Australian Energy Transition Research Plan

REPORT FIVE

Transition Dynamics

5

ACOLA RESEARCH BRIEFING PAPER

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ACKNOWLEDGEMENT OF COUNTRY

ACOLA acknowledges all Aboriginal and Torres Strait Islander Traditional Custodians of Country and recognises their continuing connection to land, sea, culture and community. We pay our respect to the Elders both past and present.

Australian Energy Transition Research Plan

The Australian Energy Transition Research Plan developed by ACOLA identifies three Research Priorities: Energy System Dynamics, Social Engagement Dynamics and Transition Dynamics. This Transition Dynamics research briefing paper is the third of three reviewing existing research and exploring research opportunities for the energy transition in Australia.

1. Introduction

The transition dynamics research theme encompasses the governance structures that we will need, how we will manage the economic, health and social risks, and how industries and employment will be transformed.

The Australian Energy Transition Research Plan (2021), developed by the Australian Council of Learned Academies (ACOLA) in consultation with key stakeholders, identified key research priorities across three themes. This paper, on Transition Dynamics, expands the third theme, reviewing existing research to identify key research gaps to address immediate and strategic needs of research users and consumers and outlining what opportunities can be realised through Australia addressing these priorities. This theme discusses the governance structures required to support the transition, how the economic, health and social risks of the transition will be managed, and how industries and employment will be transformed.

The report's key findings validate the need for further research insights especially on how bottom-up approaches and advances in urban transition can be enhanced to drive the energy transition in Australia and support greater energy system resilience. International literature provides a wealth of examples, approaches and frameworks which can be utilised in the Australian context.

The market governance system that has characterised Australia's energy transition is associated with slow and fragmented process for transition outcomes. The absence of a clear direction of energy transition in Australia has been affected by political divisions, regime resistance to adaptive change, and a disconnect between climate and energy policy. This is one of the key risks for Australia's energy transition, alongside unexplored implications in the areas of energy security, geopolitics, economic and social aspects related to the supply of key metals and minerals, and energy justice.

While there is some research into the resilience of the Australian energy system, additional insight is required into how an evolving energy system relying mainly on clean energy will adapt to chronic stresses and extreme events, including the COVID-19 pandemic.

Australia has relied on bilateral energy partnerships to maintain its status as a trusted partner in global energy supply chains. Still, its strategic weakness on climate policy is challenging its status as a trusted partner in the Pacific. Further research is needed to explore other avenues for Australia to enhance energy cooperation with current and future partners. International literature provides insights on relevant skills required for the transition, as skills shortages and workforce requirements are increasingly considered domestically. There is also a timely debate within Australia regarding the need for self-reliance in clean energy industry capability. Further research is required to balance the degree of self-sufficiency while maintaining international competitiveness. Australia has many opportunities to export clean energy industry skills and capabilities. Finally, the Australian energy research community can benefit greatly from engaging with energy transition lessons in other countries, including Germany's *Energiewende*.

In pursuing research on Transition Dynamics, a mix of urgent and more strategic local and international research across all disciplines needs to be pursued, including multidisciplinary and interdisciplinary considerations. The energy transition needs to happen at a rapid pace and scale, and insights derived from this project and the Research Plan will provide important knowledge for further and future domestic and global transitions.

2. Discussion of the Identified Research Priority

Following extensive consultation with stakeholders, ACOLA released the Research Plan (Report One). The Research Plan identified key research priorities for Australia's energy transition. These priorities offer those in the research ecosystem guidance on where and what research is being undertaken and what critical research is not being done to direct efforts and funding to high priority areas. The key research priorities are organised into three themes consisting of three topics, with each topic consisting of high-level driving questions for research over the next decade. These are classified as urgent (where robust answers are needed in the near future) or strategic (where robust answers are required in the longer term.

Three theme papers expand on each research priority from the Research Plan, taking a deep dive into the high-level questions. From these, the papers present a review of the existing Australian and international research base, noting critical research gaps and highlighting where Australia must accelerate or establish research efforts for a successful transition.

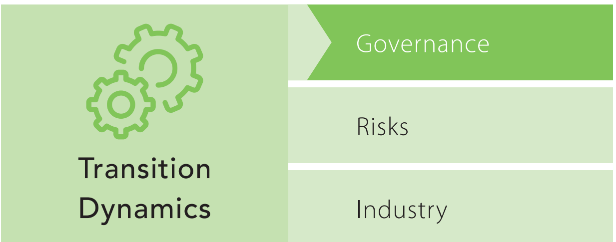
Further specific research questions are developed from each high-level driving question. The framing high-level questions from the Research Plan are highlighted in boxes. The additional research questions for each of the sub-topics are highlighted throughout and gathered at the conclusion of the paper.

The third research priority, Transition Dynamics, consists of the topics governance, risks, and industry. These encompass the governance structures that Australia will need for the energy transition, how to manage the economic, health and social risks, and how industries and employment will be transformed.

3. Literature Review

Domestic and international government bodies are the clear top-down drivers of energy policy settings, and therefore any transition; however, industry, businesses and community can and do exert important action from below. These non-governmental actors can significantly influence the development of renewable energy policies. Indeed, their actions can enable, focus, motivate and drag political (in)action.

This paper aims to review the domestic and international research in relation to the theme of transition dynamics, identify research gaps, and recognise what opportunities can be provided if Australia pursues research in this area.



3.1 Governance

3.1.1 Institutional models

> What institutional governance models are best suited for the Australian energy transition and are there learnings from international experience?

Governance systems

A nation's institutional governance system refers to how state and private interests are organised and relate to each other, affecting socio-economic outcomes (Griffiths & Zammuto, 2005). Such a framework is useful for understanding national approaches to energy transition, focusing on how state and industry actors interact and coordinate decision-making and economic activity (see Figure 1).

Under market governance systems, market forces are used to achieve adaptation, with fragmented value chains and low-level state involvement in industry. Energy transition approaches are seen as a cost rather than an opportunity, and institutional governance systems focus on protecting access to resources. Such a governance system has characterised energy transition in Australia and is associated with slow and fragmented progress (Griffths et al., 2007). The same applies to corporate governance approaches, as in the United States, where the pace of outcomes is dictated by corporate strategy.

In contrast, state governance systems involve the state playing a role in negotiating outcomes between significant groups in society while leaving the activities of a fragmented value chain to market forces and the actions of managerial hierarchies. While the state actively encourages the ecological modernisation of industry, energy transition goals take place within a broader economic and social priorities framework. There is a great deal of variation within Europe on how individual states negotiate energy transition outcomes and goals, such as the approaches of the Netherlands, the UK and Finland (Laes et al., 2014; Bosman & Rotmans, 2016). Rate of energy transformation and innovation can be slow initially but faster after extended negotiation periods.

Joint governance describes approaches where the state is involved in industry decision-making and integrated industrial value chains. These governance systems can intervene in the economy, encourage broader systems of product and process innovation, and encourage economic and industrial learning (Calder, 1995, Amsden, 2001). These approaches are associated with the fast and future-oriented growth in capabilities that enhance export-driven energy transformation. Such an approach characterises the German *Energiewende* and its impact on industry. Numerous studies focus on relevant lessons for energy transition that can be learned from the case of Germany, discussed in detail in section 3.1.2 (Strunz, 2014; Kungl & Geels, 2018; Gawel et al., 2019; Valdes et al., 2019).

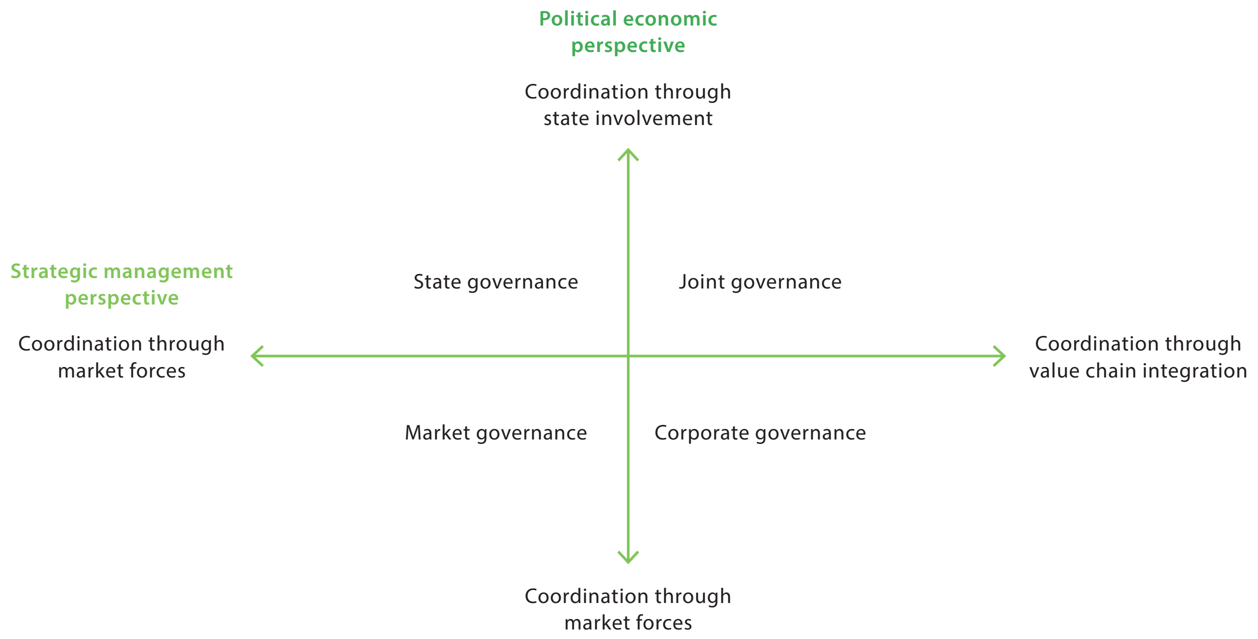


Figure 1: Four institutional governance systems

Source: Griffiths et al (2007).

