



Title **Zero-carbon energy for the Asia-Pacific**

### What is your Grand Challenge?

In the coming decades the world must decarbonise its energy use to avoid catastrophic climate change. The Asia-Pacific will drive two-thirds of energy demand growth, so decarbonising the region's energy use will be crucial. Our Grand Challenge will undertake inter-disciplinary research to underpin a transformation in the way Australia trades with the Asia-Pacific – based on renewable energy. In particular, we will explore barriers and opportunities for large-scale generation and export of renewable energy from NW Australia in the form of electricity, energy-rich metals and materials, and hydrogen-rich fuels, as well as create new policy frameworks for adoption in the Asia-Pacific.

### 1. Impact and alignment with ANU Strategic Plan (20% of proposal score)

This Grand Challenge (GC) will place ANU at the forefront of research that will underpin **a new economy** based on Australia's cheap and abundant renewable energy, providing zero-carbon export of electricity, fuels, products and capabilities. These will replace our existing sunset fossil-fuel industries, and ensure that Australia's exports are not carbon-exposed to future overseas carbon-pricing systems.

Our GC will investigate four *socio-technological pathways* to Zero-Carbon Energy for the Asia-Pacific that integrate social, legal, economic, political and technological solutions. The first two pathways involve reducing the carbon content of electricity consumed in the region via:

1. *Large-scale renewable electricity generation for NW Australia, and also for export via subsea cable.*
2. *Policies and frameworks for renewable electricity generation and use in other Asia-Pacific countries.*

The other socio-technological pathways embed our zero-carbon energy in exports via:

3. *Large-scale renewable electricity production of hydrogen-rich fuels and other products.*
4. *Large-scale renewable refining of metal ores (especially iron).*

The benefits of our research to Australia and the region will be multiple. First, by transforming our trading relationship with the world, Australia can have far more **impact on global carbon emissions** than anything undertaken on a purely domestic level. The emissions from current overseas refining of our iron ore exports alone are up to five times those from Australia's domestic electricity sector, and if refined in Australia could add up to \$200 billion dollars in value-added exports. Furthermore, Australia's renewable energy resources are so great that we could provide most of the renewable energy needed for Indonesia's proposed electricity expansion of 35 gigawatts by 2025 (23% renewable or 8GW), and in 2017 Japan identified Australia as a key potential trading partner for their import of hydrogen as part of its future decarbonisation program to reduce their dependence on fossil-fuel imports.

The second benefit is to create **new zero-carbon export opportunities** that transform Australia's trade from being raw-material and fossil-fuel based, to value-added and renewable-energy based. This will enable Australia to transition into a carbon-constrained international trading world, retain its energy export leadership, and create long-lasting, widely-shared benefits. Furthermore, Australia could **contribute to regional security** by spreading these benefits across a number of countries to multi-lateralise the risk and advantages, and we will investigate how this could tie Australia more closely to the region. Importantly, there is the opportunity for **transformative development towards multi-generational prosperity for Australian Indigenous communities**, in line with the goals of the ANU Strategic Plan.

Our research has the potential for immediate impact through companies that are starting to develop projects for zero-carbon exports. For example, in parallel with earlier work by Interim GC team members Blakers and Nadolny which in 2012 evaluated the export of renewable electricity from NW Australia via a high-voltage, direct-current (HVDC) subsea cable to Indonesia, one of our industry partners (CWP Renewables) has independently started development of an Asian Renewable Energy Hub (AREH) in the Pilbara region. This multi-billion dollar, 11+GW wind, solar and energy storage project will eventually be the second-largest power station in the world. It aims not only to provide electricity for export to Indonesia and beyond (up to 6 GW) through a HVDC subsea cable, but also for new domestic industries in NW Australia that will create hydrogen-rich fuels, or refined zero-carbon embedded energy products such as fertilisers and metals based on Australia's massive mineral resources in the region. The AREH project is just one example of the many commercial collaborations that our research program is likely to create.

Our socio-technological pathway research will provide insights into the risks, challenges, barriers and opportunities that arise in transforming Australia's energy industry and exports. This research can only be undertaken in a multi-disciplinary university environment such as the ANU Energy Change Institute (ECI).

