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## ANNUAL REPORT 2012 ENERGY CHANGE INSTITUTE

# Director's Statement



This is the first Annual Report produced by the ANU Energy Change Institute (ECI) following its formation on December 1<sup>st</sup>, 2010. The establishment of the ECI was formally announced by the then Vice-Chancellor, Professor Ian Chubb, on the occasion of the opening of the Solar 2010 conference hosted at ANU.

Since that time the ECI has made rapid progress and has emerged as a key player in the Australian energy research landscape. The ECI includes around 90 research staff, and together with postgraduate students comprises some 200 researchers overall. With facility investment totalling \$100 million, supported by a major portfolio of external grant funding that embraces research activity across all seven ANU Colleges, Energy Change is one of the key research themes of the University.

However, the significance of the ECI goes further than sheer size. Research in Energy Change at the ANU covers a complete spectrum – from energy science, engineering, efficiency and technology, to implementation expertise in the economic, legal, sociological and policy issues surrounding Energy Change. This broad portfolio of research activity is unique in the country.

Education as well as research makes the ECI a key national entry point for expertise in Energy Change. This year marks the first degree offering – the Master of Energy Change. In addition, this is the second year that a professional short course has been provided – “Energy Change in a Carbon Trading World”. The range of educational offerings is expected to expand in the coming years, so please watch this space.

The broad portfolio of research and education enables the ECI to contribute through public policy to the wider community. Situated in the national capital, the location of the ANU facilitates a unique opportunity to inform government and the public service on a range of energy issues. Consequently, the ECI plays a key role through the ANU Institute for Public Policy. This year, of the nine inaugural ANU Public Policy Fellows announced, one third are members of the ECI.

This first Annual Report showcases these and other highlights of the first two years of operation of the ECI as it has developed a unique profile in the Australian energy landscape. I commend this Report to you.

A handwritten signature in black ink, appearing to read 'Ken Baldwin'. The signature is fluid and cursive, with a long horizontal line extending to the right. It is positioned above a dashed horizontal line.

**Professor Ken Baldwin**  
Director  
ANU Energy Change Institute



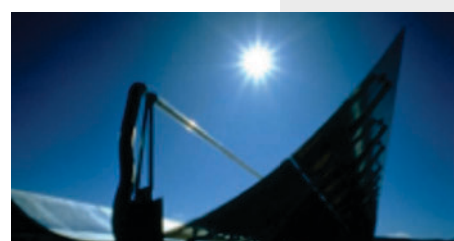
# ENERGY CHANGE INSTITUTE

[energy.anu.edu.au](http://energy.anu.edu.au)

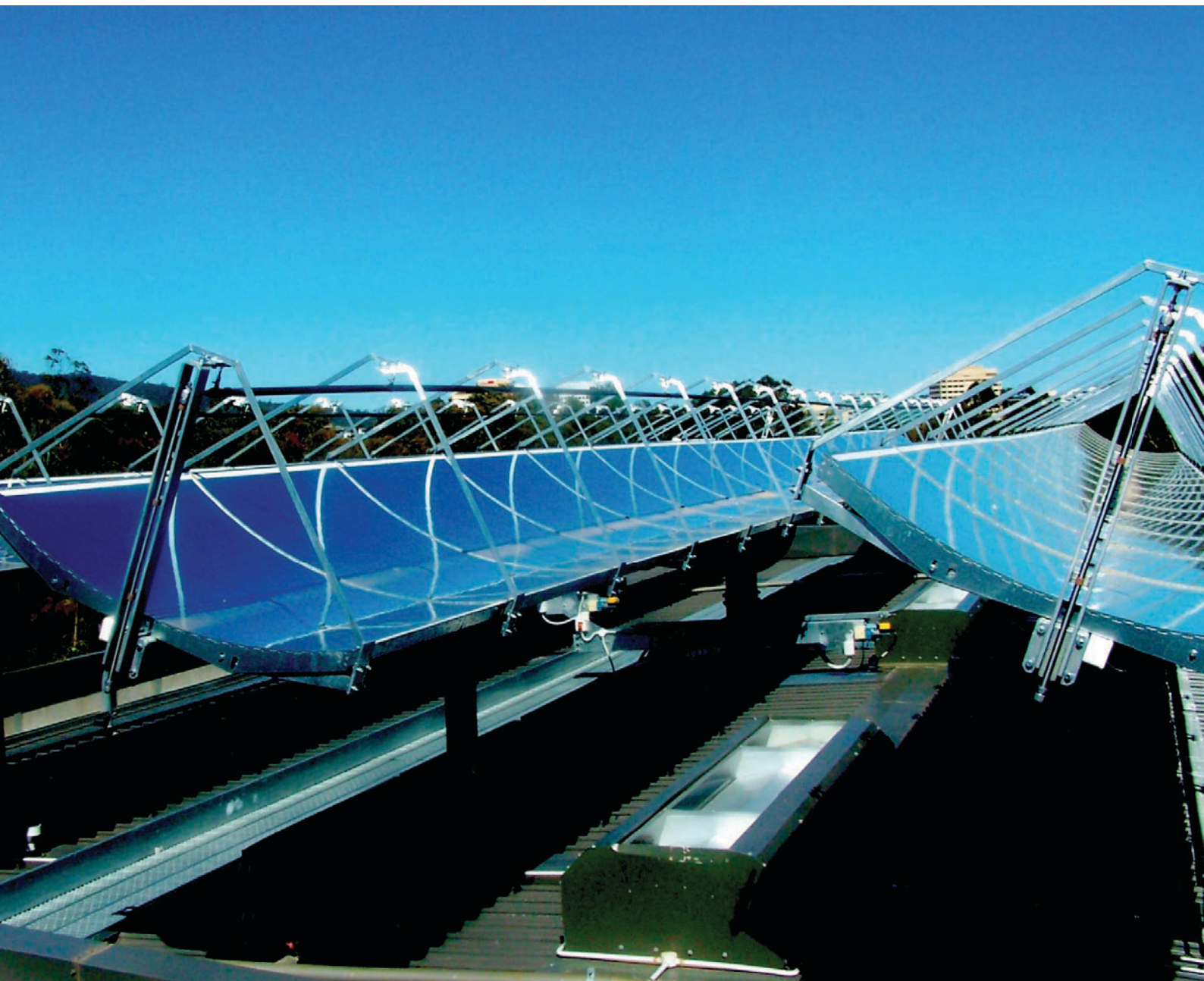


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# Highlights 2010-2012

The activities of the Energy Change Institute have seen numerous highlights during the first two years of its operation, and many of these stem directly from the achievements of the individual research groups themselves.

The following chronological list relates to the collective highlights of the ECI during this period.

## December 2010

- Establishment of the ECI at the Solar 2010 conference hosted by ANU.

## March 2011

- The Prime Minister Julia Gillard visits the solar laboratories of the Australian Solar Institute at ANU.
- ANU hosts the Australia-China Climate Change Forum – organised by the ANU Climate Change Institute, with the Renewable Energy Forum arranged by the ECI.

## April 2011

- Hon Martin Ferguson, Minister for Resources, Energy and Tourism, launches the ASI Round Two Photovoltaic Core Project, which will see ANU collaborating with Trina Solar, one of the largest manufacturer of solar cells worldwide.



The Prime Minister Julia Gillard visiting the Big Dish solar thermal facilities with Dr Keith Lovegrove.

Photo by Lisette Hähnel

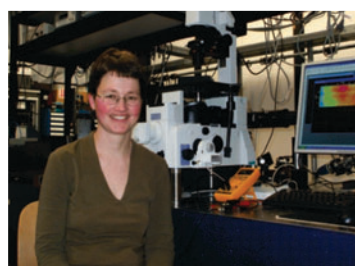
## May 2011

- Dr Kylie Catchpole is the winner on 'The New Inventors' ABC television show for her plasmonic light trap technology.
- ECI in collaboration with ANIPP hosts the National Energy Security Assessment Methods Advancement Project (NESAMAP).

## July 2011

- ECI Professional Short Course – “Energy update”.

Ken Baldwin addresses the inaugural ECI Open Day



Dr Kylie Catchpole, winner of ABC's 2011 "New Inventors" award



ANU Public Policy Fellows, including Warwick McKibbin (l) and Ken Baldwin (3rd l), with ANU Chancellor Gareth Evans at the ANIPP Public Policy Fellows launch



Hon Martin Ferguson, Minister for Resources, Energy and Tourism with winners of the Australian Solar Institute "Three Minute Thesis" competition

## September 2011

- Launch of the Master of Energy Change at the ECI Public Seminar "Energy for the Future".

## April 2012

- Announcement of the inaugural ANU Public Policy Fellows – one third of whom are ECI members (Professors Baldwin, Blakers and McKibbin).
- ECI makes submission to ACT Government Draft Action Plan.
- ECI makes submission to Draft Energy White Paper.

## July 2012

- ANIPP Public Policy Fellows Launch: "Scholarship, public debate and public policy", including presentations by two ECI Fellows, Ken Baldwin and Warwick McKibbin.

## September 2012

- ECI Professional Short Course – "Energy in a carbon trading world".
- Australian National Conference on Renewable Energy (ANCRE) 2012 discussion panel presentation by Ken Baldwin.

## October 2012

- "Australia's Energy Future" - a major national forum hosted by the ECI involving government, industry and academia.