Further research is required to understand how aspects of governance systems that support rapid and comprehensive energy transition outcomes can be applied in Australia (Wood, 2019). Particular insight may be found from state and joint governance systems across Europe, as more than two-thirds of geographically-focused peer-reviewed publications surveyed as part of this research used European case studies or examples. Research is also needed on what corporate governance structures need to be amended or transformed to support the energy transition. Further research for Australia would be best addressed by universities in close partnership with relevant state and federal government departments.

RQ: Which governance systems and corporate business models are best suited for Australia's transition, and what reforms are needed to support any shifts in governance and business structures?

Urban transition governance

Australia is a highly urbanised country (Australian Bureau of Statistics, 2018) and has a growing strength in research on urban transition governance. There is early work on the role of community governance in planning the sustainable energy needs of regional communities (Costello, 2011). Analysis of Australian renewable energy governance argues that development is best promoted at the urban level, as grassroots action by consumers and local governments may offer greater potential than a centrally-imposed energy policy framework. Bottom-up action by local government is essential to the uptake of renewable energy (Hamilton & Kellett, 2013).

Other recent examples of Australian urban transition governance research include research on how:

- In partnership with other state and non-state actors, the strategic pursuit of urban interests creates opportunities for energy transition when cities are faced by institutional obstacles (Dowling et al., 2018).
- Building energy transitions are shaped purposefully by opportunistic responses to specific material and commercial conditions and legacies in each city (Carr et al., 2019).
- Most urban council energy projects are reliant on some degree of funding from commonwealth and state government grants, which are often associated with political uncertainty and a lack of continuity in programs and funding (Cheung et al., 2019).
- An urban green transition towards a net-zero city is likely to reshape the city's image and reconfigure relationships within and beyond the city in varied ways (Pollard, 2019).
- Facilitating greater socio-technical interactions with residents can lead to the faster establishment and more efficient community-level shared renewable energy systems (Hansen et al., 2020).
- Large-scale energy transitions require that the urban development is delivered using evidence-based policies that promote regenerative urban outcomes (e.g., decarbonizing energy, recycling water and waste, generating local food, integrating biodiversity) to help mitigate risks (Thomson et al., 2020).
- Extension of the capacity of industry proponents beyond their traditional roles, to include the process of intermediation, has important implications for urban energy transition governance in terms of responsibility and transparency (Page & Fuller, 2021).
- Transformative changes that are required for a sustainable urban development transition involve multiple interconnected domains of energy, water, transport, waste, and housing (Newton & Frantzeskaki, 2021). Newton & Frantzeskaki (2021) present a national platform for urban innovation in Australia as a foundation for a governance system aimed at promoting regenerative urban development and energy transition.

This growing research base in Australia demonstrates the potential for supporting further research into urban context as a driver of energy transition. International literature, mainly focusing on Europe, offers numerous avenues and useful frameworks and databases for further research direction in the Australian context. These include broad comparative research of combinations of various governance processes (Haarstad, 2016) and sustainable energy initiatives across various scales and urban areas in Europe (Goggins et al., 2019). It also includes evaluations of network governance (Nochta, 2020; Nochta & Skelcher, 2020) and local governments (Piñeira Mantiñán & Rodríguez, 2021) in supporting energy transitions for European cities. These provide rich case study material that can be explored to advance the research agenda in Australia. This research would best be addressed by grassroots communities in partnership with local councils/governments and locally-based sustainable industry partners.

RQ: How can and should cities/towns of different sizes, from urban to regional, be supported and empowered as drivers of Australia's energy transition?

3.1.2 Research community

> How can the Australian energy research community (funders, researchers and research users) be structured to optimise their contribution to the transition, including the effective translation of research into impact?

Australia's energy research community includes funding bodies, researchers, including research institutions and organisations, and research users. The community includes federal and state-based organisations, such as the Australian Research Council (ARC), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and the Australian Renewable Energy Agency (ARENA), collaborative research centres (CRCs), such as Race for 2030 CRC, Future Battery Industries CRC, Future Fuels CRC, and Future Energy Exports CRC, philanthropic organisations and university researchers, including university-based energy-focused research centres and institutes. This community has a key role to play in contributing towards successful energy transition and enhancing Australian competitiveness. Its ability to optimise the contribution to the energy transition is partly dependent on how it is structured.

Australia could learn from key successes that other international jurisdictions have had with their own energy transition. This includes Germany which has historically been a global leader in renewable energy research and currently ranks in the top 10 of the Global Innovation Index (World Intellectual Property Organisation [WIPO], 2021). There are more than 180 universities and 120 research institutes involved in Germany's energy-transition programme, *Energiewende* (Curry, 2019). The renewable energy field employs nearly 340,000 people in Germany, as many as the renewable energy sectors in France, the UK and Italy combined (European Commission, 2018). *Energiewende* has set Germany in a pioneering position for many renewable energy technologies, which offers opportunities for German research and industry in international markets. In 2015, the export ratios reached 70% for PV, 66% for wind, 50% for biodiesel and 66% of heat pumps produced in Germany were consigned for export (European Commission, 2018).

Germany's structuring of its energy research community has contributed significantly to the pace of its energy transition (European Commission, 2018). The German government recognised that effective exchanges among key stakeholders such as funding bodies, researchers and research users is necessary to coordinate energy research activities. A comprehensive institutional set-up enables these exchanges, with a single department, the Federal Ministry for Economic Affairs and Energy (BMWi), responsible as program lead for energy transition. The BMWi regularly discusses energy research with state representatives, represents Germany in European and international bodies, and is jointly responsible with the Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Food and Agriculture (BMEL) for the strategic orientation of energy research funding (BMWi, 2021). The German Energy Research Programme is based on a cross-ministerial, thematically-oriented structure, and subdivided into project funding and institutional funding (BMWi, 2018). A strategic advisory Energy Transition Research and Innovation Platform (R&I Platform), hosted by the BMWi, provides a forum for dialogue between policymakers, the business and scientific communities, and civil society. This platform is supported by nine energy research networks that represent the broad research scene and serve as dialogue-oriented forums. The Academies' Energy Systems of the Future (ESYS) organises the expertise of the German academies of science (BMWi, 2021). Dialogue, exchange, and networking are considered crucial for the energy transition in all its complexity to bring together the many elements, development trajectories and dynamics.

Germany is not alone, as other countries have also had key successes with their energy transition. For example, the United Kingdom (UK) ranked 4th on the 2021 Global Innovation index (WIPO, 2021). Through their Energy Programme, the UK has invested approximately £1.1 billion between 2004-2020 on energy research across the remit of several Research Councils including the Engineering and Physical Sciences Research Council (EPSRC), which leads the Programme (Perspective Economics 2020). The investment portfolio is developed in partnership with diverse stakeholders (EPSRC n.d.). A recent review of the program has found that it has generated strong academic and non-academic impacts, including more than 1000 tangible policy impacts (Perspective Economics 2020). Similarly, the Swiss government, which topped the 2021 Global Innovation Index (WIPO, 2021), has also demonstrated strong support for energy research through their Energy Funding Programme (2013-2020). A core element of the Programme was the development of 8 national 'Swiss Competence Centers for Energy Research' (SCCER) in the fields of biomass, storage, networks, energy supply, legal and economic aspects, mobility, and energy efficiency in buildings, districts and industrial processes. A recent review of the Swiss program demonstrated that the SCCERs significantly increased the level of cooperation between different types of research institutions thereby improving the coherence of Swiss energy research activities. It also facilitated greater networking between participating research institutions and implementation partners, public institutions and policymakers thus leading to greater visibility and awareness of Swiss energy research activities (Innosuisse 2021).

Lessons from these international examples may be helpful for key Australian energy research stakeholders to consider to optimise their contribution to the energy transition, especially regarding their structure. However, as the German example demonstrates, shaping a research community takes a long time. Key questions for Australia that stem from the international examples are outlined below and would best be addressed at the highest level of Australia's energy research community, including major actors from government, industry, universities, and funding bodies.

