highlights that follow demonstrate the outstanding achievements of ECI researchers, and illustrate the enormous potential for greater outcomes under these new funding opportunities.

ARTIFICIAL PHOTOSYNTHESIS

Professor Tom Faunce
Professor Elmars Krausz
Dr David Ollis
Dr Ron Pace
Professor Robert Stranger

Photo: Dr Kastoori Hingorani and Prof Ron Pace (Stuart Hay/ANU)

The Artificial photosynthesis research effort at ANU involves the collaborative efforts of four ARC funded research groups. The group's research areas include the mechanism of water-splitting, the fundamental processes and efficiencies of biological photo-energy conversion and the design and properties of biomimetic molecular assemblies.

A key aim of the ECI artificial photosynthesis consortium is to develop a range of effective biomimetic catalyst systems, particularly those to catalyse the splitting of water into hydrogen and oxygen under benign conditions and to construct a corresponding prototype reactor.

This is a year of breakthroughs for the Artificial Photosynthesis group. Dr Ron Pace and his team successfully replicated one of the crucial steps in photosynthesis, opening the way for biological systems powered by sunlight which could manufacture hydrogen as a fuel.

The team created a protein which, when exposed to light, displays the electrical heartbeat that is the key to photosynthesis. This process sheds light into the way that plants produce hydrogen by splitting water which, until now has been poorly understood. The system uses a naturally-occurring protein and does not need batteries or expensive metals, meaning it could be affordable in many countries.

The ECI research group has also made two major discoveries regarding fundamental charge separation and the oxygen evolving system in photosynthesis, published in high profile journals and presented at major conferences with much interest.

In addition, the group won a $400,000 ARC grant to work on the relevance of the low energy charge transfer state in photosystem II to artificial photosynthesis. It is expected that the outcomes and the techniques developed in this project will be applicable to the design of solar energy devices. This project is co-led by Professor Elmars Krausz.

Professor Tom Faunce continues to work on drawing attention on the regulatory and policy needs of this emerging technology. In July, he organised a global gathering of leaders in solar fuels and chemical projects and research to present the latest in artificial photosynthesis in the context of the policy challenges for globalising a practical technology. The Theo Murphy scientific meeting took place at the Royal Society in London. This landmark meeting produced principles for prioritising and specialising work while enhancing the funding and public policy profile of artificial photosynthesis.

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 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.

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, biotechnology and high throughput analysis.

The research is developing high lipid producing microalgal strains for large scale cultivation. 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.

Professor Michael Djordjevic
Professor Graham Farquhar
Dr Colin Jackson
Dr Ron Pace
Dr Dean Price

CARBON CAPTURE & STORAGE

Dr Rowena Ball
Professor Mark Knackstedt
Professor Tim Senden
Dr Adrian Sheppard

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 successful storage of the carbon dioxide (CO2) depends on the interaction between existing salty groundwater and the injected CO2 inside the labyrinth of sub-millimeter gaps in the underground rocks.

In the next 50 years, the world's fuels must be decarbonised. Endex thermoreactive principles underpin new high efficiency systems for separating carbon from fuels and flue gases. Researchers in this group are developing a suite of Endex carbon capture technologies, in collaboration with Imperial College London, the University of Leeds, CanMet Energy, and an industry partner.

This year, the CCS research group received major infrastructure funding and made some important findings in work that is currently in progress. For instance, in association with the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC), the ANU was granted $5.1m in infrastructure funding from the Department of Education's Education Investment Fund (EIF) that supports clean energy research infrastructure. This funding is being used to construct a lab that will provide imaging and core-flooding capabilities that are critical for determining the viability of carbon storage within aquifers at the CCS flagship sites.

In work supported by the Australian National Low Emissions Coal Research & Development (ANLEC R&D), researchers at the ANU x-ray CTLab successfully conducted core-flow studies of super-critical CO2 (scCO2) and brine at elevated pressure and temperature in an x-ray micro-CT instrument. These experiments provide direct 3D imaging of the distribution of scCO2 within the pores of rocks that come from a proposed carbon storage site in Queensland. Early results indicate that scCO2 is strongly non-wetting relative to brine and that high levels of capillary trapping of CO2 is possible at the trailing edge of a migrating CO2 plume.

In further work supported by the ANLEC R&D program, a comprehensive study was undertaken to determine suitable pore-scale modelling techniques for super-critical CO2: brine flow at proposed sequestration sites. The research explored major questions about the role of surface forces, buoyancy, viscosity, flow rate and pore structure. We concluded that the relatively lightweight method of quasi-static pore-network modelling is suitable for the proposed aquifers at all locations except near wellbore.

ENERGY ECONOMICS & POLICY

Expertise in energy economics and policy at ANU is concentrated in the Crawford School of Public Policy and the Research School of Economics and draws on disciplinary strengths in economics and political science.

Through the Centre for Climate Economics and Policy (CCEP) at the Crawford School, ECI researchers provide insights on the economics of climate change, its implications for public policy, and the design of climate and energy policies. This year, Associate Professor Frank Jotzo, Director of CCEP, co-lead Australia's contribution to the global "Deep Decarbonization Pathways" project, led by Prof Jeff Sachs for UN Sustainable Development Solutions (UN SDSN) Network and presented to UN Secretary General Ban Ki-Moon and world leaders at the UN Climate Summit in September 2014.

Frank also leads collaborative research program with top Chinese universities on China's climate change policies and energy sector reform, funded partially by an Australian government grant. The program on market mechanisms for climate change policy brings together researchers from leading Chinese institutions and Australian universities. Collaborators include Tsinghua, Fudan and Wuhan Universities, the Beijing Institute of Technology, the Australian National University, the University of New South Wales and the University of Melbourne.

Topics of joint research include options for pricing carbon in China's power sector and their economic effects; the impacts of a carbon price on electricity sector investments; energy demand and energy mix at the provincial level; the design and performance of China's pilot emissions trading schemes; and prospects for national emissions pricing in China. The research combines state of the art expertise in China with methodological and policy experience in Australia.

The Climate and Energy Program in The Centre for Applied Macroeconomic Analysis is an international network of scholars working in Climate and Energy and is integrated with the Climate and Energy Economics Project at the Brookings Institution in Washington. This Centre also hosts the G-Cubed model – an international macroeconomic model developed specifically for analysing climate policy scenarios. The model has been widely applied including in the 2008 Treasury Review of Australia's climate mitigation options and is used by governments and international agencies around the world.

Researchers in this area also examines the political context of domestic and international energy issues.

Professor Robert Breunig
Dr Paul Burke
Professor Bruce Chapman
Professor Quentin Grafton
Dr Carolyn Hendriks
Associate Professor Frank Jotzo
Dr Adrian Kay
Dr Andrew Kennedy
Professor Warwick McKibbin
Dr Arianto Patunru
Dr Hugh Saddler
Professor David Stern

Current projects include: the politics of energy security in Asia, particularly China and India; comparative business-government relations in the biofuels industry, with a particular focus on the EU, US and Brazil; and the democratic challenges of energy reforms including questions of effective citizen engagement and public legitimacy.

Dr Paul Burke's article on green pricing in Asia and another article co-authored with Dr John "Jack" Pezzey discussing an indicator for global sustainability were published this year. His research with Dr Shuhei Nishitateno, documenting a motorcycle Kuznets curve, which sees motorcycle dependence increase and then decrease as economies develop, was also published this year.

ENERGY EFFICIENCY & DEMAND MANAGEMENT

Dr Mike Dennis
Professor Denis Evans
Associate Professor Weifa Liang
Mr Bartholomew Meehan
Dr Hugh Saddler
Dr Michael H. Smith
Mr Tom Worthington

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.

This year, the highlights in energy productivity includes the publication of a hallmark report by the United Nations Environment Programme (UNEP) that was co-led by Dr Michael H. Smith. The report focused on how to achieve a step change in energy and resource productivity and was entitled “Decoupling: Technologies, Opportunities and Policy”.

Dr Smith also lead a partnership with UTS, the Alliance to Save Energy, University of Newcastle and Monash University to co-develop an Energy Productivity Roadmap for Australia (2014-2015) funded by the Department of Industry. The first reports for this project show how Australia can double energy productivity by 2030.

In energy efficiency, Dr Hugh Saddler published the first detailed analysis, entitled “Power Down”, explaining how and why Australia’s electricity demand has been reducing since 2010.