After 5 years of GC funding, our research success would be demonstrated by enabling:

- The establishment of new frameworks for participation and benefit-sharing between renewable energy investors and communities – particularly Indigenous ones in NW Australia. These frameworks differ from those in extractive industries such as mining, and will create a best-practice model for expansion of renewable energy industries throughout the Asia-Pacific and beyond.
- A blueprint for the creation of new zero-carbon processing of fuels and raw materials, paving the way for new industries and trading relationships which simultaneously create high-quality jobs in Australia, and provide clean and cheap inputs for sustainable development in the region.
- Understanding of the geopolitical, economic and technological drivers for successful trade in renewable electricity, and in embedded energy products and fuels.
- The development of institutions and legal frameworks supporting international renewable energy trade and investment across borders throughout the region.
- The techno-economic basis for renewable energy being broadly viewed as a secure, reliable economic opportunity rather than a risk or threat, both here and in neighbouring countries.
- Enhancement of the University's reputation for world-class trans- and inter-disciplinary research, in new fields that will help transform the way Australia trades with the world.

### 3. Transformative Research (15% of proposal score)

Our Interim GC was funded with \$500K from ANU and \$190K from our industry partners. Since we commenced at the end of May 2018, our trans-disciplinary research team of 15 part-time GC postdoctoral fellows and research staff have worked hard to establish the understandings needed to set the directions for our full 5-year proposal. The key research questions they have established are:

- **Where is the greatest market potential for Australian renewable-energy exports, either as electricity, reduced metal-oxides or hydrogen-rich fuels and products?**
- **What geopolitical, economic and technological frameworks are needed for successful trade in renewable electricity, and in embedded energy products and fuels, including hydrogen?**
- **How might the growth of a multi-generational, renewable energy industry contribute to sustainable development for Indigenous communities in Australia?**
- **What are the prospects for renewable-energy-based, value-added manufacturing in the Pilbara?**
- **What new technological developments and economic mechanisms are needed for the creation of novel zero-carbon products and processed raw materials?**
- **How can frameworks be developed to support international renewable energy trade and investment across borders, especially in the context of a trans-Asian 'One Belt, One Road'?**

Common to all these research questions are research lines based on the premise that energy research with the potential for massive-scale societal change requires novel integrated social research. Our research will be conducted along 3 research lines:

- **Stakeholder & Impact:** What are potential impacts on stakeholders and communities (particularly Indigenous)? How can the outcomes support the UN Sustainable Development Goals? How can we best engage groups to maximise positive outcomes? Which gatekeepers could block impact?
- **Techno-economic:** What is the techno-economic potential of the available and emergent technologies? How do we maximise their performance? Can they compete in the relevant markets in the timeframe required? How do technologies compare on environmental and social criteria?
- **Policy & Governance:** What role might policy, legal and institutional ('governance') frameworks have in supporting or inhibiting the transition via each pathway? What role can governance play in optimising the sustainable development impacts of a transition along each pathway?

The outcome of this research will be the creation of a new paradigm by which Australia trades with the world, contributing significantly to the decarbonisation of the Asia-Pacific based on our competitive advantage in renewable energy. The methodological paradigm shift will be the application of a trans-disciplinary approach that integrates both social and technological energy research (see also Approach).

### 4. Approach (15% of proposal score)

Our aim is to produce high-quality, high-impact research. To do this we will combine world-class ANU expertise in Energy, the Asia-Pacific and Indigenous Policy in an inter-disciplinary, action-oriented research program. We will achieve the disciplinary excellence and cross-cutting cohesion through:

- **Projects led by a Convenor with specific expertise.** There will be one project for each of the four zero-carbon transition pathways, plus one for Indigenous and Community Engagement, and one for International Governance and Politics. (See governance appendix.)
- **GC-funded research staff (Grand Challenge Fellows 1.0 FTE)** who will work on questions from a particular research line and across multiple WPs – mainly from the social sciences.
- **A GC-funded Trans-disciplinary Research Leader (0.8 FTE)** who works across all six projects, facilitates interaction and cohesion, ensures consistency in interactions with external stakeholders, and provides a supplementary supervisory and mentoring channel for the GC Fellows.