RQ: What aspects of successful international energy transition models could be implemented in Australia to optimise the energy research community's contribution to energy transition?

RQ: Drawing from international models, how could Australia's funding ecosystem be amended/ restructured to better coordinate the application of Australia's energy research policy and the associated benefits?

3.1.3 Roles and practices

> How should the roles, structures and practices of governments, regulators, researchers, industry, NGOs and communities adapt to most effectively facilitate the transition?

The complex nature of the energy sector is characterised by fragmented roles, structures and practices among governments, regulators, researchers, industry, NGOs, and communities. This system is deeply embedded into societal fabric of institutions, infrastructure, and economy. The energy transition requires all actors to adapt and redefine their traditional roles and practices to facilitate the transition effectively. What makes the transition challenging is that there is no consensus about the urgency of the problem nor about the most favourable solutions or strategies. Governing the energy transition in a sustainable direction is highly complex, as a participatory multi-level and multi-actor process with different perspectives, values and goals involved (Loorbach et al., 2008).

Research on energy transition governance in Australia is limited to the general evaluation of the country's governance structures and institutions, with several case studies identifying barriers and opportunities. Analysis of Australia's NEM and international models shows that while there is an appetite for energy decentralisation from many stakeholders, current Australian governance system is more suited to the efficient running of a centralised system (Judson et al., 2020).

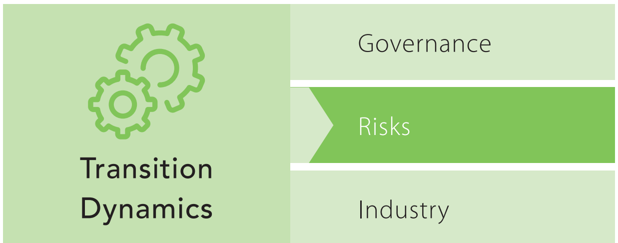
Internationally, the consensus in the literature is that centralised, or state-centred governance, such as in the Australian case, is increasingly replaced by decentralised approaches and perspectives. The latter includes the participation of local, urban, regional, state/provincial, and national/federal governments, along with industry and community stakeholders (Ostrom, 2010; Wu et al., 2018; Judson et al., 2020; Guerra & Atalay, 2021). The importance of national policies and regulations in enabling local authorities and other stakeholders to pursue energy transition policies means decentralisation should occur within a context of central support (Wu et al., 2018). International research suggests that decentralised governance is best approached by promoting self-organised centres of decision-making at local, urban, regional, state and/or national level that are formally independent of each other but operate under an overarching set of rules (Hvelplund & Djørup, 2017; Muinzer & Ellis, 2017; Muinzer, 2018; Knodt & Ringel, 2019; and Saurer & Monast, 2021). There is also an enhanced need for coordination of various levels of government, particularly in federal systems. Accordingly, central government should play an active role in this process as a facilitating party, but still as one party among many. Future research in the Australian context should consider the pros and cons of a centralised as opposed to a decentralised system of energy governance and their effect on the energy transition. This research would best be addressed by federal and state governments in partnership with universities.

RQ: What would be the key features, benefits and challenges of a decentralised energy governance system in Australia vis-à-vis a centralised system and what would be required to shift to such a system?

Various international studies have analysed the roles of key energy stakeholders in accelerating the energy transition. This includes research into partnerships across public and private sector, the role of intermediaries, and community organisations (Heldeweg et al., 2015; Hiteva, 2017; Dignum, 2018; Tzankova, 2020; Urbano et al., 2020), as well as on shifting power relations (Avelino & Wittmayer, 2016) and collaboration across key stakeholders (Danielson et al., 2018; Fischer et al., 2020). This growing body of work provides valuable insights regarding roles and practices of key actors that require consideration in the context of Australia's energy transition. As a first step, Australia requires a systematic understanding of shifting roles, practices, and power relations of key energy stakeholders in Australia, including companies of different sizes and types, from large corporations to small and medium-sized enterprises. This research would best be addressed by universities in collaboration with other key energy stakeholders.

RQ: What types of roles and partnerships should be encouraged to accelerate the energy transition, and how should stakeholders be incentivised or encouraged to take these up?

RQ: How can the roles and responsibilities in relation to achieving net-zero emissions be justly distributed among companies of different sizes and types?



3.2 Risks

3.2.1 Risks

> What are the technical, economic, environmental, geo-political and social risk scenarios (including social justice) that could impede successful transition to net zero-emission systems, and how can these best be mitigated?

Politics, divisions and regime resistance

There is a large body of literature that examines risks and obstacles associated with Australia's energy transition. The most cited issues include:

- political division, or national polarisation, between those who support large-scale exploitation of fossil fuels and those who advocate that the nation should grasp the opportunity of its rich renewable resources (Hamilton & Kellett, 2013)

- disconnect between climate policy and energy policy (Warren et al 2016; Wood, 2019)
- paralysis in climate change policy in the context of the inability of the political establishment to develop a sustainable consensus on climate change (Ali et al., 2020)
- resistance of legal and regulatory arrangements in the electricity sector to adaptive change (Judson et al., 2020)
- influence of energy-intensive industry players and fossil fuel interests, along with the energy regime that sustains them (Falk & Settle, 2011; Holley et al., 2019; Curran, 2020; Hancock & Ralph, 2021)
- without consistent, supportive federal policy, long-term visions, and a clear process, state energy transition processes are at risk of being 'captured' by the powerful resources sectors using the narrative of 'environment vs. jobs' (Goddard & Farrelly, 2018)
- institutional features that constrain local actors and reinforce the existing regime (Chandrashekeran, 2016; Jehling et al., 2019), and
- Australia's federalist system of government (Kallies, 2021).

Several studies discuss how some of the risks and obstacles identified above could be addressed in the Australian context. Bunning (2011) investigates how regulatory barriers to energy systems can be overcome to allow for large-scale implementation of distributed energy options, suggesting areas where future governance investigation could enhance sustainable planning and development in Australia. Goddard & Farrelly (2018) apply the just transition management framework to identify the political barriers to transitions and outline an approach that creates powerful niche actor-networks to counter the narratives and influence of the incumbent resource sector. Holley et al (2019) discuss governance pathways that could be pursued beyond state law to achieve more effective and sustainable energy governance. Finally, while noting social and political complexity in Australia's energy transition, particularly in resource-dependent regional communities, Colvin (2020) argues that the transition is best served by place-based, bottom-up initiatives congruent with local identity, values, preferences, and priorities.

International literature offers further insights which can be leveraged to accelerate the transition in the Australian context beyond the path dependencies, including on:

- the importance of path dependencies for governance and energy policy choices (Nochta & Skelcher, 2020; Saurer & Monast, 2021)
- how changes in rules and institutions are often incremental and path-dependent (Judson et al., 2020)
- historical lessons from the destabilisation of existing regimes and industries, such as the British coal industry (Turnheim & Geels, 2012)
- how network development can be utilised to address limited personnel and financial resources (Köhler et al., 2021)
- how path dependencies of socio-technical systems and established governance configurations may be challenged (Jørgensen et al., 2017), and
- how the creation of federated polycentric structures may offer a partial response to the existence of vested interests, in favour of the status quo (Bauwens, 2017).

There is much scope to advance this research agenda in the Australian context. Key insights from the international literature can be leveraged to learn how fossil fuel path dependencies can be overcome and how Australia can effectively integrate energy and climate policies. This research would best be addressed by universities in collaboration with federal and state governments.

RQ: How can Australia more effectively integrate energy and climate policies to mitigate risks to the energy transition and move beyond path dependencies?

Energy security and geopolitical risks

The International Energy Agency (IEA) defines energy security as the uninterrupted availability of energy sources at an affordable price (IEA, 2019). In recent years, the reliability of energy supplies has been threatened by factors ranging from geopolitical risk, weather events (the frequency and intensity of which are exacerbated by climate change), terrorist activities, industrial accidents, cyberattacks, and the impacts of the global COVID-19 pandemic, particularly on supply chains. Over the past half-century many countries have invested significant time and effort into reducing oil supply vulnerability. Still, similar security-related considerations for new forms of energy have yet to receive comparable analysis (Strunz & Gavel, 2019). New energy forms can help reduce vulnerability to oil supply outages, but they also introduce new vulnerabilities and risks. The transition towards renewable energies yields challenges for security of supply, with the tension between energy security and transition identified as a systemic risk (Bellos, 2018). Energy security is a key issue that must be addressed during global energy transition (Finley, 2019; Smith, 2020).

There is a tension, or the lack of alignment, between policies for decarbonisation and energy security (Månsson et al., 2014; Roelich et al., 2014). Research on sustainability transitions has paid little attention to the influence of energy security threats on energy transitions, or on security policy in policy mixes (Kivimaa & Sivonen, 2021). There is considerable scope for research to better conceptualise and understand the issues and opportunities for enabling the sustainable and secure development of energy systems. This includes the role of governance, especially how proprieties like flexibility, robustness and resilience can be delivered through the market or forms of strategic interventions (Hoggett et al., 2014). There is also a need for more interdisciplinary approaches that consider supply chain challenges, risks, trade-offs, and non-technical barriers/issues. This could include a more systematic mapping of all energy supply chains, possibly through a common socio-technical risk assessment framework (Hoggett et al., 2014).

