Office of the Deputy Vice-Chancellor (Research)
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THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CREATE CHANGE

ACOLA Australian Energy Transition Research Plan: Response to Design Issues Paper

Contents

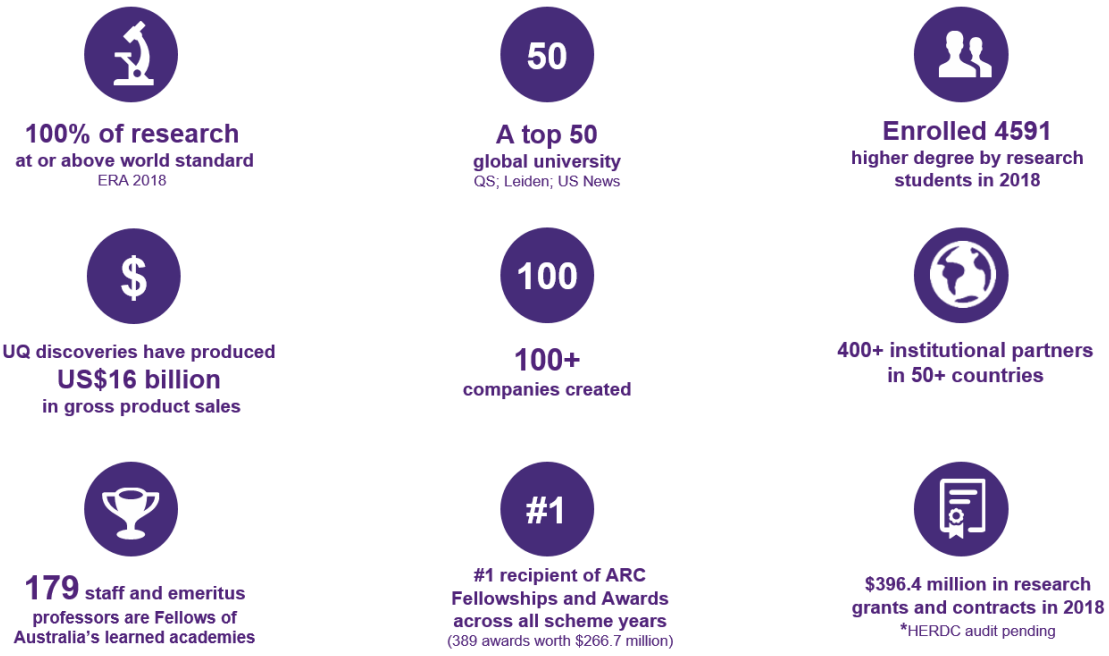
The University of Queensland **3**
Consultation questions **4**
Appendix A: Preliminary Mapping of UQ Energy Research Capability **11**
Contributors **17**

The University of Queensland

For more than a century, The University of Queensland (UQ) has maintained a global reputation for delivering knowledge leadership for a better world.

Our research has global impact, delivered by a transdisciplinary research community of more than 1500 researchers at our six faculties, eight research institutes and more than 100 research centres. Our research is providing solutions to global challenges, supported through partnerships, commercialisation and collaboration.

UQ has won more Australian Awards for University Teaching than any other university. This commitment to quality teaching empowers our 52,000 current students, studying across UQ's three campuses, to create positive change for society.



Consultation questions

1. Would you or your organisation be willing to participate with ACOLA in the development and ongoing support of a Research Plan?

Yes, the University of Queensland is willing to participate with ACOLA in the development and ongoing support of a Research Plan. We have a broad range of expertise across engineering, science, social sciences, economics and business. UQ researchers are deeply engaged in fundamental and applied energy research, development and systems analysis and work collaboratively with industry. For questions and opportunities please contact dvc.research@uq.edu.au.

2. What should be the scope of the Research Plan (how should we define 'energy', 'transition' and 'research')?

Definitions and scoping will be vital to the success of the research plan. We recommend that ACOLA engage stakeholders in a collaborative framing exercise in order to develop an agreed framing and set of definitions for key terms. The three concepts raised in the Design Issues Paper (henceforth DIP) ('energy', 'transition' and 'research') are not the only contestable terms that require closer scrutiny, and even 'net zero' requires consensus on a definition. Planning engagement and co-design properly from the very beginning are essential to secure a license to operate and public trust/engagement.