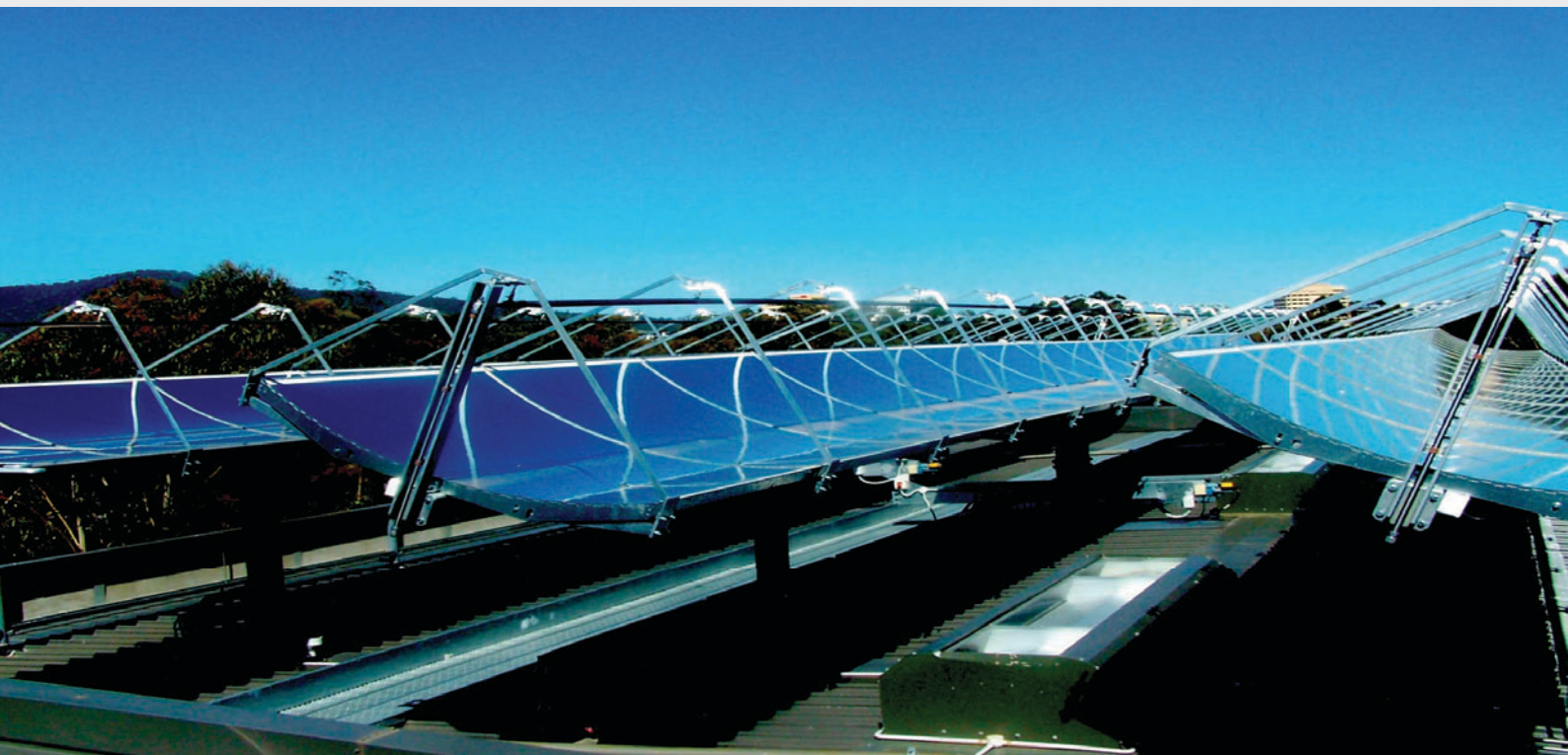
# Mission

A key to many challenges facing the world 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; and
- improving energy access and security.

The ECI aims to provide authoritative leadership in Energy Change research and education through a broad portfolio ranging from future energy technologies to energy efficiency, regulation, economics, sociology and policy.

A key feature of the ECI is that we are **technology and policy neutral**. That is, the ECI undertakes research and education in key areas of energy technology and energy policy without favouring any particular area, enabling open competition for good ideas leading to Energy Change.





# Governance

The ECI comprises around 90 academic staff and their postgraduate research students, bringing the total complement to around 200 researchers.

The wider ECI membership meets twice a year: at the annual business meeting in early March which establishes the programme for the coming year; and at the ECI Open Day in October which presents research highlights to the ECI stakeholder community.

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

## ECI Executives

Professor Ken Baldwin - <i>Director</i>	CPMS
Professor Andrew Blakers	CECS
Professor Michael Djordjevic	COMBE
Professor Thomas Faunce	COL
Professor Elmars Krausz - <i>Education Convenor</i>	CPMS
Professor Warwick McKibbin	CAP
Dr Igor Skryabin - <i>Business Development Manager</i>	CECS

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, whose membership comprises:

<b>Drew Clarke</b>	Secretary, Department of Resources, Energy and Tourism
<b>Stephen Devlin</b>	General Manager Assets Division, ActewAGL
<b>Jenny Goddard</b>	Chair of the Board, Australian Solar Institute
<b>Ian Farrar</b>	Board Member, Centre for Sustainable Energy Systems; former Chair and CEO of the Joint Coal Board
<b>Dan Nocera</b>	Massachusetts Institute of Technology
<b>David Papps</b>	ACT Government
<b>John Poate</b>	Colorado School of Mines; Member of National Renewable Energy Laboratory (US) Advisory Board
<b>Will Steffen</b>	Fomer Director, ANU Climate Change Institute

The Advisory Board meets with the Executive once each year on the occasion of the ECI Open Day in October.

# Education

In 2010-2012, the ECI education program comprises the following two streams:

- *Master of Energy Change; and*
- *Professional Short Courses.*

## MASTER OF ENERGY CHANGE

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 need for changes in global energy generation and usage is well established. At present, too few professionals have an effective overview of the many factors involved in these matters. The program provides both a strong basis in the fundamentals of economics, governance, sociology, policy and technology related to energy change, as well as allowing students to undertake advanced courses and research in areas of energy change targeted to their individual needs, interests and skills.

The Master of Energy Change degree is structured to meet the needs and aspirations of professionals, equipping them to engage with the broad spectrum of challenges in Energy Change. The Program brings together the wide-ranging Energy Change 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 compulsory and 19 elective courses. The first compulsory course, PHYS8013 “Principles of Energy Generation”, was specifically developed for this degree. With the inclusion of a unit from Sociology, the program now involves almost all ANU Colleges.

Considering the strong interdisciplinary 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

### The Courses

#### Compulsory Courses

PHYS8013	Principles of Energy Generation and Transformation
ENGN6516	World Energy Resources and Renewable Technologies

#### Elective Courses

LAWS8180	International Climate Law
CRWF8006	International Climate Change Policy and Economics
ENGN6224	Energy Systems Engineering
ENGN6524	Photovoltaic Technologies
ENVS8005	Climate Change Science
PHYS8202	Reactor Science
ENVS8003	Climate Change Vulnerability and Adaptation
LAWS8189	Fundamentals of Environmental Law
CRWF8009	Energy Politics and Governance
CRWF8014	Domestic Climate Change Policy and Economics
CRWF8017	Energy Economics
EMSC6021	Fundamentals of Climate System Science
ENGN6410	Semiconductors
ENGN6410	Engineering Sustainable Systems
ENGN6525	Solar Thermal Technologies
ENVS6025	Solving Complex Environmental Problems
PHYS8205	Nuclear Fuel Cycle
LAWS8181	Australian Climate Law
SOCY8002	Risk and Society



numeracy skills and an accredited ability in English.

The program commenced in first semester of 2012. Professor Elmars Krausz is the convener of the program. Following many enquiries from Australia and overseas, seven students were accepted and enrolled in the first semester with one withdrawing and two deferring. Another student enrolled in second semester.

Current students are enrolled on a part-time basis, and combine studies of Energy Change with full-time work in Canberra. There has been interest from many domestic and overseas students to enrol next semester. Carefully targeted promotion of the Master of Energy Change is the key to advancing this program.



Master of Energy Change students celebrating after their first exam.

"...the Master of Energy Change has fulfilled my expectations. The available units are from multiple fields--engineering, physics, politics, law and commerce--and allow a student to individualise their studies. In addition to this, the staff have been keen to give students access across the university to its expertise, including attendance of professional short courses run by the Energy Change Institute." - **Scott Beltman, Australian Public Service.**

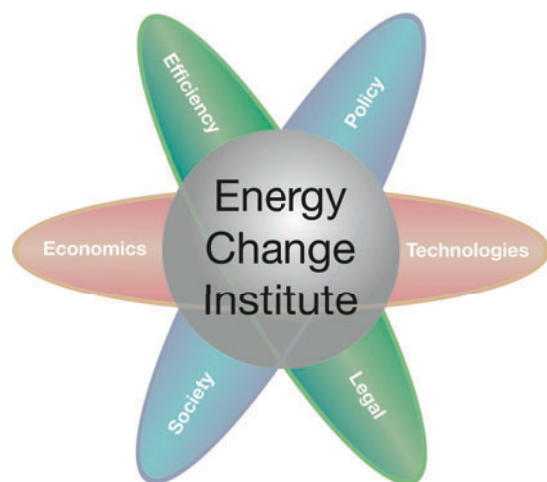
## PROFESSIONAL SHORT COURSES

The first ECI Professional Short Course (***Energy Update***) was developed specifically for senior employees of the Department of Resources, Energy and Tourism, and was delivered in July 2011. Based on the success of the first delivery, ECI offered its 2012 course to a broader audience in the Australian Public Service.

The 2012 Professional Course (***Energy change in a carbon-trading world***) was offered in recognition of challenges and opportunities presented by the Federal Government's Clean Energy Future package. Attendees received a 3-day, state-of-the-art professional short course covering the latest updates on new technologies and energy change implementation. The course was conducted by leading experts from academia, government and industry who examined the social, economic, policy and governance issues surrounding the transition to a clean energy future.

The 2012 Professional Short Course was supported by the Crawford School of Public Policy, which provided valuable input into the design and administration of the course. Feedback analysis revealed a high level of course satisfaction with the course, which secured an average ranking of 4.2 out of 5 from participants.

# Research



The ECI has considerably expanded its research programme from its initial base, and now includes around 90 research staff from all seven ANU Colleges.

This year two new research themes have been added to the portfolio:

- **Energy Efficiency & Demand Management**
- **Energy Sociology and Risk**

bringing to 14 the total number of research topics reported in the research highlights below.

## ECI RESEARCH AREAS

Artificial Photosynthesis  
Biosolar Energy  
Carbon Capture and Storage  
Energy Economics and Policy  
Energy Efficiency & Demand Management  
Energy Regulation & Governance  
Energy Sociology & Risk

Enhanced Oil & Gas Extraction  
Fusion Power  
Hydrogen Fuel Cells  
Nanostructure Photovoltaics  
Nuclear Science  
Solar Photovoltaics  
Solar Thermal

## ARTIFICIAL PHOTOSYNTHESIS

Tom Faunce  
Warwick Hillier  
Elmar Krausz  
David Ollis  
Ron Pace  
Robert Stranger

Research into the many aspects of Artificial Photosynthesis is expanding at the ANU with the addition of a number of new groups and individuals to the ECI team. Tom Faunce in the Law School has spearheaded the promulgation of the prime concepts and international development of Artificial Photosynthesis worldwide, with the publication of a number of books, book chapters and refereed articles as well as championing public outreach with appearances at public lectures and national radio programs.

The groups of Hillier, Pace, Stranger and Krausz have continued their collaborative work on fundamental processes driving photosynthetic systems. A significant development is provided by the case study below. The Hillier group is developing new infra-red and mass-spectrometric techniques targeting the identity of water molecules involved in water oxidation. Isotopic signatures are being explored to establish similarities between Mn, Co and Ni based water oxidising catalysts.



The Krausz group has combined with a new group at the RSC headed by Colin Jackson to investigate a two-electron hydride transfer enzyme  $F_{420}$ . This two-electron catalytic process is significantly simpler than the four-electron oxidation of water but provides a useful model system to study multi-electron catalysis.