Dr Michael H. Smith, in collaboration with Chris Browne, Dr Peter Stasinopoulos, Associate Professor Paul Compston and Dr Marina Lobastov, created an online energy efficiency engineering educational resource funded by the Department of Industry, used now in 10 ANU courses. In addition, a new MOOC (Massive Open Online Course) in energy efficiency/sustainability and ICT has been introduced to the ANU’s edX system, an effort led by Tom Worthington and Hao Wu.

Bart Meehan delivered an international webinar, co-organised workshops at MIT/Harvard and published on the topic of building occupant behaviour and energy efficiency.

Dr Mike Dennis has been leading research into solar powered cooling and storage technologies to meet air-conditioning needs in ways that reduce peak electricity demand in national electricity market. His research has investigated solar cooling technology and complimentary gas hydrate cold storage technology. This energy storage technology offers practical and exceptionally low cost energy storage for air conditioning such to provide electricity demand shift capability.

ENERGY REGULATION & GOVERNANCE

The energy regulation and governance research area investigates a broad range of governance and regulatory issues in the field of renewable energy and emerging clean energy technologies such as artificial photosynthesis.

Professor Thomas Faunce is a leading expert on global governance of artificial photosynthesis, energy and nanotechnology, and nanotechnology and energy security. This year he continued his work in engaging the stakeholders of artificial photosynthesis by organising a global gathering of experts at the London Royal Society, examining governance and policy aspects of the emerging technology.

Dr James Prest has obtained funding from the Australia-Indonesia Centre to examine the regulatory barriers to renewable energy deployment in Indonesia and to establish a network of Australian and Indonesian experts in the field of renewable energy regulations and governance. Dr Prest also has a number of publications in progress on financial incentives, examining the dominant model of renewable energy legislation in Australia. The Austrlian model creates a market in tradable renewable electricity certificates, which is described overseas as renewable portfolio standard (RPS) laws – which he compares to the alternative legislative model (feed-in tariffs).

Ongoing research includes assessing barriers to distributed energy, issues arising at the nexus of emissions trading and renewable energy, anti-false claims legislation and carbon market dynamics.

Other research includes projects on design principles to support the creation of a low carbon energy regime and encourage energy innovation (eg pooling resources to create a global technology development fund; minimising intellectual property constraints and integrating developing countries effectively into global energy governance). This work is done through the Regulatory Institutions Network (RegNet) at ANU with Professor Peter Drahos and Professor Neil Gunningham.

Finally, Professor Timothy Bonyhady was awarded the Queen's Honours for significant service to education in the field of climate and environmental law, as an academic and researcher, and to the visual arts.

Dr Tim Bonyhady
Professor Peter Drahos
Professor Tom Faunce
Professor Neil Gunningham
Associate Professor Andrew MacIntosh
Dr James Prest

ENERGY SOCIOLOGY & RISK

Dr Jan Hayes
Emeritus Professor Andrew Hopkins
Dr Sarah Maslen

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 attention more than others? How best can transformation in energy consumption be facilitated? The ANU School of Sociology hosts a range of projects concerned with the social dimensions of risk and disasters. Research activities include a program in public safety and security of supply for the Energy Pipelines Cooperative Research Centre. This program addresses distinctly social aspects of risk and safety management including safety incentive schemes, the impact of organizational design on safety practices, and how younger members of the profession view their safety responsibilities.

Several research projects have examined major industrial accidents to determine what can be learnt retrospectively about risk management. Examples relevant to energy change include the Montara (Australia) and Deepwater Horizon (US) oil well blowouts and the San Bruno (US) pipeline explosion.

This year, Professor Andrew Hopkins and Dr Sarah Maslen completed a research program on the impact of incentives on the catastrophic risk management in the resources sector (oil and gas, petrochemical, mining), the findings from which are being published in a book entitled Risky Rewards (available Jan 2015 - Ashgate).

Dr Sarah Maslen and Dr Jan Hayes have also published an article in Environment, Systems and Decisions on the operation of Wivenhoe Dam during the Queensland floods in 2011. The article examines expert blame using as a case study the decisions of engineers who operated Wivenhoe Dam during the Queensland floods and the criticisms of those decisions by the subsequent Commission of Inquiry.

ENERGY STORAGE & RECOVERY

This research area comprises of fuel cell research, carried out in the Research School of Physics and Engineering and materials chemistry research for energy conversion and storage at the Research School of Chemistry.

The fuel cell research focuses on the development of new plasma processing techniques (similar to those used for microelectronics) to fabricate fuel cell components and on the electrical testing of fuel cell assemblies. Research areas include electrode development using platinum coated carbon nano-tubes and testing of integrated manufacturing system using commercially available membranes to separate electrons and protons.

Research areas in materials research comprises the creation of nanomaterials, thin films and bulk ceramics as well as organic/inorganic composites via a solid state reaction or wet chemical approach, the use of innovative diffraction techniques for structural and defect analyses. Additional research areas include functionality characterisation and device fabrication such as energy harvesting and storage devices.

Professor Ray Withers and Associate Professor Yun Liu achieved a major research breakthrough through the development of a new material that can store large amounts of energy with very little energy loss. The material has practical applications in renewable energy storage, electric cars and defence and space technologies.

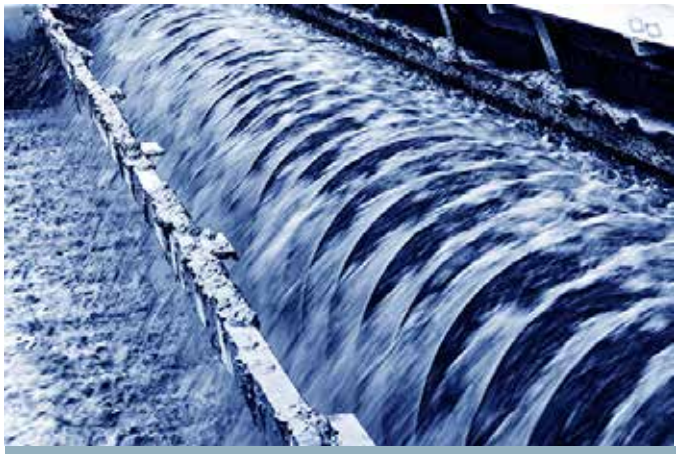
The new metal oxide dielectric material outperforms current capacitors in many aspects, storing large amounts of energy and working reliably from -190°C to 180°C, and is cheaper to manufacture than current components. The material could be particularly transformative for wind and solar power, which can cause problems when fed into the power grid at low demand times. Researchers have been trying to design new dielectric materials to make more efficient energy storage devices for years.

Finally, Associate Professor Yun Liu and the materials research group successfully hosted the Royal Australian Chemical Institute (RACI) and Materials Australia (MA) symposium of materials researchers at ANU Kioloa campus.

Professor Rod Boswell
Professor Christine Charles
Associate Professor Yun Liu
Professor Raymond Withers

Photo: Professor Ray Withers and Associate Professor Yun Liu (ANU)

ENERGY-WATER NEXUS



Professor Stephen Dovers
Associate Professor Karen Hussey
Professor Quentin Grafton
Dr Barry Newell
Dr Michael H. Smith
Dr James Pittock

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 tackle these goals.

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 it is an integrative and interdisciplinary endeavour, incorporating scholars, policymakers and industry.

Key areas of research focus include energy consumption in the urban water supply chain, water demands in the energy sector, water and energy for food security, and water and energy demands in other industrial sectors i.e. chemical production, paper, transport and mining.

One of the key projects currently undertaken by Associate Professor Karen Hussey and PhD candidate Keith Sue is a project that looks into the technical and institutional barriers to the application of distributed energy storage in the ACT. This project is supported by the ACT Government.

ECI researchers in the area has also written extensively on the nexus of climate change, energy and water governance. An article was published in the *Australian Geographer* in 2013 by Dr James Pittock, Associate Professor Karen Hussey and Samuel McGlennon that looks into the conflicts and synergies of climate, energy and water policies.

Dr Hussey has also co-authored an article that examines the implications of the energy sector transformation for water governance published in the *Australian Journal of Water Resources*.

ENHANCED OIL & GAS EXTRACTION

Photo: Professor Tim Senden (Fairfax/Katherine Griffiths)

This research group within the Department of Applied Mathematics, Research School of Physics and Engineering, aims to find the most efficient and cleanest methods for the extraction of oil and gas. The industry has developed numerous sophisticated techniques that have enabled them to return to mothballed oil and gas fields and produce large amounts of relatively clean energy. One important modern technique is the injection of carbon dioxide to maintain pressures and force the oil out, which has the additional benefit of reducing carbon emissions.