2.1 Scope

The Research Plan should acknowledge uncertainty and remain broad in scope and flexible enough to respond quickly to a changing national and global landscape. Input from UQ experts in relation to the scoping of the Research Plan highlighted the following:

2.1.1 Industry engaged

The Research Plan must be deeply engaged with a range of industries. Industrial needs should inform research agendas, while industrial knowledge must feed into the research commercialisation chain. The transformation of primary energy demand and of energy systems involves large scale changes within large industrial enterprises – deployment expertise is an industrial skillset.

Additionally, the scope should be broader than the energy industry, and include industries such as transport, mining, digital and manufacturing. To take transport as an example, large energy end users include rail, road freight, air, maritime, and personal surface transport. The transport industry (especially rail and maritime) are currently large distributors of energy resources, beyond the traditional electric power distribution networks. Overall there is a much greater need to find the connections and overlap between different sectors, given many aspects are often considered in a vacuum/isolation, and ignore inter-dependencies. The research plan should aim to map these systems.

One approach to this could be the inclusion of economy-wide tracking to understand the impact of initiatives across sectors. For example, if hydrogen is used in transport, will there be sufficient energy generation to also support hydrogen for export, steel and cement manufacturing? There should be an understanding that some cases of inter-dependencies can be complementary, and in other cases can be competitive (e.g. limited hydrogen resources spread across multiple applications).

2.1.2 Technology agnostic

The ACOLA Research Plan must not set foci or preferences on particular technologies. It must take a broader view to understand where different applications make more sense, as opposed to promoting a specific agenda where a solution is preferred *a priori*. Specifically:

- The Research Plan should include decarbonisation of fossil fuels. Both the Intergovernmental Panel on Climate Change (IPCC) and International Energy Agency (IEA) consider this essential.
- The assertion in the Design Issues Paper that Australia has 'no cheap domestic gas' is contestable. Australia has a wide range gas resources and is a high cost environment. A significant proportion of our endowment is "expensive" by world standards. However, cost is influenced by both geology/geography and by policy settings. Appropriate policy choices by governments (as well as new technology development) can ameliorate the potential cost disadvantage and unlock significantly more Australian supply.

A significant amount of research worldwide has been directed at a narrow range of targets (renewable electricity) while largely ignoring the more difficult problem of renewable liquid fuels. Gap analysis (with attributable value) should identify this problem. To achieve zero net emissions all energy sources need to be addressed. The more difficult ones may need higher rather than lower priority.

2.1.3 Sustainable Development Goals-aligned

The Research Plan should include links with UN Sustainable Development Goals (SDGs) and specifically alignment with UN climate change advice. This must be broader than those goals most obviously linked to energy (i.e. achieving universal energy access (SDG 7), reducing the impacts of air pollution (SDG 3.9), tackling climate change (SDG 13) and promoting economic development). As demonstrated in the IEA analysis of Energy and Gender, energy transition relates to many of the SDGs. In short, the energy transition is just a part of a wider developmental 'transition'. The SDGs could also provide a helpful organising principle to collate information from the audit and to inform the ongoing research plan.

2.1.4 International

The context for considering Australia's 'energy transition' is most appropriately seen nested within a global context. We are an energy exporter in a competitive environment for goods and services where relative input cost (including energy) matter. Given Australia is too small to 'move the dial' by our internal domestic actions alone, any meaningful engagement with energy transition to net zero must set itself within a global context. Therefore, Australia needs a broad research agenda to understand how to benefit from the global energy transition underway by developing policies that direct our resources towards the new opportunities at the same time as addressing regional disruption and disparities. The Research Plan should seek to inform policy that can support economic development in the regions, at the same time as reducing domestic emissions as well as those of our trading partners. Energy use is demand driven. If transition-preferred sources cannot fulfil that demand adequately (e.g. cost, access, security, etc.), history shows that the energy demand will be met in less sustainable ways.

2.2 Definitions

2.2.1 Energy

'Energy' should be defined in the broadest sense of 'energy service value chains'. This encompasses the extraction and harvesting of primary energy resources, energy carriers, energy conversion, transmission, distribution and utilization across all economic sectors.