The energy transition will have a significant effect on energy security of both energy importing and exporting states, such as Australia. The Clean Energy Council (2018) relates energy security to how the electricity grid or power system reacts to events that may influence it, but this is a narrow view of the issue and limits the scope of power system resilience. The existing research in the Australian context does not consider broader energy security implications of the energy transition away from fossil fuels and energy security implications associated with an energy system that is primarily based on renewable sources. For example, how can Australia move away from petroleum while maintaining energy security in the transportation sector? What are the energy security implications for Australia, across various levels of analysis (individual, community, local, regional, state/territory, and national), of a net-zero energy system?

In addition to energy security implications, the global energy transition away from fossil fuels and towards renewable energy sources is causing significant geopolitical realignments, as competition increases for access to strategic locations and natural resources (Overland, 2015). Historically, geopolitical and energy security considerations hastened the transition from oil to coal (Ediger & Bowlus, 2019). There is significant uncertainty about the geopolitical implications of a shift to renewable energy (Vakulchuk et al., 2020). There are a range of identified challenges, including risks to the supply of key metals and minerals, with researchers advocating for a 'whole systems' approach to energy geopolitics (Hafner & Tagliapietra, 2020; Blondeel et al., 2021). Overland et al (2019) present an index of geopolitical gains and losses that 156 countries may experience after a full-scale transition to renewable energy. The index provides useful pointers for strategic energy and foreign policy choices by demonstrating that geopolitical power will be more evenly distributed after an energy transition. There are mixed results from this index for Australia, which is to gain significantly from renewable energy sources while losing from a shift away from fossil fuels.

Geopolitical shifts associated with the energy transition include major realignments in the global supply and demand for energy transition metals and minerals. Metals and minerals are essential components in many of today's rapidly growing clean energy technologies, and demand for some are growing quickly. Changes in metals and minerals markets and supply chains on an unknown scale and scope bring numerous challenges and opportunities related to new technologies, supply chain security and sustainability, as the nature of material needs and geopolitical change grows increasingly interconnected (Lee et al., 2020; Månberger & Johansson, 2019). The World Energy Outlook Special Report provides a comprehensive analysis of the complex links between key metals and minerals and the prospects for a secure, rapid transformation of the energy sector (IEA, 2021a). There is much scope for analysing the geopolitical impact of changes in the global supply and demand of key metals and minerals for the energy transition, in the Australian context.

As with energy security, there are currently no studies that examine the geopolitical impact of the global energy transition on Australia. Among those international publications that discuss the geopolitical implications of the decline of fossil fuels, there is also an over-focus on oil producers and a lack of attention to the countries that rely heavily on coal, such as Australia (Vakulchuk et al., 2020). Australia leads the world in selling coal and gas; when Australian fossil fuels are burned overseas, the amount of carbon dioxide they produce is higher than the exported emissions of the world's biggest oil and gas-producing nations (Moss, 2020). Australia's mining industry is a pillar of the economy, with the country being one of the world's largest exporters of numerous metals and minerals. Nearly half of Australia's export value in 2018-19 ($160 billion) came from hard-to-abate industrial sectors, including the production of iron and steel, aluminium, other metals, chemicals and liquefied natural gas products (Energy Transitions Commission, 2020). More broadly, a global shift away from fossil fuels is going to have significant energy security and geopolitical consequences for Australia that require careful consideration and management and require deep interdisciplinary consideration to guide actions by Australian policy makers and industry. This research would best be addressed by universities in collaboration with federal and state governments and industry.

The technical and geopolitical impacts on the energy transition via ongoing energy security challenges are complex and a critical research gap. Underpinning an imperative to maintain uninterrupted energy at an affordable price are issues of policy optimisation and local and global interdependencies. Research is needed into how Australia can best improve synergies between policies to address decarbonisation and energy security. Australia must also investigate its navigation of shifting geopolitical circumstances, including short- and long- term interdependencies with other states, especially related to fossil fuels and supply of key metal and minerals, to maintain energy security.

RQ: How can Australia navigate the energy transition while maintaining uninterrupted energy availability at affordable prices?

Risks to economy, and social and energy justice

The concept of a 'just transition' to a low-carbon economy is firmly embedded in mainstream global discourses about mitigating climate change. An important dimension of this transition is that not everyone will benefit equally without specific efforts made to ensure an equitable transition. The US Green New Deal specifically embeds equity and social justice within climate change mitigation goals. It emphasises commitments to job training and economic development support for individuals and communities that might be adversely affected by a transition to new energy sources. The problem of energy vulnerability, energy poverty and energy justice are widely discussed in published studies. A consistent argument in the literature is that energy and related sectors policies should support economic and social development and energy poverty alleviation (Bainton et al., 2021). A related issue is that the decarbonisation of electricity and transport sectors may pose an ethical conundrum where global carbon emissions are reduced at the expense of an increase in socio-environmental risks at local mining sites (Watari et al., 2021). Increased extraction rates of energy transition metals may also augment the stress placed on people and the environment in extractive locations, reflecting heightened demand, major metals like iron and copper are set to disturb more land (Lèbre et al., 2020).

There are innumerable gaps in the collective understanding of how deep the inequalities associated with the energy transition are, exactly who is on the frontlines, what is in place to assist individuals and communities, whether everyone can serve as a stakeholder in decision-making processes, and how to design effective programmes (Carley & Konisky, 2020). These gaps exist both internationally and in Australia.

A just transition is critical for many Australian communities reliant on coal mining, the export of coal and domestic power generation. Governments will have to pay attention and play a key role to support intervention for a successful just transition (Evans, 2007). There are implications of place attachment and loss for generational coal mining communities, as examined in Lithgow, New South Wales by Della Bosca & Gillespie (2018). Acknowledging this relationship adds a useful perspective to energy transition discourse by highlighting how hidden dimensions of loss can act to reinforce local support of the extractive industry. Applying this understanding to decarbonisation strategies can inform a more effective, and more just energy transition in Australia (Della Bosca & Gillespie, 2018). Advocates from afar who adopt tactics that appear to place local groups in conflict are unlikely to convince regional communities of the need for energy transition (Colvin, 2020). Instead, the just transition is best served by place-based, bottom-up initiatives congruent with local identity, values, preferences, and priorities.

Energy transition also provides a specific opportunity for Australia to address socio-economic inequalities between Indigenous and non-Indigenous Australians. Within the Australian context, Hunt et al (2021) examine the conditions under which Indigenous involvements may be enhanced as part of a transition to renewable energy in northern Australia. The energy transition has been suggested as a basis for reconciliation in the international context. In Canada, the prospects of mutual benefits could turn the energy transition into an opportunity to bring together Indigenous and non-Indigenous people (Meng-Benza et al., 2021). There is much potential to advance further understanding of the socio-economic consequences of the energy transition and opportunities for scholars to provide basic scientific research to inform policymaking. This research would best be addressed by universities in collaboration with affected communities, industry participants, and regional and local governments.

RQ: How can Australia's energy transition be used to reduce socio-economic inequalities and create opportunities for Indigenous and non-Indigenous Australians?

3.2.2 Resilience

> How do we build and maintain energy system resilience against natural disasters, climate change, cyberthreats and power system changes?

Systems resilience, smart energy systems and micro-grids

Resilience is the ability to prepare, plan for, store, recover from, and more successfully adapt to adverse events (The US National Academy of Science, 2012), be it a bushfire, a pandemic or personal circumstance. In terms of the energy system, resilience is linked to continual energy supply during and after an incident.

The patterns of evolving energy demand and the transition towards renewable, and increasingly localised, energy supply can affect energy system resilience. In addition, changes in the nature, intensity and frequency of climate-related extreme events have imposed a higher risk of failure on energy systems, especially those at the community level. There is existing research investigating how energy systems can be planned and reconfigured to address these challenges without compromising the system's resilience against chronic stresses and extreme events, such as the multi-layered energy resilience framework and set of metrics for energy master planning of communities introduced by Shandiz et al (2020).

Within the Australian context, resilience has been a key topic for some time, particularly following the 2016 South Australian blackout, the Finkel Review (2017) and AEMO's 2018 Integrated System Plan (ISP). The Australian Government undertakes activities to support enhanced energy sector resilience to all hazards, including the resilience of energy infrastructure to natural disasters, cyber-attack, and other human and environmental threats (DISER, 2021a). The Department of Industry, Science, Energy and Resources (DISER) provides secretariat and program support for the Trusted Information Sharing Network for Critical Infrastructure Resilience Energy Sector Group, attended by owners and operators of critical energy infrastructure and government representatives (DISER, 2021a). In a major report, the Australian Government has recently been criticised for failing to accept direct responsibility for the lack of resilience in the national energy system (Global Access Partners et al., 2021a). The report argues that energy system resilience is a prerequisite for protecting Australian sovereignty, national security, and way of life. Markets cannot be held responsible for energy resilience as this is a component of national security, and governments must take that responsibility (Global Access Partners et al., 2021a).