## CASE STUDY

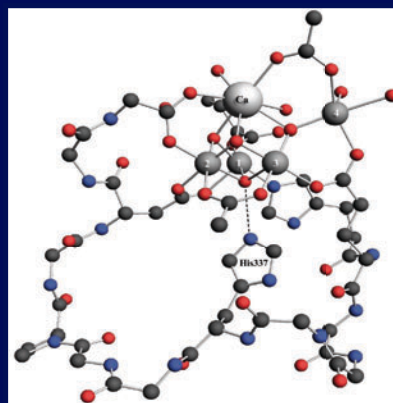
### The Structure and Mechanism of the OEC in Photosystem II

*Rob Stranger and Ron Pace; Research School of Chemistry*

Life on earth is supported by Photosystem II (PSII) which, by the function of its unique Mn/Ca oxygen-evolving-complex (OEC), effectively splits water into hydrogen and oxygen. The OEC is by far the most efficient water oxidizing system known but details of its structure and mechanism are still not fully resolved. Their elucidation will guide the creation of artificial photosynthetic systems offering totally renewable hydrogen generation from seawater.

Significant progress has recently been made via the publication of the crystal structure of PS II at 2.9 and 1.9 Å resolution. Aspects of these structural data of the OEC appear to be at odds with X-ray Absorption Spectroscopy (XAS) studies. It has been suggested that the crystal structure samples of PS II have been compromised by the effect of X-ray photo-reduction during data collection.

However, Stranger and Pace have provided strong evidence that the Mn oxidation levels in the functional OEC cluster are indeed lower than currently thought. Computational results as well as all available experimental data, appear entirely consistent with a lower Mn oxidation state model, without the need to invoke X-ray photo-reduction.



Computational model of the OEC (incorporating the most local protein elements to date) which highlights a mechanistically important interaction between His337 and the core Ca/Mn cluster.

## BIOSOLAR ENERGY

The interests at the ANU hub have focused on biofuels from algae. The mass cultivation of microalgae as a biomass feedstock for liquid biofuels is being assessed worldwide. Microalgae have high photosynthetic productivity and growth rates and the high energy major carbon storage molecules constitute possible feedstock for the production of liquid biofuels. Our work has focused on the optimisation of algal strains and to identify metabolite, lipids and other storage products produced under a range of optimal and nutrient stress conditions.

Michael Djordjevic  
Graham Farquhar  
Warwick Hillier  
Dean Price

These findings have paved the way for a joint CSIRO collaborative project to genetically modify the sugar accumulation biochemical pathways and to enhance biofuel accumulation.

We were successful in gaining grant funds for the genetic manipulation lipid levels in cyanobacteria from a CSIRO Flagship grant. Details are: GD Price (lead-co-PI), S Blackburn (lead co-PI, CSIRO Hobart), W Hillier, M Djordjevic, C Hocart ; CSIRO OCE Flagship Collaboration grant "Aviation fuel from cyanobacteria: molecular approaches to increased yield" \$150k, for 2012-2013.

## CASE STUDY

### **Lipid profile and productivity of *Chlamydomonas reinhardtii* under temperature and N deprivation.**

*Michael Djordjevic, Dean Price, Warwick Hillier*

The Biosolar initiative at RSB has been working to optimise the intrinsic properties of high energy storage molecules of microalgae and to determine what environmental conditions favour higher quality feedstock production. As a proof of concept, we have investigated if strains can be engineered to direct carbon storage from starch production toward high energy lipids. A fivefold increase in lipid production was achieved with certain strains.

We have also determined parameters for optimising growth and the potential fuel properties of the resultant high energy lipids. Lipid content was further raised to 76% of dry weight and the level of more desirable monounsaturated lipids was optimised. These studies demonstrate the use of genetic selection combined with the use of environmental parameters such as temperature to manipulate the algal biosynthetic pathways for enhanced lipid production and to generate desirable fatty acids compositions that may be suitable for conversion to liquid fuels.



Culture flasks of algae testing for biomass and lipid profiles



# CARBON CAPTURE & STORAGE

Rowena Ball  
Tim Senden  
Adrian Sheppard  
Mark Knackstedt

The successful sequestration of industrial carbon dioxide (CO<sub>2</sub>) depends on effective capture and storage mechanisms that are both energy and cost efficient.

Rowena Ball from the Mathematical Science Institute, ANU, is collaborating with P. Fennell from Imperial College London to improve the efficiency of CO<sub>2</sub> capture processes through a better understanding of entropy generation during these processes. The researchers have recently carried out a detailed second law of thermodynamics analysis of an Endex process for CO<sub>2</sub> capture, which quantifies the vastly superior thermodynamic performance of this process. Are these results (a) too good to be true, or (b) too true to be good? If (a) then the exergy consumption has been underestimated. If (b) we must titrate superior thermodynamic performance against capital costs - a classic technoeconomic dilemma. This work was presented at an International Energy Agency Technical Meeting at Tsinghua University in Beijing 20-22 Aug 2012

On the side of storage, it is critically important to understand the interaction between injected CO<sub>2</sub> and groundwater inside the sub-millimeter pore network of the underground rocks. Researchers at the Department of Applied Mathematics, Research School of Physics and Engineering at ANU are using a custom X-ray microtomographic facility, along with specially designed high pressure flow apparatus to directly visualise CO<sub>2</sub>-water interaction inside these tiny pores. This unique apparatus is providing a better understanding of the micro-scale process that take place when we try to sequester carbon dioxide deep underground.

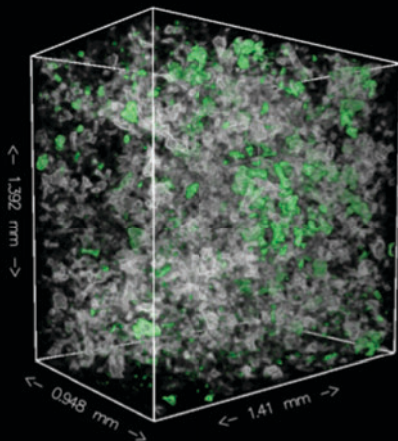
In 2012, the ANU was awarded funding to undertake several research projects as part of the Australian National Low Emissions Coal (ANLEC) R&D program, which aims to provide scientific support for the Carbon Capture and Storage pilot projects being run at 3 locations around Australia. Each of these projects aims to store millions of tonnes of CO<sub>2</sub> in subsurface formations. The ANU is performing experimental, imaging and modelling studies of capillary trapping of CO<sub>2</sub> and rock dissolution by CO<sub>2</sub>, digital core analysis, modelling and upscaling of various rock properties, as part of a program to better characterise the rocks into which the CO<sub>2</sub> is being injected.



Dr Rowena Ball

### Characterisation of CO<sub>2</sub> capillary trapping and reactivity by core-flood experiment and micro-CT imaging

*Rowan Romeyn, Michael Turner, Tim Senden*



3D mapping of residual trapping of toluene by glycerol in a complex subsurface rock sample from WA, imaged at the ANU micro-CT facility. Toluene-Glycerol is an analogue for the supercritical CO<sub>2</sub>-brine system, but without the same sensitivity to temperature and pressure.

CO<sub>2</sub> injected into subsurface formations at elevated temperature and pressure forms a supercritical phase (scCO<sub>2</sub>) which is mostly immiscible with water. Its physical and chemical properties are very dependent on temperature and pressure. One critical short-time mechanism for trapping CO<sub>2</sub> is *capillary trapping* in which the CO<sub>2</sub> phase breaks into tiny bubbles, each trapped in its own microscopic pore.

In addition, scCO<sub>2</sub> is also highly reactive with many of the minerals commonly found in rocks, particularly the carbonic acid that forms after the CO<sub>2</sub> has dissolved in water. We have investigated both capillary trapping and the reactivity of CO<sub>2</sub> through micro-CT imaging and through core-flood experiments with analogue fluids. Part of this work formed the honours thesis of university medallist Rowan Romeyn.

## ENERGY ECONOMICS & POLICY

The Energy Economics & Policy research program consists of ten researchers working on various aspects of energy change. Research areas include the transition to a low-carbon energy system, efficient ways to achieve improvements in energy efficiency (see box), and citizen engagement in energy reform. Researchers in the group actively engage in public policy discussions and are frequent contributors of opinion pieces for media outlets in Australia and overseas.

Robert Breunig  
Paul Burke  
Quentin Grafton  
Carolyn Hendriks  
Frank Jotzo  
Adrian Kay  
Andrew Kennedy  
Warwick McKibbin  
Hugh Saddler  
David Stern

The research program collaborates with two ANU research centres: the Centre for Climate Economics and Policy (CCEP) and the Climate and Energy Program of the Centre for Applied Macroeconomic Analysis (CAMA). CAMA hosts the G-Cubed model – an international macroeconomic model developed specifically for analysing climate policy scenarios.

## CASE STUDY

### **Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries**

*Paul Burke, Shuhei Nishitateno*

Cost-effective ways in improving energy efficiency is an important part of moving to a low-carbon economy. Research papers by members of the Energy Economics & Policy research program have helped us to improve our understanding of how best to achieve these improvements. In a forthcoming paper in *Energy Economics* (with Dr. Shuhei Nishitateno), Dr. Paul Burke examines the factors affecting the adoption of fuel-efficient vehicles, and finds that the petrol pump price is an important part of the story. Consumers in countries that subsidise petrol prices – such as Indonesia – typically purchase larger, less efficient vehicles than they would if they faced internationally-normal pump prices.

In another paper also in press at *Energy Economics*, Professor David Stern examines overall energy efficiency at the country level and finds that countries without large fossil fuel endowments tend to use energy more efficiently. His paper also concludes that technological change is the most important explanation for why economic growth has been able to outpace increases in carbon dioxide emissions in many countries.

In a third project, published in *Nature Climate Change*, Dr. Frank Jotzo led a research group examining the unusual spike in global carbon dioxide emissions from energy in 2010. The researchers found that an increase in the energy intensity of the global economy contributed to the 2010 emissions surge. This increase in energy intensity was associated with falling fossil fuel prices in 2010.



A fuel-efficient car

Photo by Ed Yourdon



# ENERGY EFFICIENCY & DEMAND MANAGEMENT

Mike Dennis  
Hugh Saddler  
Michael Smith  
Idris Sulaiman  
Tom Worthington

ANU has expertise in all aspects of energy efficiency and demand management from a technical, economic, and policy perspective. ANU also has expertise in research, design and the implementation of effective energy management systems. In the past two years, the group has been highly productive, publishing international books, book chapters and articles as well as assisting, CSIRO, the Commonwealth Government, UNEP and the next IPCC Assessment. For instance, ANU was chosen to lead the research and development of 14 “Business Sector” and 11 “Technology” reports, now featured online through the Coalition of Australian, State and Territory Government’s (COAG’s) Energy Efficiency Exchange Web Portal (EEX).

As well as policy expertise in the field of demand management, ANU has technical experts in this field as well. Led by Dr Mike Dennis, ANU is pioneering novel ways to address rising peak electricity demand through decentralized solar powered air conditioning and hybrid residential solar thermal solutions. This is critically important because current growth in peak electricity demand is largely driven by the rising use of air conditioning in Australia. Decentralised solar powered air conditioning combined with energy efficiency measures in buildings offers a far more cost effective and lower carbon strategy to address rising air-conditioning demand compared to building more poles, wires and large fossil fuel power stations.