Fuels (~80% of energy demand) must be included in the definition. H2 and microalgae fuels are two front runner fuel areas for research and commercialisation.

Given the acknowledged classification challenge for 'energy' and 'energy research' ACOLA should consider the existing IEA 'primary energy' definitions, and the energy conversion and energy use definitions from IEA's Energy Technology Perspectives Model.

2.2.2 Transitions

'Transitions' should be framed in terms of the multi-decadal shifts in energy service value chains being driven by varying societal responses, over time, to environmental challenges, including but not limited to, climate change, resource availability, economic competitiveness, and social norms. The Research Plan should consider the short, medium and longer term challenges that will emerge during the course of these transitions. It should also consider related socio-economic-environmental transitions facing industries, communities and landscapes which are likely to be the consequence of energy transitions.

The research program should explicitly address disparity and disadvantage in energy transitions at the level of individuals, households, workforce and communities. Potential foci could include shifts in the costs of, access to, and understanding of, the energy supply market. Opportunities are already evident in the use of network analytics and visualisation techniques to promote participation in an equitable energy future. Consideration should be given to unintended, unplanned or inadvertent effects of a transition that might act to increase social disparities and disadvantage. Such effects might include those related to health (e.g. cooking technologies and their effects on indoor air quality, the effects of high efficiency LED street lighting on skyglow, and community sleep health but also community security), with differential impacts along social and economic gradients.

A research program should directly engage consumers, including those that are currently marginalised or vulnerable, and should deliver to consumers and agencies straightforward and usable tools for decision making in their own interests. Strong inclusion of social science methods will be necessary to ensure that such engagement, and translation to benefit, is genuine.

The United Nations Framework Convention on Climate Change technical paper *Enabling a Just transition of the Workforce, and the Creation of Decent Work and Quality Jobs* is a vital resource in considering the social and equity dimensions of an energy transition.

2.2.3 Research

'Research' should span the disciplines and time-horizons, and continue to explore fundamental, applied and systems-level questions. In the context of a *circa* 30-year energy transition, the prospects for fundamental discoveries to play a significant part in transition may seem limited. Nonetheless, the energy transition will not end with the achievement of net-zero emissions, and such fundamental discoveries can offer long-term economic value. In particular, given the current state of progress, and current technological limits, longer range research into a possible 'overshoot period' will likely be essential. The plan will need to include and differentiate both mitigation and adaptation work as well as short, medium and long term to material implementation.

3. What processes and products should the Research Plan deliver?

The capacity to efficiently translate academic research output to have an impact on the energy transition is a critical success factor for the Research Plan. The processes and products to be delivered by the Research Plan should therefore seek to facilitate visibility, access and input by industry, government and other stakeholders to relevant research capability, current priorities and latest outputs. A key role of the Research Plan processes should also be to facilitate increased collaboration between research groups and between researchers and industry, governments and relevant agencies.

3.1 Processes

The Research Plan will need to include:

- Framing and definitions of success
- Agreed design tenets
- Agreement on classifications, terminology and frameworks
- A process to 'map' or congruence check with government policy (including international agreements)
- A regenerative 'evergreen' process which includes solicitation from industry on what they 'need to know'
- A process for progress monitoring and updating
- A way of monitoring investment levels by research area
- A way of monitoring progress through the Technology Readiness Level (TRL) and Commercial Readiness Level (CRL) series and into implementation
- Reports on all the above.

3.2 Products

In addition to the processes listed above, the following products are proposed.

3.2.1 Data mapping and needs

Energy data is incomplete and inconsistent. There is incomplete and inconsistent ABS historic data by state, and by sub-division, to be able to conduct robust research. Therefore we need a robust understanding of what energy information is available at a national and regional level, what can be estimated, what information is necessary for the research scope, and plans to address the gaps.

We also need a robust understanding of industry performance data requirements (i.e. revenue, value-add, and employment) at a national and regional level over a long-enough period to be able to support robust research.

Finally, we need a comprehensive database of historic and current information that harvests data from a wide spectrum of sources that can be readily accessed by all researchers, not just those that are fortunate enough to have access to proprietary information for research use.