In 2019, the Australian Energy Market Commission (AEMC) recommended a range of new mechanisms to enhance resilience in the power system. This includes a range of changes to the power system's security framework to help the market operator manage the risks of extreme events including severe storms (AEMC, 2019).

In late 2019, Arup released an Energy Resilience Framework (ERF) to assist those responsible for energy systems in evaluating their overall resilience to a range of potential disruptors and identifying and prioritising improvement measures (Arup, 2019). Finally, a report by ACOLA (2021) evaluates the role of energy storage in Australia's future energy supply mix. The report demonstrates that energy storage is a technically and economically realistic approach to improve energy system resilience by 2030 as Australia's energy system becomes increasingly dominated by variable renewable energy (ACOLA, 2021).

Smart energy systems provide opportunities to increase efficiency and build resilience. A smart energy system takes an integrated holistic focus, combining smart electricity, thermal and gas grids with storage technologies to achieve an optimal solution for each sector, and the overall energy system (Lund et al., 2017; Xu et al., 2020). Smart energy systems present a scientific shift in thinking on improving energy system resilience and benefit from the integration of all sectors and infrastructures (Lund et al., 2017). This research is already underway in Australia. CSIRO (2021) are developing new systems, such as the Stored Energy Integration Facility (SEIF), that intelligently manage the way energy is used, transmitted, and generated to reduce greenhouse gas emissions, minimise energy consumption, and save money. Monash University is partnering with global technology and consulting company Indra for the Smart Energy City project, supported by a grant through ARENA's Advancing Renewables Program. The Smart Energy City project will develop a grid-interactive microgrid at Monash University's Clayton campus to optimise the distributed energy resources and loads, coordinated through Indra's technology platform and the development of a transactive energy market (Monash University, 2019).

The existing research in the Australian context offers important insights and indicates a healthy existing research agenda into how energy system resilience may be enhanced. It is important to align future research on energy system resilience and smart energy systems with research into micro-grid systems and community-based grassroots initiatives, and how these contribute to system resilience (see Bauwens, 2017; Wagemans et al., 2019; Schmid et al., 2020; and Putnam & Brown, 2021). This would effectively link top-down and bottom-up efforts and provide a holistic approach for improving the resilience of Australia's energy system. International research demonstrates that physical and information flows in energy systems are increasingly complex and distributed, leaving centralised structures inefficient. Other countries, particularly those in Europe, are increasingly moving away from a centralised model of large generators supplying customers over long distances to a more decentralised system with dispersed renewable generation. This includes a future where customers will be at the heart of the system as prosumers, generating and consuming their own electricity.

Two studies provide a strong foundation for further research in the Australian context. Freeman & Hancock (2017) analyse how distributed smart renewable energy micro-grid systems can mitigate adverse impacts from natural disasters through outage prevention and rapid service restoration, increase rural and regional resilience, and offer communities opportunities for socio-economic development. Hill & Connelly (2018) analyse the dynamics of a community-based campaign, Clean Energy for Eternity (CEFE), which has successfully promoted the use of solar and wind power on the far south coast of New South Wales (NSW). Australian research efforts should focus on understanding how micro-grid systems and community-driven and grassroots initiatives, can enhance Australia's energy system resilience and link this research with the broader research agenda on energy system resilience, as discussed above. This research would best be addressed by universities in collaboration with industry bodies, governments, and grassroots community organisations.

RQ: How can the Australian energy system, including the role of key stakeholders, be reconfigured to enhance its resilience against chronic stresses and extreme events?

RQ: How can smart energy systems, micro-grid systems, and community-based grassroots initiatives enhance energy system resilience and how can their implementation be supported?

Energy sector digitalisation and resilience

A growing array of threats impact the resilience of the energy system including digitalisation, cybersecurity, and technological changes of the electricity system (Ratnam et al., 2020). There is a growing body of international research on the potential and applicability of digital technologies, such as the blockchain, Artificial Intelligence (AI) and the Internet-of-Things (IoT) in the energy sector transition, including in achieving greater systems resilience (Vangulick et al., 2018; Andoni et al., 2019; Brilliantova & Thurner, 2019; Diestelmeier, 2019; Teufel et al., 2019; Ahl et al., 2020; Wang & Su, 2020; Wentworth et al., 2021). For example, blockchain technology could help smooth out peaks and troughs in the power system by creating a robust system for peer-to-peer trade of energy created by prosumers, such as household PV. IoT-enabled devices can better track and manage their own energy use, with benefits to the consumer and networks by reducing grid investment needs. International research demonstrates that such digital technologies can improve the resilience of the energy system, support deeper penetration of renewable and distributed energy sources, and help support the development of innovative products and services for consumers (Wentworth et al., 2021). Digital technologies can also transform current methods of energy generation, transmission, regulation, and trading, though also bring broader challenges related to technology, regulation and impact on consumers (Wentworth et al., 2021).

Within this context, blockchains or distributed ledgers are an emerging technology that has drawn considerable interest from energy supply firms, start-ups, technology developers, financial institutions, governments, and the academic community (Andoni et al., 2019). The electricity sector is testing blockchain technology to support the decentralisation of energy production, while the oil & gas sector uses the blockchain for business process optimisation. Blockchain-based technologies have the potential to play a key role in this transition by offering decentralised interfaces and systems as well as an alternative approach to the current organisation form of the energy market (Teufel et al., 2019).

The technology also can facilitate distributed, peer-to-peer energy trading with reduced transaction costs, increased security via cryptography, and prosumer choice (Ahl et al., 2020). The number of publications about blockchain technology in the energy sector has increased exponentially since 2018, which indicates that it is a new cross-cutting research area with increasing attention (Wang & Su, 2020). At the national level, developing countries are catching up or even surpassing several traditional developed countries in the field of energy blockchain (Wang & Su, 2020).

There is no evidence of published peer-reviewed research that examines how digital technologies, such as the blockchain, AI, and the IoT, can support decarbonisation and improve the energy system's resilience. There is strong potential for advancing this research agenda in the Australian context. The RMIT Blockchain Innovation Hub provides a new way to understand the global blockchain evolution and serves as the most promising vehicle for advancing the research agenda on blockchain technology application in the energy sector in Australia. The broader research agenda on the application of digital technologies to enhance energy sector resilience would best be addressed by universities in collaboration with industry bodies and energy market operators.

RQ: How can digital technologies, such as blockchain, artificial intelligence and the Internet of Things, be leveraged to support decarbonisation and enhance the resilience of Australia's energy system?

Impact of COVID-19 on system resilience

The COVID-19 pandemic is having a significant impact on energy demand and supply patterns and energy system resilience. The pandemic was largely responsible for a 4.5% contraction in the global energy demand in 2020 (BP, 2021). A growing body of international research examines the impact of COVID-19 on the energy transition and offers conflicting conclusions regarding its effects (Henry et al., 2020; Hosseini, 2020; Steffen et al., 2020; Pianta et al., 2021; Quitzow et al., 2021). The COVID-19 crisis may deepen the gulf behind nations leading the global energy transition (Quitzow et al., 2021), though intelligent policies could convert this negative effect into great opportunities for renewables (Hosseini, 2020). An acceleration of the global energy transition is likely overall, driven by four mutually reinforcing factors: changes to the global energy system that predated the pandemic, pandemic-driven changes to the investment climate, recovery priorities that mesh well with clean energy goals, and growing public support (Black, 2020). A survey of over 200 policymakers supports this and stakeholders from 55 countries to collect climate policy expectations in various sectors and regions in the next five years (Pianta et al., 2021), with expectations of accelerating decarbonisation efforts were widely shared. This would have consequences for Australia's energy export markets and energy use, including electric vehicle (EV) sales and usage. Unfortunately, the literature on energy transition opportunities facilitated by the pandemic (such as Klemeš et al., 2021) exclusively focuses on the international context. There is scope to advance research on the impact of the COVID-19 pandemic on Australia's energy transition and the resilience of the energy system. This research would best be addressed by universities in collaboration with governments and industry bodies.

RQ: How has the COVID-19 pandemic impacted Australia's energy transition and energy system resilience, and what can be learnt from international and this domestic experience to further accelerate our energy transition and improve resilience?

3.2.3 Global trust

> How do we ensure that Australia remains a 'trusted partner' in global energy supply chains?

Australia is a top-two coal exporter globally and second in exporting LNG (Australian Government 2021). Australian fossil fuel energy exports provide reliable supplies to numerous international markets, primarily in the Indo-Pacific, with China and Japan the largest export markets. Historically, countries in the region have regarded Australia as a reliable, competitive, and trusted trading partner, free from political and strategic government market intervention.