This research group is researching, publishing and developing online teaching resources on how to identify and implement energy efficiency opportunities across many major economic sectors. For instance, Information Communications Technology (ICT) products and services represent one of the fastest areas of energy demand and greenhouse gas emission growth, of any sector, nationally and internationally. Led by Tom Worthington and Dr Idris Sulaiman, ANU’s College of Engineering and Computer Science offers research opportunities, undergraduate and post graduate courses in ICT and Sustainability that focus on energy efficiency, total cost of ownership and e-waste management.

## CASE STUDY

### COAG Energy Efficiency Exchange Web Portal ([www.eex.gov.au](http://www.eex.gov.au))

*Michael Smith*

In 2011, an ANU consortium, led by Dr Michael Smith (Fenner School) won the Commonwealth Government tender to lead the development of the core “Business Sector” and “Technology” reports for The Energy Efficiency Exchange web portal. This involved developing detailed reports to assist the identification and implementation of energy efficiency opportunities for commonly used technologies and for all major business sectors. The Energy Efficiency Exchange web portal also has chosen, for its education and training sub-section, to feature two “energy efficiency and demand management” online textbooks co-authored by Dr Smith, from this research group, and Peter Stasinopoulos (ANU PhD Scholar, TNEP) with collaborators at Curtin University, QUT and The Natural Edge Project namely “Energy Transformed” and “Whole System Design”. This is currently the sole source of Commonwealth Government recommended information on energy efficiency for business and educators.



# ENERGY REGULATION & GOVERNANCE

Tim Bonyhady  
Peter Drahos  
Tom Faunce  
Neil Gunningham  
Andrew Macintosh  
James Prest

Legislation, rules and regulation as well as institutional arrangements play a pivotal role in enabling, supporting and safeguarding energy change. In the past two years the Energy Regulation and Governance group has carried out and published research, as well as articles and opinion pieces, that looks into the global governance of various energy technology, such as artificial photosynthesis and energy and nanotechnology, legislation of renewable energy, particularly in Australia, energy governance and implications for climate change and energy security.

Highlights include Tom Faunce's book, "Nanotechnology for a Sustainable World: Global Artificial Photosynthesis as the Moral Culmination of Nanotechnology" and James Prest's articles, "The Future of Feed-in Tariffs: Capacity Caps, Scheme Closures and Looming Grid Parity" in *Renewable Energy Law and Policy Review* and "Denying the Winds of Change: Land Use Planning Law and Wind Energy Projects in NSW" in the *Local Government Law Journal*. The group has also published several book chapters on energy change regulation and governance, including a book chapter co-written by Neil Gunningham and Peter Drahos on energy security in Indonesia in the book "Energy and Non-Traditional Security in Asia".

## CASE STUDY

### Challenges of Global Carbon Pricing for Global Artificial Photosynthesis (Solar Fuels)

Tom Faunce

Tom Faunce gave a detailed presentation at "The 2012 Eastern Asian Legal Forum on Climate Change and Energy: Adapt to Climate Change-Innovative Energy Policy and Law", which was held by National Tsing Hua University, Hsinchu, Taiwan, 21-23 August 2012. In this presentation, he introduced scientific research on globalizing artificial photosynthesis (GAP), or solar fuels, that principally adopt nanotechnology to not only produce fuel through the use of sunlight (solar energy) to split water as a source of hydrogen, but may also one day absorb carbon dioxide to create fuels.

Faunce also pointed out that unless the carbon price set nationally or globally is high enough, it will not incentivise the transition to such GAP technology effectively. He further emphasised that continuous technological improvements in this field require stable and certain incentive laws, which include a proper mechanisms to avoiding fraud in a carbon price.



Professor Tom Faunce at the Eastern Asia Legal Forum on Climate Change and Energy

# ENERGY SOCIOLOGY & RISK

Jan Hayes  
Andrew Hopkins  
Stewart Lockie

Energy change raises a host of social and political issues. How are risks associated with existing energy systems, and their alternatives, distributed? Why do some risks capture our collective attention more than others? How best can transformation in the consumption of energy be facilitated? The ANU School of Sociology hosts a range of projects concerned with the social dimensions of risk and disasters. These include a research 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 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) oilwell blowouts and the San Bruno (US) pipeline explosion. Effecting change in energy systems is as much about the transformation of consumption as it is the transformation of production and transmission. Major projects address urban sustainability and the greening of food consumption and supply chains.

## Risk management in design of hazardous facilities

*Dr Jan Hayes*

Investigations into the causes of man-made disasters have repeatedly shown that ongoing public safety depends on decisions made, often many years earlier, during the design stage of infrastructure or facility development. Despite the criticality of design choices in reducing risk and achieving the best safety and environmental outcomes, little social science research has investigated the social processes in workplaces that produce the technical information that dictates the form of hazardous facilities such as oil refineries, petrochemical plants and pipelines.

Studies of relationships within organizations and their impact on safety have focused mainly on management and workers, and hence issues of leadership, power and blame. This paper describes results of the first phase of a research project investigating other social relationships and factors that influence outcomes. The second phase of this project will be a longitudinal study to track attitudes and key relationships for a large resources development project as the project team crosses a series of major milestones. The paper concludes with some reflections on challenges of undertaking sociological work in this highly applied way.

## CASE STUDY



Dr Jan Hayes



# ENHANCED OIL & GAS EXTRACTION

The Department of Applied Mathematics, Research School of Physics and Engineering, at ANU has been working for a decade with many of the largest petroleum companies in the world to better understand the underlying science and help in the development of new techniques for enhancing the efficiency and effectiveness of oil and gas extraction.

Mark Knackstedt  
Tim Senden  
Adrian Sheppard

The petroleum industry today is undergoing a revolution as traditional oil reservoirs are being supplanted by *unconventional* fields such as shale oils and coal seam gas formations. In these new fields, one cannot simply pump out the fluid hydrocarbons; it is necessary to improve the flow properties of the subsurface rock formations, usually through hydraulic fracturing. Despite the enormous economic return already reaped from these unconventional fields, there is very little understanding of the underlying processes involved in either the fracturing or the subsequent recovery.

The ANU DigiCore research consortium, recently expanded to include 14 companies, now has a strong focus on improving our understanding of unconventional fields and is investigating shales, tight gas sands and coals with a combination of experiment and micro-CT imaging.

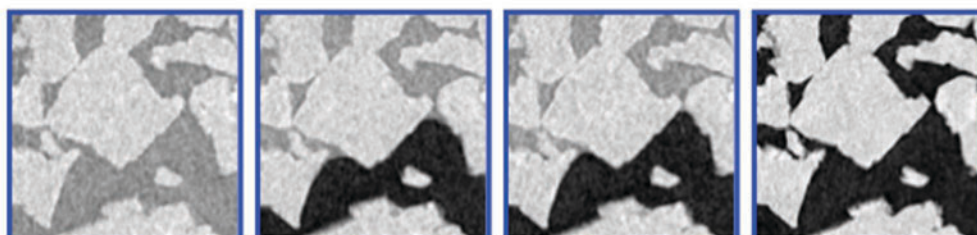
## CASE STUDY

### Dynamic tomography: real-time 3D microscopy

*Glenn Myers, Andrew Kingston, Trond Varslot, Adrian Sheppard*

Predicting oil recovery can only be done by understanding multiphase fluid flow, the flow of multiple immiscible fluid phases, such as oil, water and gas through tiny crevices in the rocks that comprise oil reservoirs deep underground. Multiphase fluid flow is extremely challenging, involving the interplay of fluid dynamics, surface forces and complex geometries.

By using data compression techniques, researchers in the department of Applied Mathematics have developed a technique called dynamic tomography and been able to take real-time movies of these processes in which each frame is a full 3D image. These direct imaging studies are able to test theories and validate numerical models in ways that was never previously possible. Parts of this ongoing work, which is supported by an Australian Research Council Discovery Project, were presented at the International Symposium of the Society of Core Analysts and published in the journal *Applied Optics*.



Small 2D cross-sections from 3D images taken using dynamic tomography, capturing in real time the displacement of water by gas inside a porous sandstone plug. The field of view shown is about 500 microns square; the original movie was composed of over 200 3D image frames, each covering the full 5mm core plug.

# FUSION POWER

Boyd Blackwell  
Cormac Corr  
Bob Dewar  
Matthew Hole  
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 20 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 a \$20 million establishment budget, and recent upgrade funds of \$7M under the Super Science scheme (from 2011). The laboratory research portfolio includes the study of magnetic plasma confinement configurations, theory and modeling of waves and burning plasmas, advanced diagnostics development, and plasma-surface interactions. Through the provision of locally developed technologies and Australian knowhow, researchers at ANU are strongly linked into the international fusion program ahead of ITER, the next step fusion experiment. ITER, a burning tokamak plasma, is the world's largest science experiment, and is now under construction in France.

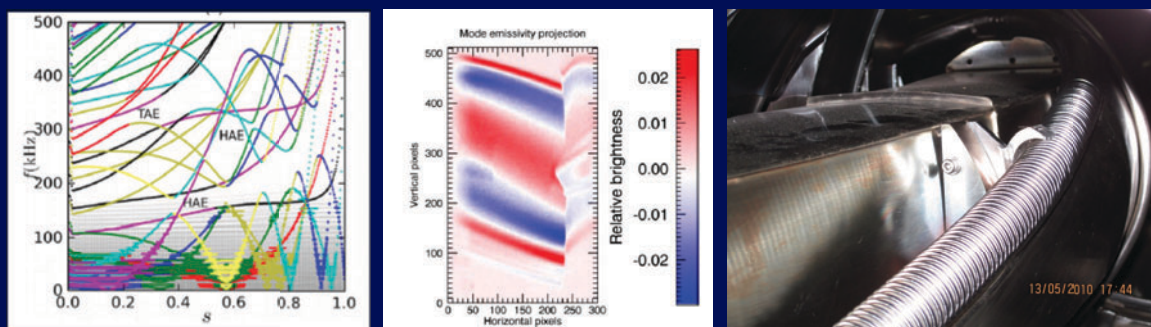
## CASE STUDY

### ANU makes waves in fusion power

*Boyd Blackwell, John Howard, Matthew Hole, Shaun Haskey, David Pretty*

The ANU fusion pursuit rode some big waves in 2012. A new 400kW radio frequency wave heating system and cooled antenna was commissioned in H-1 and produced record plasma parameters. A new 80 channel helical magnetic fluctuation array revealed a rich range of spontaneously-excited and actively-driven electromagnetic wave activity. This diagnostic, which provides information about wave mode frequency, polarisation and mode number, was complemented by a new optical technique for imaging wave mode structure, which synchronises an intensified camera with fluctuation coil signals at various phase delays. The use of sophisticated electromagnetic wave codes revealed both wave modes with similar wave frequencies and mode structure. Understanding and controlling these waves are key to ensuring good confinement of fast ions, and thereby sustaining fusion reaction.

In other work, a helicon wave field antenna was used to produce plasma in the MAGPIE device in a new laboratory, purpose-built for the Materials Diagnostic Development Facility. MAGPIE is designed to study the physics of interactions between the hot plasma and the containing vessel in the extreme environment of a fusion reactor.