3.2.2 Research mapping

ACOLA should consider the expertise of research performance analysis and library teams in developing a methodology for mapping the current research landscape. Data mining and bibliometric techniques may offer effective and replicable methods of analysis. Such approaches can be repeated at set milestones to measure trends in the scale and topics of outputs in the Australian energy research landscape.

When mapping current capability, careful consideration of parameters will be essential. For example, there has been considerable research across this space that would not be listed as 'transition' research. The audit will be critical to make sure it captures all of the technical, social and economic work that is relevant.

In mapping international research that 'may help to address research gaps in Australia' (DIP p. 4), care needs to be taken with the transferability of research to the Australian context. Energy production is a highly commercial endeavour. As such the intellectual property associated with international research may not be made available to further Australian national interests. In some cases in may be in the national interest to duplicate international research in order to establish domestic industrial capability.

More broadly, the value of research gaps needs to be the critical guiding parameter. The value can be assessed in a number of ways but should include economic cost or economic opportunity, greenhouse gas reduction potential and energy return on investment (ERoEI). The latter is an energy equivalent of the economic ROI which can be used to assess the longer term viability of different technologies.

3.2.3 Initiatives and structures mapping

In addition to mapping the Australian energy research landscape, a mapping exercise should be carried out to gain a broader appreciation of the various actors involved in the Australian energy transition, how they contribute, and what the interdependences are. Without this approach, decisions made in the energy sector could conflict with actions taken elsewhere, and overall, not achieve the ambition of transitioning the energy sector to net-zero emissions.

This should include mapping of structures that are supporting, funding or conducting research into energy and energy transition, as well as an indication of how the ACOLA Research Plan links with these existing initiatives, complements, and bridges gaps in and between them. Structures to include:

- Energy Research Institutes Council for Australia (ERICA)
- Industry Growth Centres, especially National Energy Resources Australia (NERA) but also the Mining Equipment, Technology and Services Growth Centre (METS), the Advanced Manufacturing Growth Centre (AMGC) and other centres.
- Collaborative Research Centres Association
- Australian Research Council
- Research Institutes, Centres and Clusters with an energy focus.
- CSIRO initiatives
- Energy industry companies and industry peak bodies.

3.2.4 Public attitudes and understanding tracking

Reporting on public attitudes and understanding of energy technologies and transition would be a valuable product of the Research Plan. An annual or bi-annual survey is recommended, which could be conducted in a variety of ways:

- Through a nationally representative public sample, similar to the CSIRO/UQ surveys of energy technologies.
- Through creating a longitudinal survey and dataset. For the first round, this would involve recruiting participants for a nationally representative sample. This cohort would then be surveyed annually/bi-annually, taking care to set up the design for drop outs/replacement rates, etc. Examples in Australia include the Household, Income and Labour Dynamics in Australia (HILDA) and Longitudinal Study of

Australian Children (LSAC) longitudinal datasets. This would create a way of tracking changes in attitudes and energy usage over time rather than as a one-off with each sample, to see how households and individuals change and adapt to the energy transition over time.

– Through a combination of a nationally representative public sample (random each year), accompanied by small and carefully selected targeted samples for longitudinal follow up.

Capturing business attitudes would require a different type of sampling strategy but could be conducted at the same time as a public random sample.

4. What existing research plans and design approaches can ACOLA draw on for the proposed Research Plan?

We suggest the approach to research planning could borrow from elements of the UK Energy Transitions Commission, and the Energy Transition Energy Research Program. Both of these benefit from a strong national government- and industry-led commitment and consensus on transition outcomes. Additionally see the European Universities plan 'Energy Transition and the Future of Energy: Research, Innovation and Education: An Action Agenda for European Universities'.

5. How would you or your organisation like to be engaged in the development of the Research Plan?

We would like to be engaged in the development and ongoing support of the Research Plan. Please direct all opportunities to dvc.research@uq.edu.au.

6. How should ACOLA govern and fund the development and ongoing support of the Research Plan?

We suggest ACOLA convene an independent steering committee comprising representatives from government, industry (multiple sectors and preferably peak bodies), other relevant stakeholders, and the research community (multiple disciplines). Funding would ideally come in the form of grants and donations from a diverse range of stakeholders (government, industry and philanthropy) with care taken not to rely heavily on any one sector to avoid perceptions of influence. Funding agreements should be made public and should explicitly avoid any suggestion of agenda setting by donors.