Recent developments have challenged this foundation. Meanwhile, Japan is increasing its efforts to move away from fossil fuels, likely leading to a long-term reduction in demand for Australian coal and LNG. These developments question the long-term viability of Australian fossil fuel exports to its two largest overseas markets (Kemp et al. 2021). Moreover, in May 2021 the International Energy Agency (IEA) issued a report on how the world can achieve net-zero energy emissions by 2050, calculating the global coal market would eventually collapse, shrinking by more than half each decade (IEA, 2021b). A recent report by the RBA states that as the global appetite for coal tapers off from 2030 onwards, Australian coal-related investments are at risk of becoming stranded assets (Kemp et al., 2021). A consensus is that a global transition to net-zero emissions will seriously curtail Australia's fossil fuel exports, regardless of domestic climate policies and political preferences. Against this background, it is critical for Australia to develop other avenues for energy exports (see section 3.3.3 for more detail) to remain a viable and trusted partner in the future.

In addition to other avenues, LNG will remain a crucial bridging fuel to a new energy system. LNG is expected to play an increasing role in meeting global natural gas demand, as it provides a flexible link between geographically-separated suppliers and customers. While primary energy demand declined by 4.5% globally in 2020, the largest drop since 1945, LNG demand increased by 0.6% during the same year (BP, 2021). As the world's largest LNG exporter, Australian exports will remain important for the global energy system transition during the next two decades. Australia must maintain its status as a trusted and reliable LNG exporter during this period. Against this background, it will be crucial for the government and industry stakeholders to remain aware of LNG market trends and where Australian LNG should and can be redirected when faced with market and price imbalances that are likely to occur during the transition period. Open dialogue with existing and potential LNG trading partners, and other major exporters, may go a long way towards maintaining Australia's status as a trusted LNG supplier and for Australian LNG to act as a stabilising force in a potentially turbulent market. Further research into how Australia should and can maintain its status as a trusted, stable, and reliable LNG trading partner is best undertaken at universities in partnership with the federal government and LNG producing and exporting companies.

RQ: How can Australia maintain its status as a trusted liquefied natural gas supplier over the next two decades?

Since the release of Australia's National Hydrogen Strategy (COAG Energy Council, 2019), the Australian Government has been advancing international collaborations with potential export partners, including Japan, through the Australian Clean Hydrogen Trade Program, and Germany, through the Australia-Germany Hydrogen Accord (DiSER 2021b). Bilateral energy partnerships such as these seem to be a preferable approach by the federal government for maintaining Australia's energy export potential in the future and maintaining its status as a trusted and reliable partner. While these partnerships build trust with bilateral partners and support their national energy security, the impact of their preferential nature on Australia's overall image and on relationships with other potential partners is unclear. Within this context, future research needs to evaluate the causes and consequences of Australia's strategic weakness in climate policy, which has led to it being labelled as 'climate pariah' (Blundell-Wignall, 2021). Climate policy weakness is also making it difficult for Australia to be seen as a trusted partner with Pacific Island countries (Hurst, 2021). Research on Australia's future as a trusted energy partner would best be addressed by universities in collaboration with the federal government and major industry participants.

RQ: How can risks associated with the effect of domestic energy and climate policy uncertainty on Australia's status as a trusted energy partner be mitigated?

RQ: What strategies will best enable Australia to manage the need to balance, taper and pivot to a trusted partner in global energy supply chains, mitigating short term risks to fossil-fuel exports to other energy exports?

3.3 Industry

3.3.1 Education and skills

> What are the critical new skills that will be needed for the transition, are there any structural barriers to them being met (time, place, quantity) and, if so, what are the appropriate policy responses?

Critical skills and structural barriers

Human capital development constitutes a vital premise for a successful energy transition. Renewable energy technologies can spur broad and sustainable social and economic development, already accounting for an estimated 11.5 million jobs worldwide in 2019 (IRENA, 2020). International research identifies key structural barriers regarding critical new skills needed in the deployment of renewable energy (Seetharaman et al., 2019). The shortage of trained workforce to design, finance, build, operate and maintain renewable energy projects is considered a major obstacle to the wide penetration of renewable energy (Karakaya & Sriwannawit, 2015). The energy transition also requires more skilled workers in construction, installation, maintenance, and transportation, and to perform site selections and assessments, as well as workers with computer and mathematical skills.

Analysis of global education and training on renewable energies data indicates that:

- the shortage is more acute in developing countries;
- there is a mismatch between education system offer and industry demand;
- there is a mismatch in the suitability of the curricula; and
- students and educators are moving towards online training for collaborating and learning (Lucas et al., 2018).

In addition to skills shortages, international research shows that incompetent technical professionals and lack of training institutes prevent renewable energy technologies from scaling new heights (Ansari et al., 2016). Design and deployment strategies of renewable energy systems also often exceed traditional engineering expertise (Kandpal & Broman, 2014). There is currently a significant digital transformation skills gap in the energy sector (EY, 2020).

To build the skills base for the transition from fossil fuels to renewables, countries and businesses will need more vocational training, more robust curricula, more teacher training and expanded use of information and communications technology for remote learning (IRENA, 2020). While many core skills will likely exist in other industries, with examples provided in the following section, there is a need to understand the current education supply worldwide. There is also a significant opportunity for advancing social inclusion through clean energy jobs.

In the Australian context, renewable energy experienced significant skill shortages and recruitment difficulties in recent years, reducing local employment and increasing costs. The major recruitment difficulties in large-scale renewable energy are for electrical and grid engineers and construction managers (Briggs et al., 2020).

The Clean Energy Council is spearheading a coordinated effort to engage industry, governments, training institutions and other relevant stakeholders in laying the foundations for a strong and secure renewable energy workforce. The largest study of current and projected employment in the renewable energy industry in Australia has found that the sector currently employs over 25,000 people and could employ as many as 44,000 people by 2025 with most of those jobs in regional Australia (Clean Energy Council, 2020).[1] Across the sector, the obstacles identified in attracting and retaining quality workers include policy uncertainty, the project-based nature of construction and installation jobs, remote site locations, and salary competition with other industries. Renewable energy developers face difficulties recruiting workers with relevant experience in certain activities, and existing training systems are not meeting industry needs. This results in the need to invest in training new workers, many of whom might leave the sector in search of more enduring employment prospects (Clean Energy Council, 2020). Further research is needed to understand why existing training systems are not meeting industry needs and how these may be improved. Research is also needed to understand the exact requirements, and develop courses and programs, for upskilling existing workers and training new workers. This research would best be addressed by universities in collaboration with the clean energy industry.

RQ: How can clean energy industry training systems be improved so that existing workers are upskilled quickly, and new workers are best prepared to meet clean energy industry needs effectively?

Policy responses

According to the ILO (2018), the job-creating potential of environmental sustainability is not a given: the right policies are needed to promote renewable energy industries while ensuring decent work within them. Without strong policy guidance and grassroots pressure, shifts from fossil fuels to renewable energy can lead to more precarious jobs and painful transition for communities.
A report by the Institute of Public Affairs (IPA) estimates that the industries directly at risk from a net-zero emissions target, responsible for 78.3% of total emissions, employ 653,600 Australians (Hussey & Wild, 2021).[2]This estimate does not include potential indirect job losses which could occur in related industries and the communities where at-risk jobs are vital. To avoid a damaging skills gap in the workforce, governments and industry must simultaneously attract talented new energy professionals, while ensuring that current workers are valued, and not left behind. As the number of traditional jobs in emissions-intensive industries shrinks, it is important to assist skilled workers in transitioning to new areas of the industry where there is strong demand for talent, relying on the key skills overlap of different energy sectors. For example, evidence from the UK suggests that offshore oil and gas workers can transfer successfully into many other energy sectors, including decommissioning, offshore wind construction and marine renewables (Platform et al., 2020). IRENA (2020) estimates that about 40% of the full lifetime costs of an offshore wind project, including construction and maintenance, have significant synergies with the offshore O&G sector. In Australia, Grattan Institute analysis suggests that green steel, green ammonia, and biofuels for aviation industries could generate 40,000-55,000 jobs in regions that host 55,000 carbon workers who would be ideally positioned to take up jobs in new industries (Wood et al., 2020).

1 The report only includes direct jobs in renewable energy generation and the associated supply chains and does not include induced jobs in other parts of the economy.

2 Using data from the National Greenhouse Gas Inventory by Economic Sector report published by DISER and industry employment data from the Australian Bureau of Statistics, IPA calculated 'at risk' jobs as the total number of jobs in industries where emissions per job are above the economy-wide average of 0.22 kt CO2.

The Clean Energy Council (2020) proposes four key policy responses for meeting the renewable energy skills challenge in Australia:

- A review of the structure and suitability of relevant training systems across the renewable energy industry is needed to better align with industry needs and deliver certainty of career pathways.
- Federal and state government policies need to play essential roles in establishing a robust and secure renewable energy workforce by supporting – or creating an environment that supports – an investment pipeline.
- The renewable energy industry needs to positively contribute to regional development planning, including by working with regional development bodies, regulators, and networks to develop innovative blueprints for training regional workers.
- To overcome the challenges that renewable energy businesses have faced in attracting and retaining talented and skilled employees, the sector must become an employer of choice. This needs to occur through collaboration with training bodies, unions, regional development organisations and policymakers.