Left: the spectrum of singular modes in H-1, the amplitude of a slice global resonant modes in H-1 plasmas, and the new helical fluctuation array

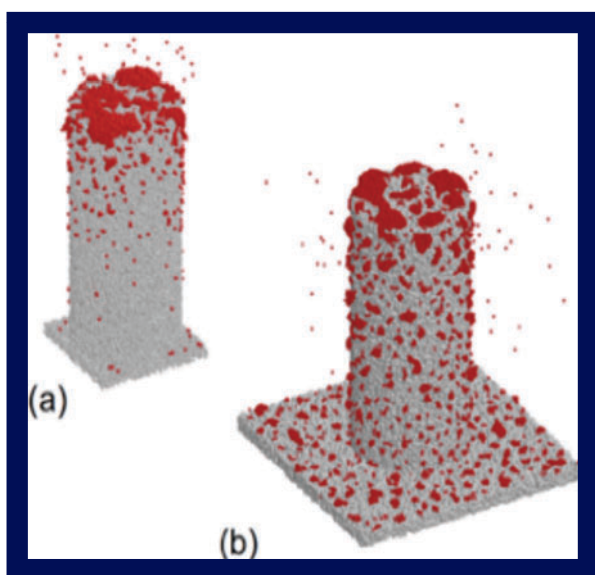
# HYDROGEN FUEL CELLS

The fuel cell research carried out in the Space Plasma, Power and Propulsion laboratory, Research School of Physics and Engineering (SP3), at ANU 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.

Rod Boswell  
Christine Charles

The Energy Change Institute research areas include electrode development using platinum coated Carbon Nano Fibers (CNFs) or Carbon Nano Tubes (CNTs) and testing of integrated manufacturing system using commercially available membranes to separate electrons and protons. ANU is the sole Australian University conducting research on Hydrogen fuel cell and maintains a close collaboration with the University of Orléans (GREMI laboratory) and the National Center for Scientific Research (CNRS) in France. The SP3 and GREMI laboratories have published over 12 joint papers in international journals which have attracted hundreds of citations. The Institute aims to be at the forefront of plasma processing of fuel cells. Two SP3 academic staff members (Prof Boswell and Prof Charles) visited the GREMI laboratory in June 2012.

A brief introduction to hydrogen fuel cells was presented by Christine Charles to ECI students as part of the PHYS8013 course.



Molecular Dynamics simulations of catalytic deposition of Platinum atoms (in red) onto model Carbon Nano Fibers (CNF in grey) after a launch of 10000 Pt atoms: temporal snapshot after (a) 3149 adsorbed Pt atoms and (b) 5982 adsorbed Pt atoms (Applied Surface Science, *in press*).

## CASE STUDY

### Platinum nanocluster growth on carbon nanofiber arrays: molecular dynamics simulations and comparison with plasma experiments

*Rod Boswell, Christine Charles*

A recent research highlight has been the development of Molecular Dynamics simulations carried out at GREMI laboratory for understanding early stages of Platinum atomic deposition on Carbon Nano Fibers (CNFs) grown onto fuel cell electrodes. The simulated catalytic Pt concentration profiles along the CNF (see figure) and the cluster size distributions are in agreement with experimental results carried out at SP3.

This study aims at increasing the fuel cell catalytic efficiency and at reducing the amount of catalyst, thereby lowering fuel cell manufacturing cost.



# NANOSTRUCTURE PHOTOVOLTAICS

Lan Fu  
Qiang (Michael) Gao  
Chennupati Jagadish  
H. Hoe Tan

Nanostructure Photovoltaics (PV) research is carried out in the Department of Electronic Materials Engineering of the Research School of Physics and Engineering. Research focuses on developing novel concepts and technologies for high efficiency nanostructure solar cells by combining the excellent properties of III-V semiconductors as photovoltaic materials with unique properties of nanostructures.

In the past year, the group has been working on developing photovoltaic devices based on quantum dots and nanowires. For the quantum dot solar cell (QDSC) research, with good quality baseline QDSCs, the group explored the fundamental physical processes affecting the solar cell operation and performance, including the dark current properties, intersubband optical transition and its implication for realising two-photon absorption for intermediate band solar cells.

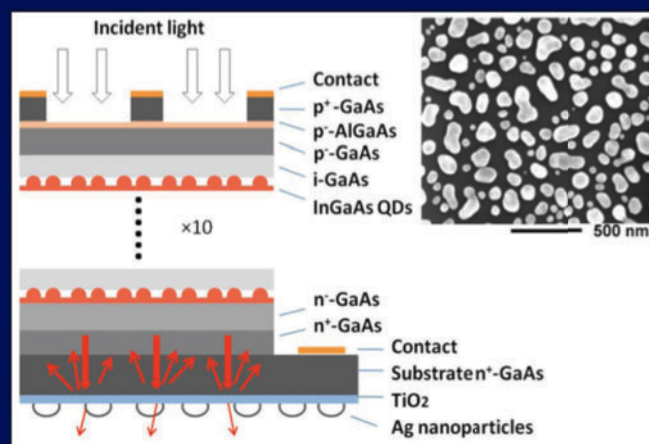
Based on these understandings, researchers have demonstrated enhanced infrared absorption and thus QDSC performance using properly designed plasmonic light trapping strategy. On the other hand, researchers developed completely new nanowire solar cell (NWSC) device fabrication processes (different from the conventional planar device fabrication) and demonstrated the first working device with good efficiency of  $\sim 3.56\%$ , which opens up lots of opportunity for our future nanowire based solar cells and other optoelectronic devices.

## CASE STUDY

### Plasmonic Quantum Dot Solar Cells for Enhanced Infrared Response

*H.F. Lu, S. Mokkapati, L. Fu, G. Jolley, H.H. Tan, and C. Jagadish*

In this work, we proposed to enhance the long wavelength photon absorption of the QDSCs by employing plasmonic light trapping effect. Light trapping refers to the phenomenon of increasing the path length of light and hence total absorption inside a thin absorber layer. Increased IR photoresponse has been demonstrated in our plasmonic QD solar cells by depositing metal nanoparticles on the solar cell surface for strong light scattering. Contrary to alternative approaches for enhancing QD absorption, our approach does not reduce  $V_{oc}$  of the solar cell compared to the reference structure. We demonstrate simultaneous increase in  $J_{sc}$  and  $V_{oc}$  of up to 5.3% and 0.9%, respectively, with respect to the reference structure. The corresponding efficiency enhancement is 7.6%.



Plasmonic quantum dot solar cells schematic

George Dracoulis  
Keith Fifield  
David Hinde  
Greg Lane  
Andrew Stuchbery

Nuclear science research at the ANU is split approximately 50/50 between basic and applied fields. The former is aimed at understanding the properties of nuclei and the interactions between them, with implications in understanding quantum systems and in astrophysics. In applied research, the heavy-ion beams from the 15 MV tandem electrostatic accelerator are used for purposes such as materials modification and characterization, and the ultrasensitive measurement of rare isotope abundances by single atom counting, for environment and resource monitoring and management. Since the beginning of 2012, staff from the Department of Nuclear Physics have published widely, with 20 refereed journal articles, over 20 refereed conference proceedings, and a book chapter “Nuclear Energy – Risk and Reward” that followed from a presentation at the international insurance conference “Catastrophic Complexity”.

In contrast to other research areas in the Energy Change Institute that have direct applications to energy production, the nuclear science performed at the ANU in most cases plays a supporting role, for example in studying aspects of climate change through geomorphological dating using accelerator mass spectrometry or measuring fundamental properties of nuclei that are important in the nuclear fuel cycle. Another important role is the provision of a critical mass of nuclear experts – staff from the Nuclear Physics Department provided over 100 interviews and a number of public lectures in the aftermath of the Fukushima nuclear accident in Japan. The Department also provides education in nuclear science, particularly through the training of postgraduate research scientists as well as the Masters of Nuclear Science program, a coursework degree with 10 students presently enrolled and a student intake from diverse areas of the private, government and industrial sectors.

## CASE STUDY

### **Nuclear Energy Post-Fukushima: The Crisis at the Fukushima Dai-ichi reactors and subsequent impact on global nuclear energy demand, policies and processes**

*Vanessa Robertson*

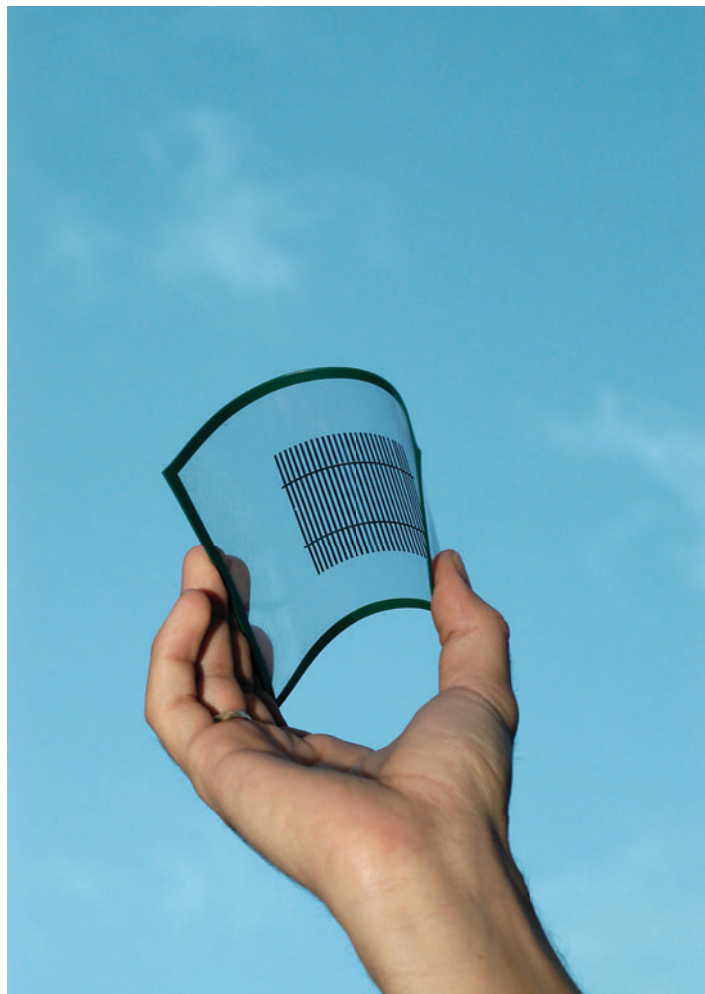
This critical review was performed as part of the Masters program, where, as one of the course components, students perform research, and present a major report on a topic that may range from nuclear physics experiments to case studies or literature reviews. Robertson compared the effects of Fukushima with the accidents at Three Mile Island and Chernobyl and noted that although Fukushima was a “blow for nuclear energy, it pales in comparison to the [effects of] the tsunami”. She suggests that in response “some countries may choose to outsource some aspects of the nuclear fuel cycle to reduce the number of domestic stages”, but finally concludes that the increasing demand for energy, especially clean energy, means that nuclear power will continue to play an important role in future world energy needs.