7. What do you see as the key risks that ACOLA will need to manage in the development of the Research Plan?

In addition to those listed in the DIP other key risks include:

Risk	Mitigation strategy
The key risk facing ACOLA in managing the development and ongoing management of the Research Plan will be to avoid perceptions among industry, government and other stakeholders that the Research Plan is driven by any one interest. The research has to be perceived as independent, relevant, outcome focused and industry-led, but free from vested influence.	To mitigate this, ACOLA should engage regularly and widely across the energy sector value chain, including with incumbent, energy actors including those in carbon-intensive energy producers and consumers.
Failure in the audit to clearly document and map existing research which results in collaboration.	Extensive engagement with all research providers for past and present research. Data mining of ARC and other research funding bodies, including overseas connections, as well as bibliometric analysis of research outputs.
Failure for institutions undertaking research to collaborate effectively.	In addition to establishing appropriate governance structures, ensure open and transparent allocation of funds and rewards for proactive collaboration.
Failure to undertake a transdisciplinary approach to the problem.	Type of research questions identified by stakeholders, and engagement of experts in supporting transdisciplinary research at scale such as UQ's Global Change Institute.
Failure to translate results of research into tangible outputs or failure to influence policy/politics.	Key deliverables defined from the start, involvement of policy representatives on the Advisory Board. See the POST notes from UK Parliamentary Office of Science and Technology for a good way to ensure uptake of information across these levels.

8. Are there any other issues that ACOLA should be considering in the design of the Research Plan?

Anticipation, Inclusivity, Reflexivity and Responsiveness (AIRR) dimensions of Responsible Research and Innovation (RRI) may be helpful guiding principles. See Table 1 in Stilgoe, Jack, Richard Owen, and Phil Macnaghten. "Developing a framework for responsible innovation." Research policy 42.9 (2013): 1568-1580.

Appendix A: Preliminary Mapping of UQ Energy Research Capability

The following analysis of UQ's energy research capability was compiled as a preliminary view for a National Energy Resources (NERA) audit in April 2020. It can be taken as indicative of the range and depth of our research capability on the topic of energy transitions. Note that this initial list already shows inherent challenges in classifying and categorisation of what constitutes 'Energy Research'.

Energy Research Capability - The University of Queensland (as provided to NERA in April 2020)							
Industry Sector, Capability or Challenge	**Item**	**Associated UQ Research Centre**	**State**	**University Related School**	**Research Partners / Supporters**	**Research Leaders**	**Research Areas**
3D Printing	1	Centre for Advanced Materials Processing and manufacturing (AMPAM)	QLD	School of Mechanical and Mining Engineering		Prof Matthew Dargusch	
		Nanomechanics and nanomanufacturing Group	QLD	School of Mechanical and Mining Engineering		Prof Han Huang	
Energy Transition – Batteries	2.1	Power and Energy Systems	QLD	School of Information Technology & Electronic Engineering		Prof Tapan Saha	
		Nanomaterials Centre	QLD	School of Chemical Engineering and the Australian Institute for Bioengineering and nanotechnology		Prof Lianzhou Wang	Nanomaterials for energy storage
		Yamauchi Group	QLD	Australian Institute for Bioengineering and Nanotechnology		Prof Yusuke Yamauchi	Nanoarchitecture of nanocrystals and nanoporous materials
Energy Transition – Solar	2.2	Power and Energy Systems	QLD	School of Information Technology & Electronic Engineering		Prof Tapan Saha	Large-scale solar integration; techno-economic and life-cycle analyses
		Nanomaterials Centre	QLD	School of Chemical Engineering and the Australian Institute for Bioengineering and nanotechnology		Prof Lianzhou Wang	Nanomaterials for solar cells
Energy Transition - Wind	2.3	Power and Energy Systems	QLD	School of Information Technology & Electronic Engineering		Prof Tapan Saha	Large-scale wind integration; techno-economic and life-cycle analyses
Energy Transition - Carbon, Capture, Utilisation and Storage	2.4	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Dept of Industry, Science, Energy and Resources, COAL21	Prof Andrew Garnett; Prof Suzanne Hurter; Hon Prof Jim Underschultz	