For over a decade, researchers in this area have worked 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.

This year, an innovative high-resolution 3D imaging technique was successfully commercialized. The company set up by ANU and UNSW, Canberra-based Lithicon AS, has been sold to the US-based FEI Company (a world leader in imaging technology for a range of markets, including oil and gas exploration) for $76M, representing the most significant commercial spinoff for ANU in the past decade.

Lithicon, previously known as Digitalcore, was originally set up in 2009 by ANU scientists in collaboration with colleagues at UNSW to develop an advanced computational approach to rapidly solving fluid behaviour in oil reservoirs. The basis of this approach is a revolutionary high-resolution 3D imaging technique. FEI also plans to develop new markets outside oil and gas using this imaging technology.The technology produces digital 3D images and simulations of fluids in rock samples, giving companies crucial information to help them work out the best way to extract oil and gas.

Professor Mark Knackstedt
Professor Tim Senden
Dr Adrian Sheppard

FUSION POWER

Dr Boyd Blackwell
Dr Cormac Corr
Emeritus Professor Bob Dewar
Dr Matthew Hole
Professor John Howard

Fusion is the process that powers the sun and stars. It has the potential to deliver effectively limitless, clean, base-load power for future generations.

The Plasma Research Laboratory, Research School of Physics and Engineering, at ANU is home to the H-1 Australian Plasma Fusion Research Facility and employs more than 20 staff and graduate students working in the area of fusion science. The H-1 facility is a medium-sized, fusion-relevant, high-temperature plasma physics apparatus, with $20 million establishment budget, recent upgrade funds of $7.6M under the Super Science scheme (from 2011) and a $1 million per annum turnover.

This year saw the completion of the Infrastructure Upgrade of the Australian Plasma Fusion Research Facility. The Facility is the foundation of Australia's fusion science experimental activity. It comprises Australia's only toroidal magnetic fusion experiment, H-1, and a plasma-materials machine, MAGPIE. The H-1 heliac, a stellarator, forms a complex 3D helical "magnetic bottle" in which to study hot plasmas.

The research group has also been working on a five year plan identifying Australia's engagement with ITER, the next step fusion experiment, under construction in France. The $10 billion international ITER project in France represents a major step towards the practical realisation of fusion.

Through the provision of locally developed technologies and Australian knowhow, researchers are strongly linked into the international fusion program ahead of ITER. The plan outlines participation with the ITER research community, strengthening Australian capability and infrastructure in fusion science, and development of a diagnostic for ITER.

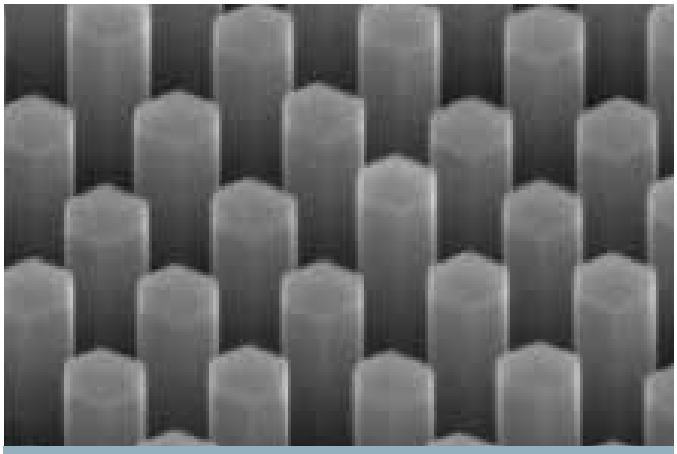
NANOSTRUCTURE PHOTOVOLTAICS

Nanostructured Photovoltaics research is carried out in the Department of Electronic Materials Engineering of the Research School of Physics and Engineering. The research is focused on developing novel concepts and technologies for high efficiency nanostructured solar cells by combining the properties of III-V semiconductors as photovoltaic materials with 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 increased efficiency. Quantum dots are predicted to form an intermediate band within the bandgap to absorb lower energy photons and also able to lead to multi-exciton generation.

In 2014, research on nanostructured solar cells has been mainly focused on development of nanowire array solar cells. The research group has developed a coupled optical and electrical simulation platform for nanowire array solar cells to optimize device design. By combining optical simulation based on three-dimensional finite-difference-time-domain (FDTD) simulation using software and the research optimised nanowire diameter and pitch constant to maximize light absorption by nanowire array. The position-dependent carrier generation rate was calculated and used to investigate the dependence of nanowire solar cell array performance on key design parameters.

The research also demonstrated stacking-fault-free and taper-free wurtzite InP nanowire array by selective area metal-organic vapour epitaxy technique. The InP nanowires show high quantum efficiency of about 50% leading to the room-temperature, photonic mode lasing. Their excellent structural and optical quality paves the pathway for further development of high performance nanowire array solar cells.

This research team has also made progress on optimising device design, material growth, device fabrication and characterisation of InP nanowire arrays to achieve prototype nanowire array solar cells with pn junction in both axial and radial directions. Researchers are investigating various device structures using a series of techniques, including light/dark IV, spectral response, 3D-photocurrent mapping and electron beam induce current (EBIC) measurements.



Associate Professor Lan Fu
Dr Yanan Guo
Professor Chennupati Jagadish
Dr Sudha Mokkapati
Dr H. Hoe Tan
Dr Fan Wang

Image: A microscopic image of an InP nanowire array grown by selective area metal-organic vapour epitaxy technique. (ANU)

NUCLEAR SCIENCE

Professor Keith Fifield
Professor David Hinde
Dr Greg Lane
Professor Andrew Stuchbery

Nuclear Science research 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 studies and research carried out in the department 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. These applications are extending our understanding of the properties of advanced fuels for Generation IV nuclear reactors, through materials characterisation to accelerator mass spectrometry. This enables climate change monitoring, determination of groundwater flows and environmental tracing of nuclear discharges via ultra-sensitive measurement of rare isotope abundances.

The Heavy Ion Accelerator Facility has many active national and international collaborations. The Facility is currently undertaking a $7.6M upgrade and enhancement through the Federal Government's Super Science scheme. It is operated as a National Facility, with merit-based access via collaborative agreements.

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

ECI researchers in the area also presented their research at a number of high profile forums. Professor Ken Baldwin was a panel member in the STA Topical Science Forum on "Nuclear energy: the debate Australia has to have". Professor Ken Baldwin and Professor Andrew Stuchbery made presentations and participated in the ANU workshop on Nuclear Power, "Nuclear Power in East Asia: The Costs and Benefits".

Professor Andrew Stuchbery participated in the meeting of the Nuclear Energy Experts Group, which met in Bangkok. The meeting brought together 29 specialists from 19 countries from 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.

SMART GRIDS

The Smart Grid group in the ANU College of Engineering and Computer Science and National Information Communications Technology Australia (NICTA) are jointly building new technologies based on mathematical optimisation, simulation, and artificial intelligence, to support future energy systems in areas including grid integration of renewables, grid and microgrid design and operations, joint gas-electricity network optimisation, demand response, home and building energy management systems, and energy price and solar forecasting.

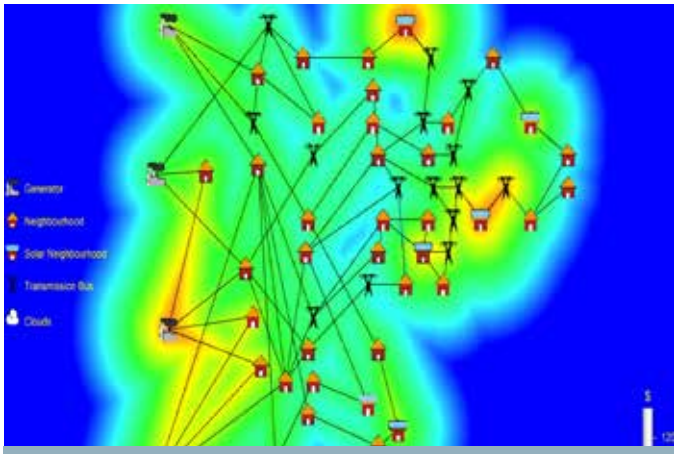
In January, the group initiated a key long term activity in the development of a new optimisation and simulation software platform supporting the planning and operations of future energy systems, the first platform to confer the ability to easily model and solve a wide range of power systems optimisation problems and to provide global optimality guarantees.