# SOLAR PHOTOVOLTAICS

ANU solar research commenced 40 years ago, with the aim of increasing the uptake of environmentally benign solar energy solutions, and is now a major component of the ECI. About 80 staff and students research photovoltaic cells, urban solar thermal and combined heat and power systems.

Active external contracts have a combined value of \$50M including from the Australian Research Council, the Australian Solar Institute, Defence and other government Departments, and industry. There is a strong commercial focus, including startup companies and international industry partners. Solar technology created at ANU is the subject of many patents, licensing agreements and production contracts that generate millions of dollars in annual revenue. Activities span the range from basic R&D through to commercialisation.

Solar research activities are supported by 30 research and funding partners. ANU is one of three core members of the \$150 million Australian Solar Institute. ANU Solar collaborates with the Energy Change Institute, providing a framework for teaching, research and outreach activities in the field of energy.



## Current projects include:

High efficiency silicon solar cells

Nanostructures for enhancing photovoltaic performance

Flexible lightweight photovoltaic modules cells for defense and consumer electronics

Solar cooling

Urban hybrid micro-concentrators for simultaneous production of heat and photovoltaic electricity

Andrew Blakers  
Kate Booker  
Kylie Catchpole  
Andres Cuevas  
Su Dongchul  
Mike Dennis  
Rob Elliman  
Vernie Everett  
Andreas Fell  
Evan Franklin  
Kean Chern Fong  
Nicholas Grant  
Stuart Hargreaves  
Niraj Lal  
Daniel Macdonald  
Rob Middleton  
Sudho Mokkapati

Jelena Muric-Nesic  
Yona Nebel-Jacobsen  
Yongling Ren  
Fiacre Rougieux  
Andrew Rollinson  
Avi Shalav  
Igor Skryabin  
Sachin Surve  
Elizabeth Thomsen  
Andrew Thomson  
Marta Vivar  
Klaus Weber  
Thomas White  
Xinbo Yang  
Jun Yu  
Ngwe Zin



## CASE STUDY

### Advanced laser techniques for photovoltaics

#### *The Laser Photovoltaic Processing Group*

Laser processing is a relatively new area of photovoltaic research at ANU and one which we believe has enormous potential for enabling higher efficiency cell concepts to be realised at low cost in industrial manufacturing environment.

Research activities at ANU are centred on fundamental aspects of localised laser doping. This is the precision introduction of dopants into the surface of a solar cell substrate, and the selective ablation of materials from the solar cell surface. Both of these processes allow for advanced cell concepts to be implemented simply and cheaply. Development of such processes requires in-depth investigation of laser radiation and material interactions and thorough characterisation of processed test structures prior to implementation in solar cell manufacture.



ANU Researcher, Chris Samundsett, demonstrating laser equipment to Prime Minister Julia Gillard.

- Development of a wide range of p-type and n-type doping processes using a 532 nm pulsed laser source and from a number of different dopant precursor sources, with heavy and deep doping profiles with excellent low resistance ohmic contacts demonstrated;
- Development of a low-damage dielectric ablation process using 248nm pulsed excimer laser, including implementation for solar cell contacting yielding very high cell voltages ( $V_{oc}$  above 695 mV);
- Development of doping from well-passivating  $Al_2O_3$  films, leading to combined passivation/locally doped contact opening process;
- Implementation of SEM Dopant Contrast Imaging for evaluation of laser doping profiles;
- Launch of a new collaborative project with Fraunhofer ISE in Germany to improve the laser delivery optics and doping homogeneity of the laser chemical processing technology;

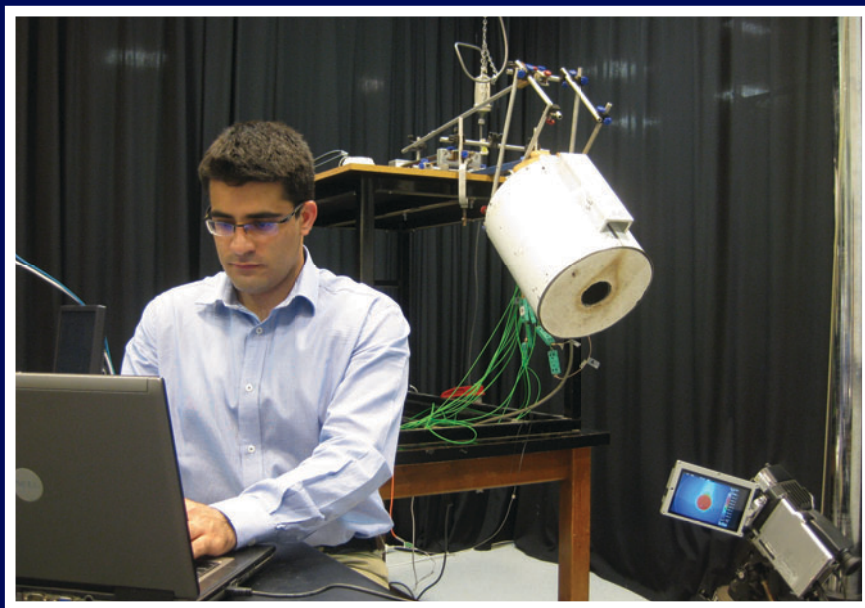
# SOLAR THERMAL

Mike Dennis  
Graham Hughes  
John Pye

Solar thermal energy has had a great year in 2012, with global installed capacity still relatively small, but steadily increasing by about 60% per year since 2008. There is widespread enthusiasm from investors, project developers and researchers, who are seeing strong potential for cost reductions and a future niche for solar-thermal power in supplying dispatchable energy through the incorporation of thermal energy storage that is already cost-competitive and deployable.

A highlight for the solar thermal group in 2012 has been the commencement of our current major project on improving the efficiency of cavity receivers, a \$1.4M project funded by the Australian Solar Institute (ASI). We have also been active in the areas of direct steam generation, thermochemical energy storage, dish field layout optimisation, energy system modelling, cloud tracking and forecasting, and optics, characterisation and control. Dr John Pye spent the first half of this year at Sandia National Laboratories working with Dr Clifford Ho on solar thermal system modelling, heliostat tracking control, and photographic methods of performance characterisation, funded by an ASI Travel Exchange grant. We have also been highly active members of a new consortium of Australian solar-thermal energy researchers seeking new programme funding from ASI, and the ANU Vice-Chancellor has also announced that a strategic appointment will be made of a senior professor to head our group.

Honours student  
Ehsan Abbasi  
conduct tests of  
natural convection  
heat loss on an  
electrically-heated  
simulated receiver  
in the ANU  
Geophysical Fluid  
Dynamics  
laboratory.



The Solar Thermal Group has also conducted studies on low-temperature technologies, led by Dr. Mike Dennis. The emphasis is on ejector-based solar cooling system development, through a commercial partnership. This includes computational and experimental work, system modelling and annual performance prediction. Another active research area is cold storage with phase change materials. Continuing a long tradition, the group hosted visits by approximately 220 visitors throughout the year, including school students, international delegations, research visitors, and professional groups interested in seeing the SG4 Big Dish at ANU, and learning about solar thermal energy technology. The Solar Thermal Group produced 13 publications in 2012, of which 5 are journal papers and 2 are book chapters.

## CASE STUDY

### **Improved High-Temperature Receivers for Dish Concentrators**

*Mike Dennis, Graham Hughes, John Pye*

This project is a major study funded by ASI. It will involve lab-scale experimental work, together with computer-aided modelling and design work, and culminate in testing of a next-generation cavity receiver on-sun at full scale. Our collaborators are Sandia National Laboratories (Albuquerque, New Mexico), and CSIRO (Newcastle, NSW). The group has now got early results for two different laboratory-scale models. We have also started several sub-projects relating to the computational fluid dynamics (CFD) modelling of receiver convective flows, and we are using the SG4 Big Dish for a new programme of experimental work.

Our laboratory work is being conducted in the ANU Geophysical Fluid Dynamics Laboratory with the close collaboration of Dr Graham Hughes and his team in the Research School of Earth Sciences. The ultimate goals are an easy-to-manufacture low-cost receiver with high thermal and optical efficiency, for future inclusion in a commercial solar thermal power plant.



The SG4 Big Dish

Photo by Robert  
Corkery



# Outreach

An integral objective of the ECI's education mission is to disseminate information on Energy Change through outreach activities in the wider community. The following is a partial list of the presentations on general ECI activities. In addition, there were many public presentations undertaken by ECI members in their specific research areas.

## Public Lectures:

- Lecture for the University of the Third Age, Canberra branch, Ken Baldwin, 16 August, 2011
- ECI Public Lecture: "Energy for the Future" - Ken Baldwin, Andrew Blakers, Tom Faunce and David Stern, 26 September 2011
- Lecture for the University of the Third Age, Goulburn branch, Ken Baldwin, 12 November, 2011
- Lecture for the Rotary Youth Leadership Conference, Canberra , Ken Baldwin, 17 February 2012
- Lecture for the University of the Third Age, Southern Highlands branch, Ken Baldwin, 2 March, 2012
- Keynote lecture to the National Science and Technology Program-Energy 2012 Exhibition Opening Ceremony, Taiwan - Igor Skryabin, 14 March 2012
- ANU Public Lecture on the innovative approaches to distinct scientific and policy challenges , Tom Faunce, 13 September, 2012
- Q&ANU: "Academic freedom in a world of cures, cloning and climate" - Ken Baldwin and Tom Faunce, 26 September 2012



ECI member Dr Ron Pace presents at ECI Open Day, 2011

## School visits:

- Electricity demonstration for North Ainslie Primary School Years 5/6, Frank Mills, 2012

## Seminars & Forums:

- Presentations by ECI members and attendance at "Towards Global Artificial Photosynthesis: Energy, Nanochemistry and Governance, Lord Howe Island, Australia, 14-18 August, 2011
- Lecture to CURF Regional Symposium: "Investing in Clean Renewable Energy – assessing Options for your Region", Batemans Bay - Igor Skryabin, 26 August 2011



Dr Igor Skryabin presenting at the  
Taipei Energy Forum, 2012

- Crawford School Dialogue, "Australia's carbon price: good policy or not?" - Frank Jotzo, Warwick McKibbin, 5 September 2011
- ANU Centre for European Studies Symposium, "Climate change and energy policy in Europe and Australia", Frank Jotzo, 13 October, 2011
- CCEP Public Seminar, "Fulfilling Australia's international climate finance commitments", ANU Crawford School, Frank Jotzo, 27 October 2011

- An invited presentation to Land Energy Forum at the Land Warfare Conference, Melbourne "Current academic focus areas in power and energy" - Igor Skryabin, 29 October 2012
- University of Tasmania, Hobart, "Sovereign Ratings and Oil-Producing Countries: Have Sovereign Ratings Run Ahead of Fundamentals?" Robert Breunig, October, 2011
- Presentation to Asia-Pacific Economic Cooperation (APEC) Forum "Energy Change: Demand for new education and research programs", Tianjin, China - Igor Skryabin, 13 November 2012
- CCEP Public Seminar, "International Climate Policy for the long term", Frank Jotzo, 14 March 2012
- Presentations by ECI members and attendance at annual conference of the International Association of Energy Economists, Perth, 24-27 June 2012
- H.C. Coombs Forum "Australia's Energy Future" incorporating the ANU / ACT Government Solar Oration by Professor Joachim Luther, 30 October 2012

#### Public Events:

- ECI Open Day: 20 October 2011
- ANU Sustainability Day - Ken Baldwin, Elmar Krausz, Tom Faunce and Igor Skryabin, 23 Feb 2012
- ECI Open Day: 29 October, 2012

The ECI has also engaged with the South East Region Renewable Energy Excellence (SERREE) network and will participate in the NSW Renewable Energy Day on 21 November 2012.