Energy Research Capability - The University of Queensland (as provided to NERA in April 2020)

Industry Sector, Capability or Challenge	Item	Associated UQ Research Centre	State	University Related School	Research Partners / Supporters	Research Leaders	Research Areas
		Andrew N. Liveris Academy	QLD	Faculty of Engineering, Architecture and Information Technology	Andrew N. Liveris	Prof Peta Ashworth	
Energy Transition - Ocean Energy - Tidal energy	2.5	Tidal energy in School of Civil Engineering	QLD	School of Civil Engineering		Dr Remo Cossu	
Energy Transition - Bioenergy	2.6	Centre for Solar Biotechnology	QLD	Institute for Molecular Bioscience		Prof Ben Hankamer	
		UQ Algae Energy Farm	QLD	School of Agriculture and Food Science		Prof Peer Schenk	
		Advanced Water Management Centre	QLD	Faculty of Engineering, Architecture and Information Technology		Damien Batstone	
Energy Transition - Natural Gas (&CCUS)	2.7	The Centre for Natural Gas - includes CCUS (very large research scope also includes research in item codes from 2.8 to 21)	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Prof Andrew Garnett	(very large research scope also includes research in item codes from 2.8 to 21)
Energy Transition - Others - esp. Energy efficiency and 'New Energy Metals'	2.8	Mining Engineering	QLD	School of Mechanical and Mining Engineering	BMA	Prof Peter Knights	
		Sustainable Minerals Institute	QLD	Sustainable Minerals Institute		A/Prof Marcin Ziemski	
		Renewable Energy Conversion Centre of Excellence	QLD	School of Mechanical and Mining Engineering		A/Prof Kame Hooman	Renewable energy transmission
		Industrial ecology in School of Earth and Environmental Science	QLD	School of Earth and Environmental Sciences		Dr Anthony Halog	Life-cycle analysis of production systems
		Energy economics and management group	QLD	School of Economics		Dr Paul Bell	Renewable energy economics
Automation - Machine Learning	3.1	Smart Machines Group	QLD	School of Mechanical and Mining Engineering		Prof Ross McAree	
		Petroleum engineering research group	QLD	School of Chemical Engineering		Dr Mahshid Firouzi; Dr Ruizhi Zhong	
Automation - Robotics	3.2	Co-innovation research group	QLD	School of Information Technology & Electronic Engineering		Assoc Prof Pauline Pounds	
Automation - Artificial Intelligence (AI)	3.3	CRC Mining	QLD	Faculty of Engineering, Architecture and Information Technology		Prof Paul Lever	
		Petroleum engineering research group	QLD	School of Chemical Engineering		Dr Mahshid Firouzi; Dr Ruizhi Zhong	

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		Power and Energy Systems	QLD	School of Information Technology & Electronic Engineering		Prof Tapan Saha; Prof Firuz Zare	Energy grid stabilisation
Automation - Computer Science, Augmented Reality	3.4	Data science research group	QLD	School of Information Technology & Electronic Engineering		Prof Xiaofang Zhou	
Automation - Sensing and control	3.5	Geotechnical Engineering Centre	QLD	School of Civil Engineering		Dr Theirry Bore	Sensor development
		Australian Institute for Bioengineering and Nanotechnology	QLD	Australian Institute for Bioengineering and Nanotechnology		Prof Joe Shapter	Sensor development
		Artificial Intelligence research group	QLD	School of Information Technology & Electronic Engineering		Prof Brian Lovell	Sensor development
Automation - Cybersecurity	3.6	UQ Cybersecurity	QLD	School of Information Technology & Electronic Engineering		Prof Ryan Ko	
Environment - Contaminates (Drill cuttings, metals, NORM's)	4.1	Centre for Mined Land Rehabilitation, Sustainable Minerals Institute	QLD			A/Prof Mansour Edraki	Contaminated land and water
		Plant and soil sciences research group	QLD	School of Agriculture and Food Sciences		Dr Richard Haynes	Contaminated land and bioremediation
		Queensland Alliance for Environmental Health	QLD	Faculty of Health and Behavioural Sciences	Queensland Department of Health	Prof Kevin Thomas	Environmental health toxicology
Environment - Biodiversity and Water Resource	4.2	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology		A/Prof Phil Hayes	Biodiversity and Water Resource; Groundwater modelling; Water-energy nexus
		Centre for Water in the Minerals Industry	QLD	Sustainable Minerals Institute		A/Prof Sue Vink	Hydrogeology and geochemistry
		Biodiversity and conservation	QLD	School of Biological Sciences		Prof Margaret Mayfield	Biodiversity
		Centre for Mined Land Rehabilitation	QLD	Sustainable Minerals Institute		A/Prof Peter Erskine	Biodiversity
		Centre for Water in the Minerals Industry	QLD	Sustainable Minerals Institute		A/Prof Claire Côte	water resource management
		Environmental Engineering Group	QLD	School of Chemical Engineering		A/Prof Steven Pratt; A/Prof Greg Birkett; A/Prof Simon Smart	Water treatment
		Advanced Water Management Centre	QLD	Faculty of Engineering, Architecture and Information Technology		A/Prof Steven Kenway	Water-energy nexus