The key milestones for the GC will include:

1. An annual workshop with key stakeholders to review progress and adjust research projects.
2. Every two years, conduct a dispassionate techno-economic assessment of Australia's competitive advantage for renewable energy generation and export, to focus on the most promising areas. In the fast-moving and prospective field of hydrogen technology, this will include expanding on the state of knowledge from the recent ARENA, Finkel, CSIRO and IRENA hydrogen roadmap reports.
3. A stage-gating process in years two and four to determine the evolution of the projects.

Year-one milestones will include:

- A workshop with Aboriginal organisations and communities in NW Australia to discuss risks and opportunities and explore their interest in engaging with the renewable energy industry. This would build on our Interim GC engagement.
- Creating a renewable energy and pumped-hydro resource map of the whole Pilbara region. This would build on our Interim GC renewable energy and pumped-hydro map for Port Hedland.
- A comparative evaluation of our hydrogen technologies: generation by novel electrocatalytic, photocatalytic and thermochemical processes (potentially cheaper than present electrolysis); and novel liquid high-density hydrogen storage for efficient low pressure/room temperature transport.
- A report on policies for zero-carbon energy adoption in key countries of the Asia-Pacific.
- A system-level study of hydrogen and direct electrical processes for iron reduction in Australia.
- Our first report on the competitive advantages of renewable energy export (embedded and direct).
- Securing our initial industry funding agreements with our commercial partners.

Year-two milestones will include (subsequent years to be determined by year-two stage gating):

- A governance and economic blueprint for subsea electricity trading in SE Asia.
- Design optimisation of Pilbara renewable energy systems to support local and international loads.
- An evaluation of socio-technological transition pathways towards a hydrogen supply chain (generation, storage, transport and delivery).
- An off-river, pumped-hydro geospatial map for SE Asia.

**Path to Impact:** A key advantage of our GC approach is the strong collaborations we have developed with stakeholders from our pathway to impact. Our GC is concerned with removing barriers to the adoption of renewable energy in the transition to a sustainable, zero-carbon economy. To ensure our research has the desired effect we will continue to involve our government, industry and civil partners as collaborators advising on the delivery of the research, and providing contextual contributions to inform the most relevant path to use. For example, our existing links with Indonesian researchers from the Australia-Indonesia Centre (AIC) will contribute insights into social and geopolitical issues in Indonesia, including with state-owned energy utility PLN. Further, we have established strong links with the ACT Government, and with Federal Departments such as Environment and Energy (DEE), Foreign Affairs and Trade (DFAT) and the Australian Renewable Energy Agency (ARENA), who we will target as primary funding sources, collaborators on policy and contributors to our governance. ARENA is also on the Steering Committee, has contributed \$20K cash for Interim GC research in the renewable energy pathway for refined metals, and is expected to be a key funding partner for our 5-year research program, leveraging ANU GC support.

A key collaborator will continue to be CWP Renewables who develop multi-billion dollar renewable energy projects in Australia and worldwide. They are four years into project development for AREH and have formed a consortium of international companies, government contacts and community stakeholders to underpin that project. CWP have collaborated closely in the Interim GC as a Steering Committee member (with \$160K funding), and will provide crucial in-kind support via up-to-date information and data, extensive networks (especially in hydrogen production, Indigenous engagement and energy development), feedback on applicability of research ideas, as well as major cash funding indicated in their letter of support. CWP will also facilitate engagement with the native title holders in the Pilbara, and our team has separately secured interest in research collaboration from other leading Indigenous organisations.

Evoenergy (formerly ActewAGL) is another key industry collaborator providing expert advice, \$10K Interim GC cash funding and a member of the Steering Committee. They will contribute in particular to the hydrogen socio-technological pathway research and have provided a letter of financial and in-kind support.

Finally, we will leverage connections with the US National Renewable Energy Laboratory (NREL), which is establishing an Asia-Pacific focused Clean Energy Solutions Centre in Canberra. Collaborating with NREL will help to embed our GC learnings into the regional energy knowledge base.