Additionally, a large-scale survey of renewable energy employment in Australia (Briggs et al., 2020) found it is very hard for the industry to invest in training and development in the context of policy uncertainty. This is especially so for the large-scale construction phase where rapid mobilisation is needed once the clean energy project secures finance to meet contractual timelines. Coping strategies, such as importing workers, are often used, which do little to build the skill base. Accordingly, an investment pipeline with greater certainty is needed to create an environment more conducive to skill development (Briggs et al., 2020). These two reports provide a solid foundation for more detailed research into how Australia can transition its workforce from emission-intensive to clean energy jobs and capabilities. Further research would best be addressed by universities in close collaboration with clean energy industry.

RQ: How can the government, industry, and other stakeholders, especially the education sector, better prepare and support workforce transition from emissions-intensive to renewable energy jobs?

A successful long-term transformation towards renewable energy requires consensus and cooperation between a range of actors, such as federal and state governments, energy producers, electricity providers, investors, impacted communities, unions, and workers (Climate Council, 2016). A formal consultation process for relevant stakeholders would facilitate this cooperation and allow for a more nuanced policy response based on actual impacts. For Australia, Germany's non-partisan, cross-sectoral approach serves a promising approach to managing the energy transition, including seeking compromise positions between competing interests in reaching the objectives of the *Energiewende* (Climate Council, 2016). In this context, Germany's industrial transition of the Ruhr Valley, going from 390,000 coal jobs in the 1960s to 39,000 in the 2000s, has been praised for a bottom-up approach and the critical role of providing equal voices to all key stakeholders (Rosenberg, 2017). Against this background, Australia needs to consider establishing an open dialogue, or a formal consultation process, on all aspects of the energy industry transformation that would give voice to a wide range of energy industry stakeholders, and specifically the workforce. This research would best be addressed by universities, state governments, and emissions-intensive and clean energy industry.

RQ: How can Australia establish more inclusive formal consultation processes to ensure that the voices of all key stakeholders, and specifically the workforce, are heard during energy industry transformation?

3.3.2 Capabilities

> To what extent should Australia be self-reliant in clean energy industry capability (both manufacturing and services)? What are the costs, benefits and potential policy responses to a range of self-reliant scenarios?

Economic self-sufficiency refers to the ability of individuals and families to maintain sufficient income to meet their basic needs consistently. When extended to clean energy supply chains at a national scale, it refers to the ability of local workers and industry to deliver clean energy manufacturing goods and services without relying on imported goods and labour. The concept of local content is at the centre of any self-sufficiency discussion, including policies imposed by governments to require firms to use domestically manufactured goods or domestically supplied services to operate in an economy (OECD, 2015). To what extent can countries, including Australia, be self-sufficient in clean energy industry capability?

There are arguments for and against local content requirements in clean energy industry. Policymakers often claim that local content requirements can help develop a domestic manufacturing base, create local jobs, promote technology transfer, and create local industrial clusters, but the benefits are heavily debated. Local content requirements directly distort trade and may have unintended effects on investment across value chains. Policies that favour some firms over others involve a cost, and can result in reduced competition and efficiency losses, thereby damaging the investment environment (OECD, 2015). Internationally, most countries using local content requirements in renewable energy base their policy choices on political motivations rather than on economic and empirical analyses, which remain largely absent (Kuntze & Moerenhout, 2013). They are often attached to expensive public financial support programs to gain additional local benefits from increased renewable energy deployment.

Local content requirements are also often poorly designed for national value creation. In many countries, the requirements are very high, which increases their trade-distorting impact and the inefficient allocation of resources. This drives up costs excessively and hampers international competition in the short-term.

It may be theoretically possible to use local content requirements to achieve local economic or employment benefits and renewable energy innovation at the same time, but this has not yet been demonstrated (Kuntze & Moerenhout, 2013). The case of Germany is useful in this context because employment objectives played an important role in renewable energy policy (Strunz, 2014). Job creation was not reflected in policy design and no local content provisions were included. Nevertheless, expectations were high, particularly regarding the creation of technology leadership and respective jobs in the solar PV industry. Deployment of renewables was conceived, at least implicitly, as a green industrial policy. Accordingly, the German experience constitutes a test case for the strong green growth assertion, which upholds that creating competitive advantage in green technologies is one way to create both short- and long-term economic benefits, such as jobs.

Key findings from the international literature remain untested empirically in the Australian context. The COVID-19 crisis has triggered calls in Australia for greater self-reliance. Arguably, investing in renewable energy technology is one of the most obvious ways to becoming less dependent on other states and less vulnerable to external shocks (Gosling, 2020). A major report entitled *Australia's Sovereign Industry Capability* suggests that the COVID-19 pandemic, discussed in more detail in section 3.2.2, exposed long-term deficiencies in Australia's domestic productive capacity; reliance on overseas supply chains that left the nation vulnerable to a range of future political, economic, and environmental contingencies (Global Access Partners et al., 2021b).

It calls for a broad investigation of Australia's manufacturing base to highlight areas of sovereign importance which could be strengthened through a range of government measures, making several references to self-reliance of Australia's clean energy industry capability. Specifically, it calls for the need to develop sovereign capability and self-reliance in renewable energy in response to the vulnerabilities exposed during the pandemic (Global Access Partners et al., 2021b). As outlined above, this assessment should be undertaken against key findings from international studies on self-reliance in the clean energy industry. As outlined in ACOLA Briefing Paper 1, this research should be undertaken once a clear picture is established on Australia's competitive advantages in clean energy industry capability. Research should also examine how self-reliance can be enhanced while not undermining Australia's economy, the international competitiveness of its clean energy technology and services, and its investment attractiveness. This research would best be addressed by universities, federal government, and clean energy industry.

RQ: How can Australia increase self-reliance in clean energy industry capability while remaining attractive to international investment?

RQ: How can Australia benefit from greater self-reliance in clean energy industry capabilities with a clearly identified competitive advantage?

Australia is ranked last among its global peers of developed nations when measuring a nation's manufacturing self-sufficiency (Stanford, 2020), with struggling global supply chains hindering the nation's security and resilience. Disruptions in global supply chains and protectionist trade policies have increased risks that Australia might not be able to access essential products (like health equipment and supplies) when needed. This leads to a need for:

- fiscal and investment strategies to accelerate renewable energy initiatives linked to domestic manufacturing opportunities; these could include fiscal support for the production and use of renewable energy, direct equity investments and co-investments in new manufacturing projects, and favourable tax treatment of sustainable manufacturing investments (such as investment tax credits);
- provision of public goods to assist firms to facilitate training for workers in transitioning industries; and
- leveraging government procurement to favour domestic manufacturers who are actively engaged with the renewable energy transition (Stanford, 2020).

Sector-specific industrial policy strategies are needed in key identified manufacturing sectors that can benefit from inputs of renewable energy, and/or that can provide Australian-made manufactured inputs to renewable energy developments (Stanford, 2020). This proposal remains untested against findings of key international research. Further research is needed into whether there is any scientific basis, and long-term economic value, for policy strategies that support greater domestic renewable energy industry capability. This evaluation is particularly important in the context of Australia's relatively small size, high cost of labour, and general lag in manufacturing compared to other OECD member states. This research would best be addressed by universities in partnership with clean energy industry.

RQ: What is value of and challenges involved in improving the domestic renewable energy industry capability?

3.3.3 Export

> What opportunities are there for Australia to export clean energy industry capabilities and skills?

A global shift towards renewable power and clean energy goods and services is underway. Domestically, it is well known that Australia is the home of some of the world's best clean energy resources (Bell 2020). However, opportunities also exist to export the capabilities and skills of Australia's clean energy industry. In particular, research recognises that through providing clean energy products and services in offshore markets and working on international clean energy developments, Australian companies are already successfully exporting their clean energy capabilities and skills.

In a bid to support and bolster Australia's export potential, Austrade published three key reports that highlights Australian industry capability in clean energy (Table 1). The reports acknowledge that Australian companies are leaders in delivering solutions and services for the power industry, with strong market design and project management capability, advanced engineering, maintenance and rehabilitation expertise and innovative renewable energy technologies (Austrade 2018). They also exemplify how many of Australia's companies that have built expertise in Australia's regional and remote areas are now applying their expertise to developing countries where renewable energy systems are being deployed to ameliorate poverty conditions (Austrade 2016). In addition to these reports, Austrade's 250-page *Clean Energy and Environment Export Directory* showcases and catalogues numerous export-capable Australian companies operating in nearly all the clean energy and environment sectors. The directory highlights the capabilities of innovative Australian companies active in offshore markets and demonstrates how these companies are already using their skills and capabilities to support domestic and international clean energy sectors, including the renewable energy, energy efficiency and CCS sectors (Austrade 2016; 2018).