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Environment - Emissions	4.3	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Australia Pacific LNG, Santos and Arrow Energy, and NERA	Prof Andrew Garnett; A/Prof Phil Hayes	Fugitive emissions - infrastructure; Fugitive emissions - shallow sub-surface
		Mining Geomechanics Team	QLD	School of Mechanical and Mining Engineering		Dr Chris Leonardi	Fugitive emissions - shallow sub-surface
Coal Seam Gas and Shale	5	The Centre for Natural Gas (former: The University of Queensland Centre for Coal Seam Gas (UQ CCSG))	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Prof Andrew Garnett; Prof Ray Johnson; A/Prof Phil Hayes	Coal Seam Gas and Shale; Shallow sub-surface processes
		Mining Geomechanics Team	QLD	School of Mechanical and Mining Engineering		Dr Chris Leonardi	Shallow sub-surface processes
		Coal seam geology and Methanogenesis in School of Earth and Environmental Sciences	QLD	School of Earth and Environmental Sciences		Prof Joan Esterle;	Coal seam geology
		Isotope geochemistry research group	QLD	School of Earth and Environmental Sciences		Emeritus Prof Sue Golding	Methanogenesis
		Petroleum engineering research group	QLD	School of Chemical Engineering		Dr Mahshid Firouzi; Prof Victor Rudolph; Prof Anh Nguyen	Enhancing gas extraction processes; 2 phase flow
Commissioning	6	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Prof Andrew Garnett; Prof Ray Johnson	
Decommissioning	7	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Prof Andrew Garnett; Dr Heinz-Gerd Holl	
Drilling	8	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Prof Andrew Garnett; Prof Ray Johnson	
Exploration	9	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Prof Andrew Garnett; Prof Ray Johnson	
		Sustainable Minerals Institute	QLD	Sustainable Minerals Institute		Dr Dion Weatherley	Seismic monitoring
		Energy, safety and environment group	QLD	School of Mechanical and Mining Engineering		A/Prof Saiied Aminossadati	Seismic monitoring
Field Development - Resource Economics	10.1.	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Prof Andrew Garnett	Petroleum Economics, royalty regimes
		Risk and sustainable management group	QLD	School of Economics		Prof John Quiggin	Natural resource economics
Field Development - Resource Law	10.2.	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Prof Andrew Garnett	Government regulation