## Press Releases by the ECI

In 2012, the ECI issued a press release in response to the report of the Australian Energy Technology Assessment (AETA), which was released by the Bureau of Resources and Energy Economics on 31 July 2012.

The AETA report calculates the Levelised Cost of Electricity (LCOE) for 40 different electricity generation sources in Australia for each decade out to 2050. ECI Director Ken Baldwin was a member of the Project Steering Committee for AETA.

The press release was picked up in 20 news articles in major online and print media and has led to interviews with 8 different media programs, both television and radio. Ken Baldwin and Andrew Blakers were also featured in a news feature in The Conversation,. Ken Baldwin was also quoted in another commentary in the Sydney Morning Herald online.



## Energy cost report opens nuclear door

By Andrea Hayward

Nuclear and wind power are already competitive energy alternatives to coal-fired power, a new report reveals, leaving the door open to reignite the nuclear debate.

The Australian Energy Technology Assessment

Nuclear power came in on par with solar photovoltaics and just

native forms of energy generation," Prof Baldwin told AAP.

"These two things combined together show that coal doesn't really have the long-term future many decades out." When it came to fighting cli-

## Media Engagement by ECI Members

ECI Members routinely engage the media, which resulted in significant exposure of research and policy commentary related to Energy Change. Below is a partial list of the media coverage produced by ECI members in the past year:

### News:

- ABC Online, 2012, "Labor's plan for 90pc clean energy" (James Prest)
- CE Daily, 2012, "Budget carbon price projection totally unrealistic, economist says" (Frank Jotzo)
- EcoGeneration, 2012, "2010 emissions surge a one-off: ANU" (Frank Jotzo & Paul Burke)
- ABC TV News, 2012, Interview regarding ACT Labor Clean Energy Policy (James Prest)

### Feature:

- The Conversation, 2012, "Australian energy cost estimates: Experts respond" (Ken Baldwin & Andrew Blakers)

- BBC Frontier Program, 2012, "Artificial Photosynthesis" (Tom Faunce)
- East Asia Forum, 2012, "The Asian Century and Australia's energy future" (Frank Jotzo)

### Commentary:

- The Australian Financial Review, 2012, "Combet's carbon incompetence" (Warwick McKibbin)
- Climate Spectator, 2012, "Labor's carbon price pagmatism" (Frank Jotzo)
- The Conversation, 2012, "UN sustainability panel says put a price on the environment" (Paul Burke)



# Public Policy

Energy policy, economics and regulation are key areas of the newly established Australian National Institute for Public Policy (ANIPP) which provides the ECI (and the rest of the University) with the wider context that policy and decision makers need. ANIPP draws together the public policy expertise available at ANU and its various specialist centres by providing an educational portal to the Australian Public Service.

ANIPP incorporates the H.C. Coombs Policy Forum, a 'think tank' operated as a strategic collaboration between the Australian Government and ANU and is focused on transforming public policy research into practice. It supports policy-relevant exploratory and experimental work at the interface between government and academia. The ECI public event "Australia's Energy Future" is supported by the H.C. Coombs Public Policy Forum.

ANIPP also provided support to the ECI Professional Short Courses in 2011 and 2012.

In a special honour for the ECI, three of our researchers were selected amongst the nine inaugural ANU Public Policy Fellows across the University:

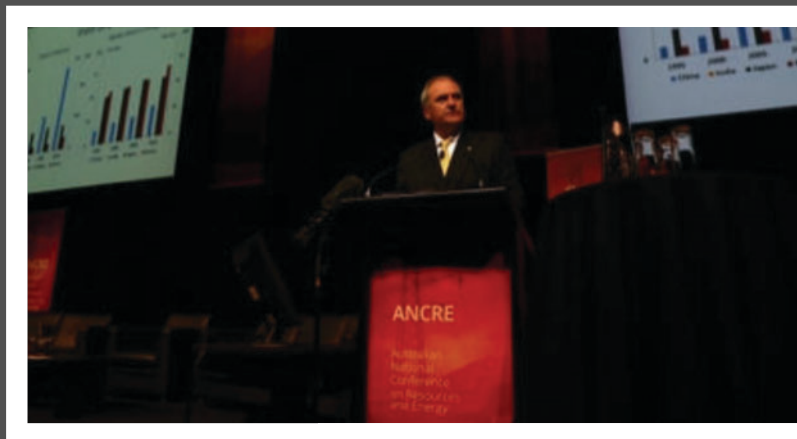
- **Professor Ken Baldwin (ECI Director)**
- **Professor Andrew Blakers (Director of the Centre for Sustainable Energy Systems)**
- **Professor Warwick McKibbin (Crawford School of Public Policy)**

This recognises the significant external contribution of the ECI through the award of one third of the University's inaugural Public Policy Fellows, who will contribute in a broad sense to energy outreach through the Crawford School of Public Policy.

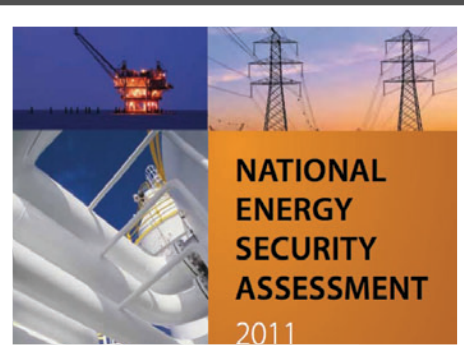
Amongst many individual contributions, ECI researchers participated in the

Professor Warwick  
McKibbin at the  
ANIPP Public Policy  
Fellows Launch at  
the Crawford  
School.





Ken Henry, head of ANU Institute of Public Policy, at the Australian National Conference on Renewable Energy.



Ken Baldwin at the ANIPP Public Policy Fellows Launch.

following public policy events through invitation to the ECI:

- **Australia-China Climate Change Forum – Ken Baldwin, Andrew Blakers and Frank Jotzo, 30 March 2011**
- **National Energy Security Assessment Methods Advancement Project (NESAMAP) – Ken Baldwin, Tom Faunce, Frank Jotzo, Keith Lovegrove and Hugh Saddler, 10 May 2011**
- **ANIPP Public Policy Fellows Launch: “Scholarship, public debate and public policy” - Ken Baldwin and Warwick McKibbin, 18 July 2012**
- **Australian National Conference on Renewable Energy (ANCRE) 2012 discussion panel – Ken Baldwin, 17/18 September, 2012**

In 2011, Ken Baldwin was invited as ECI Director to be a member of the Project Steering Committee for the first Australian Energy Technology Assessment (AETA) report which was launched on 31 July 2012.

Through their research expertise, many ECI researchers contribute to public policy development as part of their everyday activities – particularly in the Energy Change implementation disciplines of economics, law, sociology and policy.

# Interaction with ANU Climate Change Institute

The Energy Change Institute is a collaborating member of the highly regarded ANU Climate Change Institute (CCI). The CCI supports a cohesive, interactive community of researchers and teachers at ANU, aimed at building a powerful capability to meet the climate change challenge, from basic science, through impacts and adaptation, to solutions based on economics, institutions and energy technologies.

The ECI works closely with the CCI given that Energy Change is a critical contributor to climate change mitigation. Both organisations collaborate through shared Advisory Board memberships. In addition, both ECI Director Ken Baldwin and ECI member Frank Jotzo serve as Deputy Directors of the CCI.

The ECI and CCI work together on a number of projects. The most high profile of these – the Australia-China Climate Change Forum held at ANU in March 2011 – was organised by the CCI, with the ECI responsible for the Renewable Energy programme.

In education, there is a strong synergy between the Master of Climate Change and the Master of Energy Change. Both degrees have common course electives, and researchers from the CCI and the ECI contribute to both teaching programmes. The professional short courses run by the ECI also include guest lectures by CCI researchers.



Minister Greg Combet  
and H E Mr Xie Zhenhua  
at Press Conference of  
Australia China Climate  
Change Forum 2011,  
University House, ANU

Photo by Stuart Hay



# Outlook

As the Energy Change Institute approaches its second anniversary, it is beginning to establish itself as an Australian leader in this field.

The appointment of Business Development Manager, Dr Igor Skryabin, early this year has given the ECI the capability to develop and promote its research, education and outreach agenda with modest resources. In this first period the operational funds available for ECI activities have been mostly self-generated, through income from Short Courses and external contracts.

From 2013 the ECI will enter a new phase in which we will combine resources with the ANU Climate Change Institute (CCI) and share a joint secretariat which will provide additional personnel and support for administration and outreach. The Vice Chancellor has approved this coalition, and with the appointment of the new CCI Director in the near future, both institutions will work together to establish the personnel and resource allocation that will support both Institutes.

ECI also aspires to broaden its educational offerings with expanded course choices for the Master of Energy Change, additional Short Courses, and potentially undergraduate subjects. This will create further synergies for members of the ECI, and will contribute additional income through a shared funding model, which the Institute hopes to develop with the ANU Colleges.

The ECI has already established its credentials in the public policy arena, through submissions to a number of government reviews and through involvement in a range of government enquiries and policy programmes. This capability was further enhanced with the announcement of three ECI members amongst the nine inaugural ANU Public Policy Fellows, opening future prospects for influential involvement in public policy.

The Institute expects that as it grows in personnel, resources, research, education and policy outputs, it will increasingly become a key entry point for industry and government engagement with our broad Energy Change portfolio.





## APPENDIX A: ECI ADVISORY BOARD



**Drew Clarke** was appointed Secretary of the Commonwealth Department of Resources, Energy and Tourism in April 2010. His previous position was Deputy Secretary with responsibilities across the three sectors. Drew's earlier roles include Head of the Energy and Environment Division, where he was responsible for energy market reform, energy security and energy-related climate change policy, head of AusIndustry, the business program delivery agency, and leadership of science agencies.



**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. Mr Devlin also holds a Bachelor of Engineering (Electrical), a Master of Business Administration and a Master of Commercial Law.



**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 1992-2002 he was Chairman/CEO of the Joint Coal Board, Coal Mines Insurance Pty Limited and the Joint Coal Board Health and Safety Trust.



**Jenny Goddard** works as an independent Director and an economic consultant. She has 23 years of experience as an economic policy adviser to the Australian Government, initially in the Treasury and later in the Department of the Prime Minister and Cabinet (PM&C) where she worked until May 2008. She also chaired the COAG working group resulting in leaders agreeing to reforms to the national energy market. Ms Goddard is the inaugural Chair of the Board of The Australian Solar Institute Limited (ASI), a Director with the Grains Research and Development Corporation and a Commissioner with the Australian Fisheries Management Authority.