In June, a 12 month international cooperative research and development agreement was announced between NICTA and Los Alamos National Laboratory (LANL) in Coupled Infrastructure Control and Optimisation. This project aims to create systems that connect and manage electricity and natural gas supplies on a shared platform in order to reduce the likelihood of failures. Professor Pascal Van Hentenryck leads the project on the Australian side.

In July, Dr Igor Skryabin presented a new method for forecasting wholesale electricity market prices (jointly authored with colleagues from University of Technology of Sydney) to the 4th Workshop of the Institute of Mathematical Statistics (IMS) and Finance, Probability and Statistics (FPS) group (IMS-FPS 2014).

In September, the group published five papers at the Power Systems Computation Conference (PSCC 2014) which takes place every three years. Two of these five papers were selected as part of the top 8% of the papers presented at the conference, and were invited to submit to a journal special issue. The results published develop state of the art mixed-integer non-linear programming approaches to find high quality reconfiguration plans for distribution and transmission systems, in situations ranging from standard operations optimisation, to minor outages, to large scale disasters.

Solar energy is expected to become the best, low-cost solution for generating energy in Australia. But the energy from sunlight is intermittent when it is cloudy. NICTA and ANU cooperate in the ARENA funded project “Machine learning based forecasting of distributed solar energy production” to develop and build low cost data loggers and camera systems which can be installed in hundreds of locations over a city. By fusing the data streams stemming from those sensors with machine learning techniques will allow not only predictions of the future solar power output but also an estimate of the uncertainty of those predictions. Those predictions can then be used by the grid operators to control the fluctuations enabling an increasing uptake of solar installations on residential roofs. Ideally data from the system will be made available in real-time to all interested market participants.



Dr Carleton Coffrin
Dr Evan Franklin
Dr Dan Gordon
Dr Alban Grastien
Dr Patrik Haslum
Professor Pascal Van Hentenryck
Professor Sylvie Thiebaux
Dr Menkes van den Briel
Mr Nicholas Engerer
Dr Igor Skryabin

Image: Using of Solar PV inverters for distributed network voltage management (ANU/NICTA)

Dr John Pye, Professor Sylvie Thiebaux and Professor Pascal Van Hentenryck are launching a new topic on the optimal integration into the Australian electricity grid of concentrating solar thermal power (CSP) with thermal energy storage (TES). The dispatchability of CSP+TES means that it is well-placed to supply power at peak demand times not well-served by other non-storage renewables, and it has been widely forecast to play a major role in future 100% renewable energy grid scenarios.

SOLAR PHOTOVOLTAICS

Professor Andrew Blakers
Dr Kate Booker
Associate Professor Kylie Catchpole
Dr Andres Cuevas
Dr Mike Dennis
Professor Rob Elliman
Mr Nicholas Engerer
Dr Vernie Everett
Dr Andreas Fell
Mr Kean Chern Fong
Dr Evan Franklin
Dr Nicholas Grant
Dr Stuart Hargraves
Dr Niraj Lal
Dr Daniel Macdonald
Dr Rob Middleton
Dr Sudha Mokkapati
Dr Jelena Muric-Nesic
Dr Yona Nebel-Jacobsen
Dr Yongling Ren
Dr Fiacre Rougieux
Dr Avi Shalav
Dr Igor Skryabin
Dr Matthew Stocks
Dr Dongchul Suh
Dr Sachin Surve
Dr Elizabeth Thomsen
Dr Andrew Thomson
Ms Marta Vivar
Associate Professor Klaus Weber
Dr Yimao Wan
Dr Thomas White
Dr Xinbo Yang
Dr Jun Yu
Dr Soe Zin

Photo: The wearable solar technology in use during trials (Department of Defence)

Solar energy research at ANU commenced 40 years ago, with the aim of increasing the uptake of environmentally benign solar energy solutions. The Centre for Sustainable Energy Systems (CSES) in the Research School of Engineering was established by University Council in 1997, and undertakes work in the areas of photovoltaic and solar thermal energy conversion. Its activities span the range from basic R&D through to commercialisation.

Over 30 research and funding partners support the work of this large research area. The area runs over 20 research projects with a combined value exceeding $30M. This year, solar photovoltaics research at ANU received a boost with a number of successful ARENA research grants with a total of over $6M. The grants support, among others, research that seeks to create low cost-very high efficiency silicon solar cells and modules through eliminating material quality barriers and the development of advanced surface and contact technologies for industrial silicon photovoltaics.

The research areas has also received a grant from the Australia-Indonesia Centre to investigate a grid that distributes electricity generated through solar PV technology in Australia to Asia through Indonesia. This year, the group has received over $3M in royalties for the Sliver cell technology, bringing the total to $11M.

The group has also successfully fabricated a 24.4% efficient silicon solar cell in a research collaboration with Chinese company Trina Solar. In addition, it has conducted a successful demonstration of wearable solar PV modules for soldiers as part of the Capabilities Technology Development project funded by the Department of Defence.

Finally, CSES continues to collaborate closely with the Energy Change Institute, providing a framework for teaching, research and outreach activities.

SOLAR THERMAL

The Solar Thermal Group in the Research School of Engineering was formed 40 years ago and has a long history of development in remote-area solar thermal power stations, thermochemical energy storage, and dish and trough solar concentrators.

Current work in the group focusses on solar air-conditioning, heat storage and low-temperature solar heating systems, under the leadership of Mike Dennis, as well as high-temperature solar thermal energy systems and dish concentrators.

A major facility of the solar thermal group is the SG4 Big Dish, a 500 m^2 dish concentrator, the largest solar dish in the world. The dish, now completed, is a valuable tool for research into high-temperature receiver design, sun-tracking algorithms, and alternative energy conversions systems such as solar Brayton engines and, soon, we aim, solar biomass gasification. The low-temperature work is supported by a laboratory dedicated to solar cooling and cold storage research. This is complemented by thermal transient and computational fluid modelling facilities for numerical investigations. The focus of the group is to develop hybrid solar air-conditioning and water heating technology.

With the recent appointment of A/Prof Wojciech Lipinski, the group is now growing rapidly, and expects to fill several research fellow and doctoral positions in the coming year. This year we have received ARENA/ ASTRI, funding for four major projects in the group in topics including heliostat field design, receiver design, production of fuels using solar-thermal energy, and high-temperature energy storage.

Our ejector-based solar air-conditioning technology has evolved through gains in efficiency and substantial cost reduction to the point where it is competitive with incumbent solar cooling technologies. We are also developing an effective and low cost means of storing cooling effect for building air conditioning. This energy storage technology can be used to time-shift demand on electricity grids and works well with conventional air conditioners as well as solar air conditioners. We aim to bring together heating, cooling and hot water into a single integrated system.

A project team led by ANU and funded by ARENA has used a range of experimental and numerical studies as the basis for a new cavity receiver design suitable for a dish concentrator. According to modelling, the design achieves an efficiency improvement of more than 2%. A full-scale prototype will be tested in mid-2015.

We have also received co-funding from ARENA to conduct two projects. The first is a $3.1M project aiming to develop a novel high-temperature thermochemical energy storage system for dispatchable solar power generation using reversible chemical reactions with manganese metal oxides. The second is a $3.5M project, ‘Bladed receivers with active airflow’, aiming to develop next-generation receivers for central tower solar power plants.

Finally, Associate Professor Wojciech Lipinski has been awarded a 2014 Future Fellowship by the Australia Research Council to conduct research on improving the efficiency of solar thermochemical fuel production.

Dr Roman Bader
Dr Joe Coventry
Dr Mike Dennis
Dr Graham Hughes
Associate Professor Wojciech Lipinski
Dr John Pye
Dr Mahesh Venkataraman
Adjunct Professor Alan Weimer
Dr José Zapata

THE ANU ENERGY PLAN

In 2013 the Vice Chancellor of the ANU, Professor Ian Young, threw out the challenge to reduce the energy and water consumption by the University by up to 10% per annum. The ECI and the Facilities and Services Division joined forces to take up this challenge, and launched the Campaign to Reduce Energy and Water (CREW).

The first step towards making smart energy choices is to gain knowledge about our energy usage, so an energy and water dashboard has been established to monitor consumption in many of our buildings. This information is collected centrally and can then be used to target reductions and monitor behavioural and structural changes.

While there are many opportunities to cut our energy usage, there are also ways in which we can generate energy. This includes solar thermal – through the generation of heat for building temperature management – and solar photovoltaics for the generation of electricity. The University is not only the largest single electricity customer in the ACT, but it also has the potential to be one of the largest institutional energy generators through installation of solar panels on its vast roof space. There are also prospects for co- and tri-generation using gas which could be cost effective.