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Industry Sector, Capability or Challenge	Item	Associated UQ Research Centre	State	University Related School	Research Partners / Supporters	Research Leaders	Research Areas
		Centre for Social Responsibility in Mining	QLD	Sustainable Minerals Institute		Dr Vlado Vivoda (Honorary Fellow)	Government regulation
		Natural resource policy in Faculty of Business, Economics and Law	QLD	Faculty of Business, Economics and Law		Prof Andrew Griffiths	Natural resource policy
		Governance and Public Policy Group	QLD	School of Political Science and International Studies		Prof Brian Head	Natural resource policy
Geoscience	12	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Australia Pacific LNG, Santos and Arrow Energy, and NERA and Energi Simulation	Prof Andrew Garnett; Prof Ray Johnson; Prof Suzanne Hurter; Dr Sebastian Hörning; Prof Ray Johnson	Geoscience; Reservoir modelling; Geostatistics; Rock properties and geomechanics; Reservoir stimulation
		Vale-UQ Coal geoscience program	QLD	School of Earth and Environmental Sciences	Vale	Prof Joan Esterle	Geoscience; coal seam geology
		Mining Geomechanics Team	QLD	School of Mechanical and Mining Engineering		Dr Chris Leonardi; Dr Zhongwei Chen	Rock properties and geomechanics; Reservoir stimulation
		Petroleum engineering research group	QLD	School of Chemical Engineering		Prof Victor Rudolph; A/Prof Karen Steel; A/Prof Tom Rufford; Dr Zhenjiang You	Permeability; Reservoir stimulation
Management - Cost Management	13.1	Accounting discipline	QLD	School of Business		A/Prof Kathleen Herbohn	
Management – Quality	13.2	Business Information Systems	QLD	School of Business		Dr Alistair Robb	
Management – Insurance	13.3	Strategy and entrepreneurship discipline	QLD	School of Business		Prof Paula Jarzabkowski	
Management - Human Resource - Skills, Behaviour, Social systems to support technology-based industrial transformation	13.4.1	Human Resource Management and Organisational Development	QLD	School of Business		A/Prof Remi Ayoko	
Management - Human Resource – Training	13.4.2	Human Resource Management and Organisational Development	QLD	School of Business		A/Prof Remi Ayoko	
Management - Asset Management, Strategy and Risk Management	13.5	Strategy and Entrepreneurship Discipline	QLD	School of Business		Prof Manuel Becerra	
		Mining engineering	QLD	School of Mechanical and Mining Engineering		Prof Peter Knights	Asset management
		Structural Engineering Group	QLD	School of Civil Engineering		A/Prof Dilum Fernando	
Management - Social Performance	13.6	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Dr Kathy Witt	Social Performance

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		Centre for Social Responsibility in Mining	QLD	Sustainable Minerals Institute		Prof Deanna Kemp	Social Performance
		UQ Culture and Heritage Unit	QLD	School of Social Science		Emeritus Prof David Trigger; Dr Richard Martin	Engagement with Indigenous peoples and native title
Offshore Structure	15	Coastal and Hydraulic Engineering Group	QLD	School of Civil Engineering		Prof Tom Baldock	
Engineering - Operation, Maintenance and Corrosion	16.1.	Advanced Materials Processing and Manufacturing (AMPAM)	QLD	School of Mechanical and Mining Engineering		Prof Matthew Dargusch	Corrosion
Engineering - Material Engineering	16.2	Smart Machines Group	QLD	School of Mechanical and Mining Engineering		Prof Ross McAree	
		Advanced Materials Processing and Manufacturing (AMPAM)	QLD	School of Mechanical and Mining Engineering		Prof Matthew Dargusch	Advanced forming mechanics
Risk, Safety and Fire	17	Minerals Industry Safety & Health Centre	QLD	Sustainable Minerals Institute		Prof David Cliff; A/Prof Maureen Hassall	
Subsea and Pipeline	18	Coastal and Hydraulic Engineering Group	QLD	School of Civil Engineering		Prof Tom Baldock	
Natural Gas	20	The Centre for Natural Gas	QLD	Faculty of Engineering, Architecture and Information Technology	Arrow Energy, Australia Pacific LNG and Santos	Prof Andrew Garnett	
Governmental Authorities and Professional Groups	21	Governance and Public Policy Group	QLD	School of Political Science and International Studies		Prof Brian Head	
		Corporate Social Performance	QLD	School of Business	KPMG	Prof Nicole Gillespie	Business-government relations
Oceanography – Climate	22.1	Oceanography – Climate in School of Earth and Environmental Sciences	QLD	School of Earth and Environmental Sciences		A/Prof Helen Bostock Lyman	Ocean circulation and relationship to global climate
Oceanography - Ocean Currents and Waves	22.2	Coastal and Hydraulic Engineering Group	QLD	School of Civil Engineering		Prof Tom Baldock	

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