**Addressing risk:** In general, a philosophy of engagement with a wide range of stakeholders in the development of the research agenda substantially reduces risk. We should make it clear that our 5-year research program does *not* depend on the realisation of the AREH project, *or* on the realisation of the subsea cable to export electricity to Indonesia. The responsibility and risk for those projects is borne entirely by CWP Renewables and its partners and, if the subsea cable is not built, the potential remains for large-scale utilisation of renewable electricity in the Pilbara region.

We also engage with a range of companies in other areas of our research program (see section 7). The highest-risk aspects for our research are those which hinge on access to key data and personnel from foreign interests – particularly the Indonesian government and PLN. We will mitigate this risk by taking a measured approach, working our way toward key decision-makers through the University's extensive networks, as well as through our contacts in the AIC and in Australian government, particularly DFAT. Furthermore, the initial stages of our research will be specifically targeted at understanding the geopolitical and political-economic landscape, in order to identify ways around potential barriers to completing our research goals.

## **5. ANU Competitive Advantage (15% of proposal score)**

ANU is the only research institution with a comprehensive, trans-disciplinary program targeting the transformation of Australian export industries, through engagement with the Asia-Pacific to ensure a zero-carbon future for our region. We are perfectly placed to exploit this by partnering, for example, with the only renewable electricity export project (AREH) into Asia, a field where we have a research track record.

The ANU, with world-leading expertise in the ECI (over 150 staff in 19 research clusters), in the College of Asia and the Pacific (Regnet, Crawford School, Coral Bell School), and in the Centre for Aboriginal Economic Policy Research, is in a prime position to exploit a first-mover research advantage. In particular, we have world-leading expertise in economic mechanisms for emissions reduction in the energy sector, in 2018 Eureka prize-winning off-river pumped-hydro research, and in renewable electricity exports. We have recently been successful in attracting around \$4m in four ARENA grants in hydrogen generation, to add to our existing programs in solar thermal chemistry and hydrogen storage, as well as in governance and economic (supply chain) research on hydrogen pathways. Overall we have identified a strong team of 27 experts in the wide range of social sciences and technology that cover the expertise required to deliver this GC, with dozens more available willing to provide advice and expertise as required.

A key competitive advantage is our strong collaborative links. We will continue to engage with the DEE Mission Innovation program to accelerate global clean energy innovation, and will complement this technology-led program with key social science research. Our links to DFAT, Austrade and the APEC Energy Working Group will help address open trade-related questions that can potentially transform the role of renewable energy in Australia's economic future. Our personnel overlap with the Australian-German Energy Transition Hub will enable us to efficiently share complementary perspectives on both technology and policy matters. We have corporate collaborations with CWP and others that will enable investigation of key barriers and opportunities to investment in renewables, both in-country and in the wider Asia-Pacific. With partners ARENA, the ACT Government, and companies such as local energy provider Evoenergy, we will trial the potential of Canberra as a test-bed for hydrogen storage, distribution and conversion.

## **6. Team & Governance (15% of proposal score)**

Our GC team has 27 members from across 5 Colleges, comprising 10 lead investigators, 5 Steering Committee members and 12 team members. One third are women, and the team covers a broad spectrum of disciplines from science, engineering and technology, to economics, sociology, regulation, policy, Indigenous Australia and the Asia-Pacific. The research team has a balanced career representation with half being ECR/MCRs up to level C, providing a blend of experience with established, world-leading researchers and new ideas. In addition to the named Participants List in our Stage 2 application, there are at least 50 other researchers across all Colleges interested in contributing expertise as the research program develops.

The team is led by the founding Director of the ECI, Professor Ken Baldwin. He is ably supported by the presentation team of Dr Emma Aisbett (Trans-disciplinary Research Leader), Dr Paul Burke (research project convenor) and Professor Kylie Catchpole (Steering Committee member). The CVs for Professor Baldwin, the presentation team and other project convenors are summarised in the attached appendix.

We will add to our inter-disciplinary team of part-time Interim GC Fellow employees (15 ECRs and students – 9 of them women) by creating more opportunities for ECRs to join the university through advertised positions. We commit to enhancing the gender balance of our team through new appointments

that reflect our balanced governance structure. The Investigators, Steering Committee and Governance Board all have gender balance, as well as the leadership capacity and experience to enhance the career development of our ECR team members.