**David Papps** is the inaugural Director-General of the ACT Environment and Sustainable Development Directorate, which was created in 2011 by the amalgamation of the Department of the Environment, Climate Change, Energy and Water (DECCEW) and the ACT Planning and Land Authority. He was previously the inaugural Chief Executive of DECCEW. Prior to that, Mr. Papps was a Deputy Secretary in the Victorian Department of Sustainability and Environment. He spent nearly four years with Macquarie Bank as Director, Policy, Innovation and Planning in the then Banking and Property Group. Mr Papps is currently the ACT's Chief Planning Executive.



**John M. Poate** (Ph.D. – Australian National University, 1967) is Vice-President for Research and Technology Transfer at the Colorado School of Mines. Dr. Poate 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 TMS. He has served on advisory panels or councils for NATO, US and overseas universities, NSF, NRC, and DOE. He currently serves as Chair of the Director's Review Committee for Physical and Life Sciences at Lawrence Livermore National Laboratory and is on the Board of the National Renewable Energy Laboratory.





**Daniel G. Nocera** is the Patterson Rockwood Professor of Energy at Harvard University. His group pioneered studies of the basic mechanisms of energy conversion in biology and chemistry. He has recently accomplished a solar fuels process that captures many of the elements of photosynthesis and he has now translated this science to produce the artificial leaf. He has been awarded the Eni Prize, IAPS Award, Burghausen Prize, Elizabeth Wood Award and the United Nation's Science and Technology Award and from the American Chemical Society the Awards in Inorganic Chemistry, Harrison Howe and Remsen Awards, for his contributions to the development of renewable energy.



**Will Steffen** is former Executive Director of the ANU Climate Change Institute at the Australian National University (ANU), Canberra, and serves on the Multi-Party Climate Change Committee (MPCCC) and as a Climate Commissioner. He is also Co-Director of the Canberra Urban and Regional Futures (CURF) initiative, a joint venture of ANU and the University of Canberra. His research interests span a broad range within the fields of climate change and Earth System science, with an emphasis on incorporation of human processes in Earth System modelling and analysis; and on sustainability and climate change, with a focus on urban systems.

## APPENDIX B: ECI EXECUTIVE COMMITTEE



**Professor 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. Since 2011, he has been a member of the Project Steering Committee for the Australian Energy Technology Assessment produced by the Bureau of Resources and Energy Economics in the Department of Resources, Energy and Tourism. Professor Baldwin is an inaugural ANU Public Policy Fellow, and winner of the 2004 Australian Government Eureka Prize for Promoting Understanding of Science, for his role in initiating and championing 'Science meets Parliament'.



**Professor 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 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 also has interest in sustainable energy policy.



**Dr Michael Djordjevic** was awarded an Australian National Research Fellowship in 1984 and a Post Doctoral Fellowship from the Australian Wool Board Trust Fund in 1985. He is a Chief Investigator and Node Leader in the ARC Centre of Excellence for Integrative Legume Research (CILR). He has initiated research to understand the lipid biosynthesis pathway in *Chlamydomonas reinhardtii* and the application of this research to biofuel production.



**Professor Thomas Faunce** is an Australian Research Council (ARC) Future Fellow researching nanotechnology and global public health, that research now focused on governance of global artificial photosynthesis. He is a project director, ARC Discovery Project Grants on methods to detect fraud and misleading representations in relation to energy policy (with Dr Gregor Urbas) and nanotechnology and security implications of energy policy (with Dr Hitoshi Nasu)



**Professor Elmars Krausz** graduated and received his PhD from the University of Sydney. He has since held 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 Warwick McKibbin** is an ANU Public Policy Fellow in the Crawford School of Public Policy and an Adjunct Professor in the Australian Centre for Economic Research in Health at the Australian National University. He was foundation Director of the Research School of Economics from 2009-12 and foundation Director of the ANU Centre for Applied Macroeconomic Analysis (CAMA) from 2003-2010 and continues to be a Professor in CAMA. He has been a consultant for many international agencies and a number of governments on issues of macroeconomic policy, international trade and finance and greenhouse policy issues, global demographic change and the economic cost of pandemics.



**Dr Igor Skryabin's** career has spanned both industry and academia. His major technical contribution was in developing commercial artificial photosynthesis in photovoltaic solar cells. He was the technical and intellectual property executive at predecessor companies to Dyesol Ltd, where together with his technical team he laid the foundations for commercial manufacture of Dye Solar Cells. He has published approximately 100 papers and has more than 30 patents and industrial designs, many are granted in Australia and overseas.



# APPENDIX C:

## ECI PARTICIPANTS

### Artificial Photosynthesis

Elmars Krausz	ANU College of Physical and Mathematical Sciences
Ron Pace	ANU College of Physical and Mathematical Sciences
Rob Stranger	ANU College of Physical and Mathematical Sciences
Warwick Hillier	ANU College of Medicine, Biology and Environment
Tom Faunce	ANU College of Law
David Ollis	ANU College of Physical and Mathematical Sciences

### Biosolar Energy

Michael Djordjevic	ANU College of Medicine, Biology and Environment
Graham Farquhar	ANU College of Medicine, Biology and Environment
Warwick Hillier	ANU College of Medicine, Biology and Environment
Dean Price	ANU College of Medicine, Biology and Environment

### Carbon Capture and Storage

Rowena Ball	ANU College of Physical and Mathematical Sciences
Mark Knackstedt	ANU College of Physical and Mathematical Sciences
Tim Senden	ANU College of Physical and Mathematical Sciences
Adrian Shepard	ANU College of Physical and Mathematical Sciences

### Energy Economics and Policy

Robert Breunig	ANU College of Asia and the Pacific, Crawford School
Paul J Burke	ANU College of Asia and the Pacific, Crawford School
Quentin Grafton	ANU College of Asia and the Pacific, Crawford School
Carolyn Hendricks	ANU College of Asia and the Pacific, Crawford School
Frank Jotzo	ANU College of Asia and the Pacific, Crawford School
Adrian Kay	ANU College of Asia and the Pacific, Crawford School
Andrew Kennedy	ANU College of Asia and the Pacific, Crawford School
Warwick McKibbin	ANU College of Asia and the Pacific, Crawford School
Hugh Saddler	ANU College of Asia and the Pacific, Crawford School
David Stern	ANU College of Asia and the Pacific, Crawford School

### Energy Efficiency and Demand Management

Mike Dennis	ANU College of Engineering and Computer Sciences
Idris F Sulaiman	ANU College of Engineering and Computer Sciences
Tom Worthington	ANU College of Engineering and Computer Sciences
Hugh Saddler	ANU College of Asia and the Pacific
Michael Smith	ANU College of Medicine, Biology and Environment

## Energy Regulation & Governance

Peter Drahos	ANU College of Asia and the Pacific
Neil Gunningham	ANU College of Asia and the Pacific
Tim Bonyhady	ANU College of Law
Tom Faunce	ANU College of Law
Andrew MacIntosh	ANU College of Law
James Prest	ANU College of Law

## Energy Sociology and Risk

Jan Hayes	ANU College of Arts and Social Sciences
Andrew Hopkins	ANU College of Arts and Social Sciences
Stewart Lockie	ANU College of Arts and Social Sciences

## Enhanced Oil & Gas Extraction

Mark Knackstedt	ANU College of Physical and Mathematical Sciences
Tim Senden	ANU College of Physical and Mathematical Sciences
Adrian Shepard	ANU College of Physical and Mathematical Sciences

## Fusion Power

Boyd Blackwell	ANU College of Physical and Mathematical Sciences
Cormac Corr	ANU College of Physical and Mathematical Sciences
Bob Dewar	ANU College of Physical and Mathematical Sciences
Matthew Hole	ANU College of Physical and Mathematical Sciences
John Howard	ANU College of Physical and Mathematical Sciences

## Hydrogen fuel cells

Rod Boswell	ANU College of Physical and Mathematical Sciences
Christine Charles	ANU College of Physical and Mathematical Sciences

## Nanostructure Photovoltaics

Lan Fu	ANU College of Physical and Mathematical Sciences
Qiang Gao	ANU College of Physical and Mathematical Sciences
Chennupati Jagadish	ANU College of Physical and Mathematical Sciences
H. Hoe Tan	ANU College of Physical and Mathematical Sciences

## Nuclear Science

George Dracoulis	ANU College of Physical and Mathematical Sciences
Keith Fifield	ANU College of Physical and Mathematical Sciences
David Hinde	ANU College of Physical and Mathematical Sciences
Greg Lane	ANU College of Physical and Mathematical Sciences
Andrew Stuchbery	ANU College of Physical and Mathematical Sciences



## Solar Photovoltaics

Andrew Blakers	ANU College of Engineering and Computer Sciences
Kate Booker	ANU College of Engineering and Computer Sciences
Kylie Catchpole	ANU College of Engineering and Computer Sciences
Andres Cuevas	ANU College of Engineering and Computer Sciences
Mike Dennis	ANU College of Engineering and Computer Sciences
Su Dongchul	ANU College of Engineering and Computer Sciences
Rob Elliman	ANU College of Physical and Mathematical Sciences
Vernie Everett	ANU College of Engineering and Computer Sciences
Andreas Fell	ANU College of Engineering and Computer Sciences
Evan Franklin	ANU College of Engineering and Computer Sciences
Kearn Chern Fong	ANU College of Engineering and Computer Sciences
Nicholas Grant	ANU College of Engineering and Computer Sciences
Start Hargraves	ANU College of Engineering and Computer Sciences
Niraj Lal	ANU College of Engineering and Computer Sciences
Daniel Macdonald	ANU College of Engineering and Computer Sciences
Rob Middleton	ANU College of Engineering and Computer Sciences
Sudho Mokkapati	ANU College of Engineering and Computer Sciences
Jelena Muric-Nesic	ANU College of Engineering and Computer Sciences
Yona Nebel-Jacobsen	ANU College of Engineering and Computer Sciences
Yongling Ren	ANU College of Engineering and Computer Sciences
Igor Skryabin	ANU College of Engineering and Computer Sciences
Sachin Surve	ANU College of Engineering and Computer Sciences
Elizabeth Thomsen	ANU College of Engineering and Computer Sciences
Andrew Thomson	ANU College of Engineering and Computer Sciences
Marta Vivar	ANU College of Engineering and Computer Sciences
Klaus Weber	ANU College of Engineering and Computer Sciences
Thomas White	ANU College of Engineering and Computer Sciences
Xinbo Yang	ANU College of Engineering and Computer Sciences
Jun Yu	ANU College of Engineering and Computer Sciences
Ngwe Zin	ANU College of Engineering and Computer Sciences

## Solar Thermal

Mike Dennis	ANU College of Engineering and Computer Sciences
John Pye	ANU College of Engineering and Computer Sciences
Graham Hughes	ANU College of Physical and Mathematical Sciences