To create an holistic framework for energy consumption, savings and generation on campus, the University has agreed to establish an Energy Master Plan. Soon the Master Plan process will be put out to tender, and the ECI will work closely with the Facilities and Services Division to ensure that the wide range of expertise in the ECI can contribute effectively to this exciting project. This will involve contributions from the ECI themes of Solar Photovoltaics, Solar Thermal, Nanostructured Photovoltaics, Smart Grids and Energy Efficiency and Demand Management, to name but a few.

Achieving cost effectiveness will be an important aspect of this project. However, risk mitigation and planning for the provision of a reliable, environmentally sustainable energy system is critical to meeting the future needs of our growing infrastrucure.

With several thousand employees, and several tens of thousand people on its extensive campus, the ANU is a model environment for large institutional precincts to systemically address energy usage and generation. This will be a fruitful knowledge generating process with which other institutions will collaborate, as well as leading to practical cost-saving outcomes for the University.

AUSTRALIA-INDONESIA CENTRE

Photo: Geothermal plant in Indonesia (AP)

This year has seen the ECI become deeply engaged with the newly established Australia-Indonesia Centre (AIC), a collaborative research centre tasked with solving shared national challenges. The Federal Government has provided $15M funding for this program over 4 years, and the ANU has contributed $1M matched by the other partners.

Photo: Energy cluster discussion facilitated by ECI Business Manager Dr Igor Skryabin, Australia-Indonesia Summit (June 2014)

Together with Monash University, the ECI leads the Energy Cluster, one of the four clusters supported by the AIC.

In the first round of AIC funding, ECI researchers were awarded three projects amounting to $125,000. The three projects are representative of the breadth of ECI's research expertise covering topics such as the feasibility of an Australia-Indonesia renewable supergrid, a case study on decarbonising the Indonesian electricity sector, and overcoming legal and governance barriers to clean energy.

In November 2014, the ECI and Monash University organized the first Energy Cluster planning workshop in Bandung, Indonesia. The workshop was attended by leading Indonesian Universities and representatives from the government of Indonesia and Indonesian energy companies.

As we look forward to the months ahead, we'll be busy planning Energy cluster activities including an investment plan for $2.5M over the next 3 years. The ECI is looking forward to its pivotal role in the Energy theme of the AIC, and to exploring new research and educational opportunities.

EVENTS

In 2014, the ECI organised and hosted a range of public events—from public lectures by eminent speakers of global standing with hundreds of attendees, 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.

In order to improve its event management, this year ECI has begun using Eventbrite, an online platform to promote events promotion and to keep track of attendance levels. As a result, the ECI has enjoyed unprecedented high level of interest and attendance at all of its public events. Eventbrite data shows more than 700 unique participants to all ECI events this year.

The audio and video ecording of all ECI events are available on the ECI website and YouTube Channel.

Below is a list of events since last year's Annual Report:

FLAGSHIP EVENTS

The ANU Energy Change Institute Open Day 2013, 11 November 2013.

The ECI Open Day serves as a platform for exchanging ideas and networking for ANU based academics and researchers working in the field of energy change. The event comprised presentations by ECI participants on their latest research, including on new ECI research areas Energy-Water Nexus, Energy Storage and Recovery and the expanded research area Energy Efficiency and Demand Management. This year, the event was attended by ANU academics and external stakeholders of the ECI, including the ACT government and officials from the Department of Resources, Energy and Tourism (now Department of Industry). The presentations were followed by a tour of ANU energy research facilities. RSVPs: 96

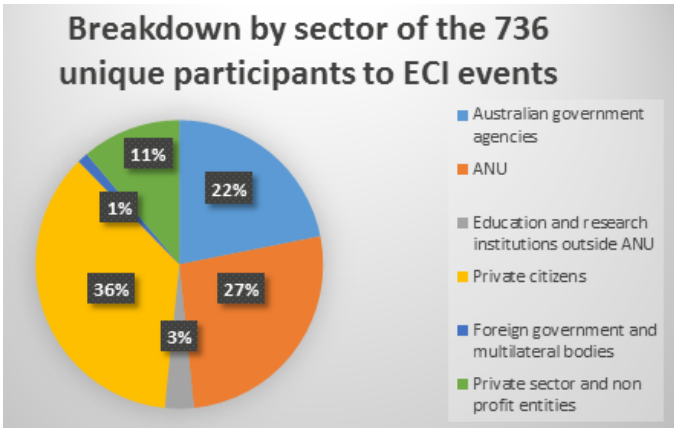


Photo: ARENA CEO Ivor Frischknecht chaired a session on energy economics at the ANU Energy Update 2014 (ECI/Adhityani Putri)

ANU Energy Update 2013: Focus on Asia, 5 December 2013.

The Energy Update brings together researchers, policymakers, industry and members of the public to discuss the latest state of play in the global energy landscape. The inaugural event in 2013 presented the World Energy Outlook 2013, which had a focus on emerging economies. The Energy Update had a particular focus on Asia, where energy demand is growing faster than anywhere in the world. High profile speakers participated in this event, including ARENA CEO Ivor Frischknecht, BREE Director Bruce Wilson, Professor Quentin Grafton from ANU, Professor Chris Greig from UQ and Professor Hugh Outhred from UNSW. RSVPs: 269

PUBLIC LECTURES

"Solar Energy Research: Past, Present and Future" Public Lecture by Dr Greg Wilson, US National Renewable Energy Laboratory (NREL), 16 April 2014.

This talk reviewed the history of PV research at NREL, the changes the program has gone through in the past 37 years, as well as exploring the directions research needs to follow to establish PV as a major source of zero-carbon energy that the world so badly needs. ACT Minister for Environment and Sustainability Simon Corbell, MLA opened the event. RSVPs: 235.

RSPE Director's Colloquium: "Length and time scales in atmospheric physics: How Windlab optimises wind energy economics" by Nathan Steggel and Keith Ayotte, 1 May 2014.

The talk showed how techniques derived from atmospheric physics plays a fundamental role in creating the computational and analytical tools to produce wind flow projections with high levels of accuracy and precision and therefore enhance the value of wind energy projects. This event is co-hosted with RSPE and did not use Eventbrite.

RSPE Director's Colloquium: "FUSION À LA PROVENÇALE: Progress towards fusion energy at ITER", 31 July 2014.

Dr David Campbell, Director at ITER, provided an update on the fusion energy research project that involves the European Union (including Switzerland), China, India, Japan, the Russian Federation, South Korea and the United States. ITER is a critical step in the development of fusion energy: its role is to confirm the feasibility of exploiting magnetic confinement fusion for the production of energy for peaceful purposes by providing an integrated demonstration of the physics and technology required for a fusion power plant. This event is co-hosted with RSPE and did not use Eventbrite.

"Dare to Dream: Icarus Rewritten!" The 2014 Solar Oration by Greg Bourne, Chair of the Australian Renewable Energy Agency, 17 November 2014.

The talk discussed the future of renewables, the creative disruption they bring and the types of responses expected from incumbent players. Greg provided technological and commercial perspectives from his business experience and also perspectives from the environmental and climate change dimensions. ACT Minister for Environment and Sustainability Simon Corbell, MLA opened the event. RSVPs: 299

PANEL DISCUSSIONS/SEMINARS

Rooftop Revolution: The latest trends in solar and wind energy featuring Danny Kennedy (Sungevity), Renate Egan (APVI) and Andrew Blakers (ECI), 24 October 2014.

This panel of experts discussed global energy trends, the speed of solar and wind energy uptake and why Australia needs to buy in now to be part of the rising renewable energy tide. RSVPs: 111

Photo: Keith Ayotte, Ken Baldwin and Nathan Steggel at the RSPE Director's Colloquium on Windlab's work in wind energy (ECI/Adam Edwards)

Photo: ACT Minister Simon Corbell, MLA, presented Yimao Wan with a prize for his outstanding postgraduate research work in solar energy at the Solar Oration 2014 (ECI/Adam Edwards)

Lab Curiosity to Commercial Process - What it takes by Adjunct Professor Alan Weimer, 24 November 2014.

ECI participant and adjunct professor Alan Weimer shed a light into what it takes to commercialise your academic discoveries, drawing from years of experience at Dow Chemicals and University of Colorado. RSVPs: 22

SYMPOSIA

ANU Energy Green Paper Forum featuring Margaret Sewell (Department of Industry, Energy White Paper Taskforce), 15 September 2014.