The leadership model for our Interim GC will provide the foundation for strong governance and leadership of our full 2019–2023 GC proposal, informed by the existing structure and networks of the ECI. Key components of our governance structure (see the attached appendix) will be the Governance Board and Steering Committee, chaired by Professor Baldwin. During the Interim GC, the Steering Committee has met at the conclusion of each of our workshops. This has proved an extremely efficient means of gaining valuable interaction with representatives of key stakeholders including ARENA, DFAT, CWP and Evoenergy. Similarly it has enabled substantive input from our key ANU researchers. If we are successful, our Steering Committee will be augmented by appointments that reflect our expanding participant and stakeholder interests. The Interim GC Governance Board will also be evolved to provide key advice into the development of our GC program.

## **7. Funding (10% of proposal score)**

The ECI GC is a large enterprise with major long-term goals, and hence we request the maximum \$2m p.a. for the GC program. There are three broad areas of budget expenditure that we envisage:

- Trans-disciplinary research staff (level B/C) who would integrate research across discipline areas. Most will be social science researchers, with their technology counterparts leveraging external agency support for the experimental activities founded primarily on existing ANU laboratory infrastructure. They will be tasked with developing the collaborative aspects of the socio-technological pathways, with skill sets and discipline backgrounds that best complement the diversity of activity. We anticipate 6 or 7 FTE positions led by our Trans-disciplinary Research Leader, Emma Aisbett, and totalling around \$1,000K p.a.
- Essential 'glue money' to ensure that the GC operates synergistically, creating a whole greater than the sum of the parts. This includes funds for workshops, industry and Indigenous engagement, field travel, public communication of our research outcomes, and a Chief Operating Officer assisted by part-time operations/administrative support. We envisage up to \$400K p.a. for these underpinning activities.
- Competitive research funding ~\$600K p.a. for external leveraging through industry partnerships, funding agencies (e.g. ARC, ARENA) and governments (e.g. ACT, Federal such as DFAT, and overseas). We envisage partnering with industry to eventually leverage external support for up to ~\$1,000K p.a. for up to 10 research positions, and for experimental equipment based mainly on existing ANU infrastructure.

Given that the ECI has an existing framework from the Interim GC on which the 5-year GC can build, we expect that the funding profile will ramp up quickly following the initial appointments and funding applications. As indicated we will be approaching our industry partners to fund the commercially-relevant programs. CWP Renewables, Evoenergy and ARENA have already contributed \$190K to our seven-month Interim GC research, and CWP and Evoenergy have made further indicative commitments in their letters of support. We are also in discussion with other companies including BHP, Fortescue Metals, Rio Tinto, Newcrest Mining, Yara, Horizon, Andritz, Arup, Macquarie Capital, Siemens and GE in relation to developing renewable energy products, and are engaging with other companies like Union Fenosa, Siemens, ThyssenKrupp, Hydrogen Utility, Hyundai, Bolu and Qantas, on renewable fuels.

Through GC support our research team and industry partners will provide a substantive launchpad of critical mass that will significantly enhance our leveraging capability. In terms of government funding agencies, ARENA and the ARC (with both of whom we have a strong track record) represent the most prospective federal sources, but we also expect to leverage through contributions from DFAT-funded programs, including the AIC. The Australia-India and Australia-China Strategic Research Funds from the Department of Industry, Innovation and Science are another key external funding opportunity.

In relation to local government, we are already closely engaged with the ACT Government and have existing collaborative funding programs for Battery Storage and Grid Integration, and for the development of hydrogen technologies. We are in contact with the Pilbara Development Commission and (through our industry partner CWP) with the WA Government, which may present further opportunities.

Our GC is therefore proposing much more than business as usual. We will utilise GC funding to synergise research across campus between discipline areas that previously had little or no connection, and we will leverage this funding from external sources – both current and new – to enhance our program.

Our GC projects will then contribute to Australia's economic future by researching new export opportunities for the nation, through avenues that currently do not exist, or in some cases that have yet to be proposed.

Our focus on exporting renewable electricity and embedded zero-carbon fuels and products, complemented by the social and policy research required to facilitate a renewable energy transition for the region, will underpin the ultimate goal of Zero-Carbon Energy for the Asia-Pacific.