This Forum convened experts from industry, government and academia to discuss issues relevant to the Energy Green Paper. Members of the Department of Industry, Energy White Paper Taskforce attended the event.ECI Director Ken Baldwin, Clare Savage (Energy Australia), Tony Wood (Grattan Institute), Iain McGill (UNSW), Jonathan Jutsen (Energetics), Michael H. Smith (ANU ECI), John Blackburn (NRMA), Neil Greet (Engineers Australia) covered topics ranging from challenges to the current energy system, options to optimise the supply and use of energy resources to meet demand, energy efficiency and energy security. RSVPs: 187

STUDENT EVENT

ANU Climate and Energy Research Student Expo Prize 2014, 24 July 2014.

The ANU Climate and Energy Research Student Expo showcases the ongoing and completed research work in the field of climate change and energy change. This event, jointly organised with the ANU Climate Change Institute, featured a special session on post PhD career pathways by Dr. Margi Böhm (CSIRO) and Dr. Nathan Steggel (WindLab). This event was attended by 20 people.

MEDIA

Photo: ECI Director Ken Baldwin in a panel with Ian Hore-Lacy and Barry Brook with moderator ABC 666 host Genevieve Jacobs (STA)

The ECI considers the media as a key partner to achieving its goals in engaging and educating the public on topics relevant to energy change. The ECI regularly provides expert commentary on news relevant to energy technology, energy policy and aspects of climate change relevant to energy change. This is routinely done through an “ANU experts alert” issued when the news breaks.

This year, Australia’s energy policy landscape underwent a transformation following the repeal of the carbon pricing policy scheme and the review of the Renewable Energy Target. ECI Director Professor Ken Baldwin and ECI researchers Professor Andrew Blakers, Associate Professor Frank Jotzo and Dr Paul Burke were among the ANU experts that have been frequently consulted by the media to provide their expert insights.

This year also marked the release of major international reports on energy and climate change. This includes the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). ECI researchers Associate Professor Frank Jotzo and Professor David Stern were lead authors of the IPCC report and were extensively quoted, particularly by the Australian media following the report’s release.

Another major report released this year was the United Nations Deep Decarbonisation Pathways Project (UNDDPP). Associate Professor Frank Jotzo is a co-author of the Australian UNDDPP report, which received global media attention. Frank’s comments on how Australia could make deep emission cuts by 2050 without significantly changing our economic structure, has been picked up by dozens of Australian and global news services, including The Guardian, The New York Times and Business Week.

Another topic that drew media interest was nuclear energy. In July, Professor Baldwin spoke in a broadcasted panel discussion, moderated by ABC 666 host Genevieve Jacobs that examined whether Australia needs to consider nuclear energy as a clean energy option. He has also commented on this topics in various media articles, including a feature piece in the Australia Financial Review (November 2014).

On the technology and innovation front, there was significant media attention with the sale of high technology start up Lithicon AS, spun off RSPE, ANU, which received more than 20 media hits in major Australian media outlets (Sydney Morning Herald, The Australian) and in various industry media.

MEDIA

The successful demonstration of wearable solar modules developed by the Centre for Sustainable Energy Systems in collaboration with the Department of Defence - a project dubbed "the solar soldiers"- was also a media highlight this year. The press release was used by 11 print and online news services, including from AAP, The Canberra Times and EnergyMatters.

Finally, one of the biggest media highlights this year for the ECI, and certainly for the ANU, was the announcement made by US President Barack Obama following his meeting with Prime Minister Tony Abbott on stronger links with the US National Renewable Energy Laboratory.

In addition to media mentions and expert comments, many of our researchers conveyed their thoughts and ideas in the form of opinion pieces, published in major news outlets and The Conversation (an independent, not-for-profit media outlet that uses content sourced from the academic and research community). Some of the notable contributors include Dr Jotzo, who published 11 pieces in The Conversation alone and a number of pieces in various other outlets; Dr Paul Burke, who wrote about the consequences of fuel subsidy (The Conversation, November 2014) and Dr Michael H. Smith, whose piece outlined the energy agenda in the G20 (Canberra Times, September 2014).

OUTREACH

Part of ECI's education mission is to disseminate information on energy change through outreach activities. It has done so via a number of different mediums:

National Workshops

The ECI has hosted a number of workshops that bring together experts from different sectors. They were organised in collaboration with strategic government and industry partners:

- Associate Professor Yun Liu (Energy Storage and Recovery) co-hosted a national gathering of materials researchers in ANU Kioloa Campus (NSW) in collaboration with Royal Australian Chemicals Institute (RACI) and Materials Australia (MA)
- The Bureau of Resource and Energy Economics (BREE) and the ECI hosted a workshop on energy market modelling at the ANU
- The Department of Defence and the ECI organised a series of workshops under the "Land, Power and Energy" program
- On 2 July Professor Baldwin presented on "The Solar Energy Contribution Scheme" to the income contingent loans workshop in honour of the visit by Nobel Prize winner Professor Joseph Stiglitz, organised by Professor Bruce Chapman.

Community forums

ECI researchers routinely spoke at public events designed to reach out to the wider community:

- Professor Ken Baldwin presented on Australia's Energy Future at the Moss Vale Probus Club on 9 January
- Professor Ken Baldwin presented in a public lecture series organised by the University of the Third Age (U3A) in Canberra on 28 May
- Professor Ken Baldwin, Associate Professor Karen Hussey and Dr James Pittock spoke at the Frank Fenner Forum Series on Energy, Climate and Water held throughout 2014 by the ANU Fenner School of Environment and Society.

Speaking Engagements

Professor Ken Baldwin has represented the ECI on a number of public events that examine scientific issues in energy change and climate change. These events include:

- On 3 April, Professor Ken Baldwin presented at a conference "2XEP – Doubling Energy Productivity"
- On 26 November, Professor Ken Baldwin presented at the Institution of Engineers Annual conference in the session "Practical Responses to Climate Change".

Government Engagements

In addition to its events and media activities, the ECI engages with the government through a number of external forums and groups. Below is a sample of some of this year's engagements:

- Several ECI researchers participated in *Science meets Parliament* (SmP) 17-18 March and the ECI, jointly with the CCI and the ANU College of Science, sponsored the SmP Press Club lunch, which featured the Chief Scientist Professor Ian Chubb
- Professor Ken Baldwin spoke on an expert panel about nuclear energy, attended by Federal MPs as part of the *Parliamentary Friends of Science.*

PUBLIC POLICY


Ken Baldwin


Andrew Blakers


Quentin Grafton


Warwick McKibbin


Karen Hussey


Frank Jotzo


Michael Raupach

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.

In 2014 three new ANU Public Policy Fellows were announced:

- Associate Professor Karen Hussey – ECI Energy-Water Nexus (Fenner School of Environment and Society)
- Associate Professor Frank Jotzo – ECI Energy Economics and Policy (Crawford School of Public Policy)
- Professor Michael Raupach – Director of the ANU Climate Change Institute and ECI Advisory Board Member

These appointments bring the total of ANU Public Policy Fellows affiliated with the ANU Energy Change Institute to seven, including the existing 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)
- Professor Warwick McKibbin – ECI Energy Economics and Policy (Crawford School of Public Policy)

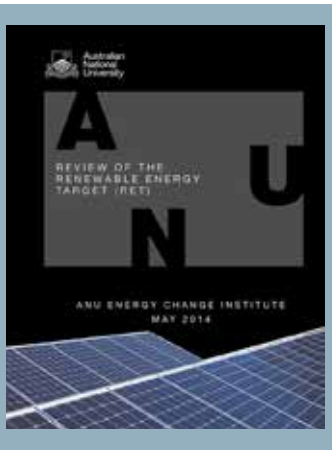
The Fellows provide expertise through the new Crawford School of Public Policy - the ANU gateway for public policy.

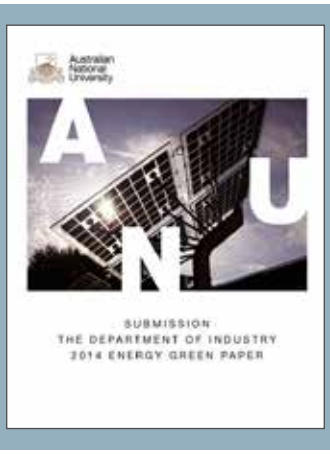
Contributing through expertise

Many ECI researchers contribute through their individual research expertise to public policy development 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 provided the following key public policy contributions:

- Professor David Stern and Associate Professor Frank Jotzo were lead authors on the recently announced synthesis report of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).
- Professor Ken Baldwin continued as a member of the Project Steering Committee for the Australian Energy Technology Assessment (AETA) which this year updated the report initially released in 2012.
- Associate Professor Frank Jotzo is a member of the Australian committee for the UN Deep Decarbonisation Pathways Project.

PUBLIC POLICY





Submissions

In addition, the ECI contributed a number of key papers and submissions to the government reviews in 2014:

- Emissions abatement options for Australia: assessments against criteria of magnitude, cost and quality
- Review of the Renewable Energy Target
- Review of the Energy Efficiency Opportunities (Repeal) Bill 2014
- Submission to the 2014 Energy Green Paper.

All these reports are available on the ECI website.

Facilitating Engagement

- The ECI continued its relationship with the Department of Defence in a series of workshops examining options for mitigating risk in Defence energy needs.
- The ECI organised and facilitated a public forum in which a task force from the Department of Industry was able to mine feedback from experts and members of the public for the Energy White Paper.
- The ECI again this year hosted the annual workshop of the Bureau of Resource and Energy Economics, where Professor Baldwin was a keynote speaker.

Photo: Department of Defence workshop at ANU(ECI/Adam Edwards)

Photo: Margaret Sewell, leader of the Energy White Paper Task Force, Department of Industry, speaking at the ANU Energy Green Paper Forum (ECI/Adam Edwards)

OUTLOOK

The ECI continues to expand its research and education activities and has now developed a strong profile in public policy. New initiatives such as the Australia-Indonesia Centre (AIC) and the ACT Government 200 MW wind energy reverse auction continue to provide opportunities to expand the ECI portfolio. A further opportunity will arise in the near future when the ACT Government announces the next 50MW advanced solar reverse auction. The ECI looks forward to participating in that process as well as other future renewable energy initiatives by the ACT Government.

Nationally and internationally the ECI will continue to be a major participator in Federal energy programs including ARENA and the AIC. We are looking to expand our memoranda of understanding with CIEMAT (the Spanish Energy Agency) to the US National Renewable Energy Laboratory, then to other institutions with which we have strong research synergies. New international education prospects are also on the horizon, with a number of institutions interested in developing joint postgraduate education programs on energy change.

These national and international research and education achievements provide the strong public profile that enables the ECI to be a significant contributor to public policy. The ECI will continue its annual Energy Update where we present the World Energy Outlook from the International Energy Agency. ECI researchers will also expand their public policy contributions into new areas informed by the expanding breadth of the ECI research portfolio.

APPENDIX Advisory Board 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 cells, 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

The Secretary, Department of Industry

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 Assets Division, 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 Director 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.

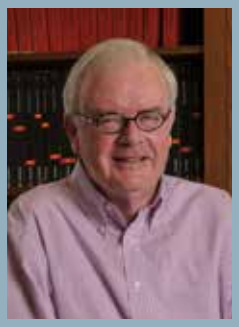
Mr Ian Farrar

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 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 Michael Raupach

Director, The ANU Climate Change Institute

Michael Raupach was appointed as the Director of the Climate Change Institute, Australian National University in November 2013. He has worked for most of his scientific career to date in CSIRO, mainly in the Canberra laboratory of CSIRO Marine and Atmospheric Research.

His scientific research interests encompass Earth System science, carbon-climate-human interactions, land-air interactions, and fluid mechanics. He is a Fellow of the Australian Academy of Science, the Australian Academy of Technological Sciences and Engineering, and the American Geophysical Union. Through his scientific career he has published over 150 scientific papers, 50 reports, numerous minor publications, and 2 edited books.

From 2000 to 2008 he was an inaugural co-chair of the Global Carbon Project, an international project studying the natural and human influences on the global carbon cycle, and the interaction of the carbon cycle with climate.

In 2009-2010 he chaired the Expert Working Group on Challenges at the Intersection of Carbon, Energy and Water, reporting to the Prime Minister's Science, Engineering and Innovation Council and Office of the Chief Scientist, Australia.

Starting in 2011, he chaired the Steering Committee of the "Australia 2050" project of the Australian Academy of Science, a multi-disciplinary project examining possible future pathways for Australia over coming decades against criteria of sustainability and equity.

APPENDIX Executive Membership

Professor Ken Baldwin

ANU College of Physical & Mathematical Sciences

Ken Baldwin is the Director of the Energy Change Institute at The Australian National University, where he is also Deputy Director of the Research School of Physics & Engineering. He is also a Deputy Director of the ANU Climate Change Institute. Since 2011 he has been a member of the Project Steering Committee for the Australian Energy Technology Assessment.

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 at the Australian National University. 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 approximately 200 papers and patents. His research interests are in the areas of photovoltaic and solar energy systems; particularly advanced thin film silicon solar cell technology and solar concentrator solar cells, components and systems. He is also interested in sustainable energy policy, and is an ANU Public Policy Fellow.

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 (1971-1973, 1978), Oxford University (1974-1975), the University of Virginia (1976-1977), the University of Sydney (1979-1980) before being appointed as Research Fellow at the Research School of Chemistry.

He was awarded fellow of the Royal Australian Chemical Institute and was appointed Professor at the Research School of Chemistry in 2002.

Professor David Stern

ANU College of Asia and the Pacific

David Stern is an energy and environmental economist whose research focuses on understanding the relationship between resource use and economic growth and development. He has investigated both the role of energy and resources in economic growth and the determinants of environmental impacts, especially air pollution and climate change. He is also interested in research assessment using meta-analysis and bibliometric techniques.

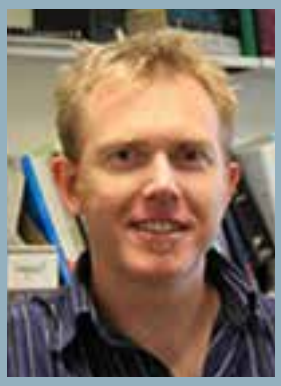
David is an associate editor of Ecological Economics, a research associate in Centre for Applied Macroeconomics Analysis (CAMA) and Centre for Climate Economics and Policy (CCEP) at the ANU Crawford School of Public Policy.

Associate Professor Kylie Catchpole

ANU College of Engineering and Computer Science

Kylie Catchpole is the education convenor of the Master of Energy Change program. Her research interests are in nanotechnology for solar cell applications. 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 the University of New South Wales and the FOM Institute for Atomic and Molecular Physics, Amsterdam.

She has published over 70 papers, which have been cited over 2500 times to date. She currently leads the nanostructures for photovoltaics group at the College of Engineering and Computer Science.



Dr James Prest

ANU College of Law

James Prest is a lecturer in law at the ANU specialising in environmental law with interests in administrative law and litigation. He is a Member of the IUCN Commission on Environmental Law. James is currently working on renewable energy law (particularly feed-in tariffs and tradeable RE certificates law); and major projects legislation. His research interests are in the areas of energy and climate change.

After graduating from the University of Adelaide and the ANU and gaining admission to practise in the Supreme Court of the ACT in 1995 he worked for several years as a legal policy officer at the Department of Prime Minister and Cabinet. He has also held positions as a Research Officer at the Law and Bills Digest Group of the Parliamentary Library in Canberra and as an adviser at Parliament House.

Dr Igor Skryabin

Business Development Manager

ANU College of Engineering & Computer Science

Igor Skryabin's career has spanned both industry and academia. His interests are in the areas of development and commercialisation of solar energy technologies and their integration into national electricity markets.

His major technical contribution has been in the industrialisation of nano-structured dye solar cells. 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.

Dr Michael H. Smith

ANU College of Medicine, Biology & Environment

Michael Smith has been a Research Fellow at the ANU Fenner School of Environment and Society since 2006 specialising in sustainable energy, sustainable design, energy efficiency and their role in improving national energy productivity.

Michael has co-authored two textbooks, "Whole System Design" and "Factor Five", on how to achieve a step change in energy efficiency through sustainable design co-published by UNESCO and the World Federation of Engineering Organisations. He has recently developed a significant part of the new COAG Energy Efficiency Exchange web portal (www.eex.gov.au). He also works to embed energy efficiency into tertiary education and training at ANU and nationally. He is an expert reviewer for the next IPCC AR5 Climate Change Mitigation report.

APPENDIX ECI participants

Artificial Photosynthesis

Professor Tom Faunce	ANU College of Law
Professor Elmars Krausz	ANU College of Physical & Mathematical Sciences
Dr David Ollis	ANU College of Physical & Mathematical Sciences
Dr Ron Pace	ANU College of Physical & Mathematical Sciences
Professor Robert Stranger	ANU College of Physical & Mathematical Sciences

Biofuels

Professor Michael Djordjevic	ANU College of Medicine, Biology & Environment
Professor Graham Farquhar	ANU College of Medicine, Biology & Environment
Dr Colin Jackson	ANU College of Medicine, Biology & Environment
Dr Ron Pace	ANU College of Physical & Mathematical Sciences
Dr Dean Price	ANU College of Medicine, Biology & Environment

Carbon Capture and Storage

Dr Rowena Ball	ANU College of Physical & Mathematical Sciences
Professor Mark Knackstedt	ANU College of Physical & Mathematical Sciences
Professor Tim Senden	ANU College of Physical & Mathematical Sciences
Dr Adrian Sheppard	ANU College of Physical & Mathematical Sciences

Energy Economics and Policy

Professor Robert Breunig	ANU College of Asia and The Pacific
Dr Paul Burke	ANU College of Asia and The Pacific
Professor Bruce Chapman	ANU College of Asia and The Pacific
Professor Quentin Grafton	ANU College of Asia and The Pacific
Dr Carolyn Hendriks	ANU College of Asia and The Pacific
Associate Professor Frank Jotzo	ANU College of Asia and The Pacific
Dr Adrian Kay	ANU College of Asia and The Pacific
Dr Andrew Kennedy	ANU College of Asia and The Pacific
Professor Warwick McKibbin	ANU College of Asia and The Pacific
Dr Arianto Patunru	ANU College of Asia and The Pacific
Dr Hugh Saddler	ANU College of Asia and The Pacific
Professor David Stern	ANU College of Asia and The Pacific

Energy Efficiency and Demand Management

Dr Mike Dennis	ANU College of Engineering & Computer Science
Professor Denis Evans	ANU College of Physical & Mathematical Sciences
Associate Professor Weifa Liang	ANU College of Engineering & Computer Science
Mr Bartholomew Meehan	ANU College of Medicine, Biology & Environment
Dr Hugh Saddler	ANU College of Asia and The Pacific
Dr Michael H. Smith	ANU College of Medicine, Biology & Environment
Mr Tom Worthington	ANU College of Engineering & Computer Science

Energy Regulation and Governance

Dr Tim Bonyhady	ANU College of Law
Professor Peter Drahos	ANU College of Law
Professor Tom Faunce	ANU College of Law
Professor Neil Gunningham	ANU College of Law
Associate Professor Andrew MacIntosh	ANU College of Law
Dr James Prest	ANU College of Law

Energy Sociology and Risk

Dr Jan Hayes	ANU College of Arts and Social Sciences
Emeritus Professor Andrew Hopkins	ANU College of Arts and Social Sciences
Dr Sarah Maslen	ANU College of Arts and Social Sciences

Energy Storage and Recovery

Professor Rod Boswell	ANU College of Physical & Mathematical Sciences
Professor Christine Charles	ANU College of Physical & Mathematical Sciences
Associate Professor Yun Liu	ANU College of Physical & Mathematical Sciences
Professor Raymond Withers	ANU College of Physical & Mathematical Sciences

Energy-Water Nexus

Professor Stephen Dovers	ANU College of Medicine, Biology & Environment
Associate Professor Karen Hussey	ANU College of Medicine, Biology & Environment
Professor Quentin Grafton	ANU College of Asia and The Pacific

Dr Barry Newell	ANU College of Medicine, Biology & Environment
Dr Michael H. Smith	ANU College of Medicine, Biology & Environment
Dr James Pittock	ANU College of Medicine, Biology & Environment

Enhanced Oil and Gas Extraction

Professor Mark Knackstedt	ANU College of Physical & Mathematical Sciences
Professor Tim Senden	ANU College of Physical & Mathematical Sciences
Dr Adrian Sheppard	ANU College of Physical & Mathematical Sciences

Fusion Power

Dr Boyd Blackwell	ANU College of Physical & Mathematical Sciences
Dr Cormac Corr	ANU College of Physical & Mathematical Sciences
Emeritus Professor Bob Dewar	ANU College of Physical & Mathematical Sciences
Dr Matthew Hole	ANU College of Physical & Mathematical Sciences
Professor John Howard	ANU College of Physical & Mathematical Sciences

Nanostructure Photovoltaics

Associate Professor Lan Fu	ANU College of Physical & Mathematical Sciences
Dr Yanan Guo	ANU College of Physical & Mathematical Sciences
Professor Chennupati Jagadish	ANU College of Physical & Mathematical Sciences
Dr Sudha Mokkapati	ANU College of Physical & Mathematical Sciences
Dr H. Hoe Tan	ANU College of Physical & Mathematical Sciences
Dr Fan Wang	ANU College of Physical & Mathematical Sciences

Nuclear Science

Professor Keith Fifield	ANU College of Physical & Mathematical Sciences
Professor David Hinde	ANU College of Physical & Mathematical Sciences
Dr Greg Lane	ANU College of Physical & Mathematical Sciences
Professor Andrew Stuchbery	ANU College of Physical & Mathematical Sciences

Smart Grids

Dr Carleton Coffrin	ANU College of Engineering & Computer Science
Dr Evan Franklin	ANU College of Engineering & Computer Science

Dr Dan Gordon	ANU College of Engineering & Computer Science
Dr Alban Grastien	ANU College of Engineering & Computer Science
Dr Patrik Haslum	ANU College of Engineering & Computer Science
Professor Pascal Van Hentenryck	ANU College of Engineering & Computer Science
Professor Sylvie Thiebaux	ANU College of Engineering & Computer Science
Dr Menkes van den Briel	ANU College of Engineering & Computer Science
Mr Nicholas Engerer	ANU College of Medicine, Biology & Environment
Dr Igor Skryabin	ANU College of Engineering & Computer Science

Solar Photovoltaics

Professor Andrew Blakers	ANU College of Engineering & Computer Science
Dr Kate Booker	ANU College of Engineering & Computer Science
Dr Kylie Catchpole	ANU College of Engineering & Computer Science
Dr Andres Cuevas	ANU College of Engineering & Computer Science
Dr Mike Dennis	ANU College of Engineering & Computer Science
Professor Rob Elliman	ANU College of Engineering & Computer Science
Mr Nicholas Engerer	ANU College of Engineering & Computer Science
Dr Vernie Everett	ANU College of Engineering & Computer Science
Dr Andreas Fell	ANU College of Engineering & Computer Science
Mr Kean Chern Fong	ANU College of Engineering & Computer Science
Dr Evan Franklin	ANU College of Engineering & Computer Science
Dr Nicholas Grant	ANU College of Engineering & Computer Science
Dr Stuart Hargraves	ANU College of Engineering & Computer Science
Dr Niraj Lal	ANU College of Engineering & Computer Science
Dr Daniel Macdonald	ANU College of Engineering & Computer Science
Dr Rob Middleton	ANU College of Engineering & Computer Science
Dr Sudha Mokkapati	ANU College of Engineering & Computer Science
Dr Jelena Muric-Nesic	ANU College of Engineering & Computer Science
Dr Yona Nebel-Jacobsen	ANU College of Engineering & Computer Science
Dr Yongling Ren	ANU College of Engineering & Computer Science
Dr Fiacre Rougieux	ANU College of Engineering & Computer Science
Dr Avi Shalav	ANU College of Engineering & Computer Science
Dr Igor Skryabin	ANU College of Engineering & Computer Science
Dr Matthew Stocks	ANU College of Engineering & Computer Science
Dr Dongchul Suh	ANU College of Engineering & Computer Science

Dr Sachin Surve	ANU College of Engineering & Computer Science
Dr Elizabeth Thomsen	ANU College of Engineering & Computer Science
Dr Andrew Thomson	ANU College of Engineering & Computer Science
Ms Marta Vivar	ANU College of Engineering & Computer Science
Associate Professor Klaus Weber	ANU College of Engineering & Computer Science
Dr Yimao Wan	ANU College of Engineering & Computer Science
Dr Thomas White	ANU College of Engineering & Computer Science
Dr Xinbo Yang	ANU College of Engineering & Computer Science
Dr Jun Yu	ANU College of Engineering & Computer Science
Dr Soe Zin	ANU College of Engineering & Computer Science

Solar Thermal

Dr Roman Bader	ANU College of Engineering & Computer Science
Dr Joe Coventry	ANU College of Engineering & Computer Science
Dr Mike Dennis	ANU College of Engineering & Computer Science
Dr Graham Hughes	ANU College of Biology, Medicine & Environment
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