Notably, Australia's superb wind and solar resource, coupled with its strong renewable energy capabilities across the full spectrum of professional services (Austrade 2018), positions the nation well to emerge from COVID-19 as a renewable-export superpower (Bell, 2020). In particular, innovative rooftop PV technologies has been recognised as an area of competitive advantage with technology export opportunities (Briggs et al., 2020). Australian companies are already leveraging opportunities to support international renewable energy projects (Austrade 2016; 2018). However, it is critical to continue to monitor the capability of Australia's clean energy industry as new technologies and sectors emerge to identify critical export opportunities, and to assess the actual and emerging demand for these exports.

RQ: What are the emerging opportunities to strengthen and export Australia's clean energy industry capabilities and what is the corresponding demand for these exports in overseas markets?

Industrial-scale hydrogen production could provide a new export potential for Australia (Hartley & Au, 2020), and help meet potential global demand (ACIL Allen Consulting, 2018). Australia's National Hydrogen strategy outlines actions that can be used to develop the Australian hydrogen industry, including to ensure that Australian companies have the capability to supply the technology, products and services required in the export markets (COAG council 2019).

Table 1: Key reports showcasing Australian industry capability in clean energy

Author	Title	Year	Topic
Austrade	*Renewable Energy*	2016	Australian capability in innovative and competitive renewable energy technologies
	Microgrids, Smart Grids and Energy Storage	2017	Australian capability in microgrids, smart grids and energy storage solutions
	Australian Capability in Power	2018	Australian capability across key sub-sectors of the power industry, including renewables. It includes case studies of Australian companies with specialist expertise
WWF-Australia	*Australian Renewable Export COVID-19 Recovery Package*	2020	practical ways in which Australia could push-start its COVID-19 recovery by utilising new clean energy technologies and renewables to grow export opportunities

Research has also been undertaken on clean hydrogen production (Beck et al., 2019), including transitioning to green hydrogen (Gurieff et al., 2021), as well as the prospects for exporting hydrogen to South Korea and Japan (Boretti, 2020), particularly coal-generated hydrogen to Japan (Hancock & Ralph, 2021). There is now growing international recognition of Australia's industrial potential to become a future major hydrogen supplier. Notably, the World Energy Council's International Aspects of a Power-to-X Roadmap identifies Australia as a giant with potential to become a world key player (Frontier Economics, 2018). The International Energy Agency's *World Energy Outlook* projects Australia producing hydrogen equivalent to 100 million tonnes of oil, an amount equating to 3% of global gas consumption today (IEA, 2020). According to the Chief Scientist, Alan Finkel, the growing demand could foster an export industry worth $1.7 billion by 2030, providing 2,800 jobs, many of them in regional areas (Australian Industry Energy Transitions Initiative, 2020).

In addition to hydrogen and renewable energy, Australia is well-positioned to benefit from other clean energy industry capabilities and skills. For example, global demand for batteries is rising rapidly due to technological transformations in the energy, industrial and transport sectors. Existing battery value chains face significant governance challenges that threaten both their security and sustainability. The battery industry offers significant economic opportunities for Australia (Wilson & Martinus, 2020). Australian governments and businesses have identified building the battery sector as a major national economic imperative. Yet, there are no policies explicitly designed to facilitate the growth of the battery industry (Best & Vernon, 2020). Australia's strong international relationships make it an ideal partner for international efforts to develop more resilient battery value chains (Wilson & Martinus, 2020). In addition to batteries, the growing global demand for electric vehicles also provides opportunities for Australia to increase its export of lithium, nickel, cobalt, and other rare earth minerals. Australia also has the world's largest uranium deposits; nuclear energy generation is projected to increase in some markets in the coming decades (Kemp et al., 2021).

Finally, a report by Grattan Institute assesses the potential of three sectors to help make Australia a green energy superpower: aviation fuel, ammonia, and steel. It concludes that green steel represents the best opportunity for exports and job creation in key regions (Wood et al., 2020). Green steel uses hydrogen, produced from renewable energy, to replace metallurgical coal to reduce iron ore to iron metal. Capturing about 6.5% of the global steel market through the manufacture of green steel could generate about $65 billion in annual export revenue and could create 25,000 manufacturing jobs in Queensland and NSW (WWF-Australia, 2020).

Evidence presented above demonstrates that Australia has numerous opportunities to export clean energy industry capabilities and skills associated with the development of hydrogen, renewable energy, batteries, and other export-oriented clean energy projects discussed above. Against this background, future research must address how key Australian stakeholders can maximise the potential of a growing suite of clean energy skills and capabilities to enhance Australia's international competitiveness. The next step for key stakeholders involved in these industries is to develop a joint strategy on maximising Australia's export potential. For example, how can hydrogen, solar, wind and battery industry stakeholders, universities, Austrade, and various key federal and state government departments, cooperate to bolster Australia's export potential and overseas market access? Are there key clean energy skills and capabilities that cross over various export-oriented clean energy industry sectors that can be developed and fostered? This research would best be addressed by universities in partnership with the clean energy industry, Austrade, and other key federal and state government departments.

RQ: What support mechanisms (policies, strategies, etc.) can be put in place to promote the international growth of Australia's clean energy industries?

RQ: What are the export-oriented clean energy skills and capabilities that Australia can strategically invest in that cross over various industries (e.g., hydrogen, renewables, batteries), and how can these be developed?

4. Key research questions, gaps, priorities, and opportunities for Australia

Section 3 has identified numerous research questions, gaps, and priorities in current research. Australian-specific research across governance, risks, and industry will need to be pursued and will require both multidisciplinary and interdisciplinary considerations.

What follows below is a categorisation of these research questions formulated from the research into a mix of research questions:

- Urgent questions – where robust answers are needed to the question posed to address issues in the near future; and
- Strategic questions – which requires research to find robust answers to the question posed to address issues in the longer term.

4.1 Governance

URGENT: Institutional models	URGENT: Research community	Strategic: Roles and practices
Report 1 framing questions		
What institutional governance models are best suited for the Australian energy transition, and are there learnings from international experience?	How can the Australian energy research community (funders, researchers, and research users) be structured to optimise their contribution to the transition, including the effective translation of research into impact?	How should the roles, structures and practices of governments, regulators, researchers, industry, NGOs, and communities adapt to most effectively facilitate the transition?
Further research questions from this report		
Which governance systems and corporate business models are best suited for Australia's transition, and what reforms are needed to support any shifts in governance and business structures?	What aspects of successful international energy transition models could be implemented in Australia to optimise the energy research community's contribution to energy transition?	What would be the key features, benefits and challenges of a decentralised energy governance system in Australia vis-à-vis a centralised system and what would be required to shift to such a system?
How can and should cities/towns of different sizes, from urban to regional, be supported and empowered as drivers of Australia's energy transition?	Drawing from international models, how could Australia's funding ecosystem be amended/restructured to better coordinate the application of Australia's energy research policy and the associated benefits?	What types of roles and partnerships should be encouraged to accelerate the energy transition, and how should stakeholders be incentivised or encouraged to take these up?
		How can the roles and responsibilities in relation to achieving net-zero emissions be justly distributed among companies of different sizes and types?

4.2 Risks

URGENT: Risks	STRATEGIC: Resilience	STRATEGIC: Global trust
Report 1 framing questions		
What are the technical, economic, environmental and social risk scenarios (including social justice) that could impede the successful transition to net-zero emission systems, and how can these best be mitigated?	How do we build and maintain energy system resilience against natural disasters, climate change, cyberthreats and power system changes?	How do we ensure that Australia remains a 'trusted partner' in global energy supply chains?
Further questions from this report		
How can Australia more effectively integrate energy and climate policies to mitigate risks to the energy transition and move beyond path dependencies?	How can the Australian energy system, including the role of key stakeholders, be reconfigured to enhance its resilience against chronic stresses and extreme events? How can smart energy systems, micro-grid systems, and community-based grassroots initiatives enhance energy system resilience and how can their implementation be supported?	How can Australia maintain its status as a trusted liquefied natural gas supplier over the next two decades?
How can Australia navigate the energy transition while maintaining uninterrupted energy availability at affordable prices?	How can digital technologies, such as blockchain, artificial intelligence and the Internet of Things, be leveraged to support decarbonisation and enhance the resilience of Australia's energy system?	How can risks associated with the effect of domestic energy and climate policy uncertainty on Australia's status as a trusted energy partner be mitigated?
How can Australia's energy transition be used to reduce socio-economic inequalities and create opportunities for Indigenous and non-Indigenous Australians?	How has the COVID-19 pandemic impacted Australia's energy transition and energy system resilience, and what can be learnt from international and this domestic experience to further accelerate our energy transition and improve resilience?	What strategies will best enable Australia to manage the need to balance, taper and pivot to a trusted partner in global energy supply chains, mitigating short term risks to fossil-fuel exports to other energy exports?

4.3 Industry

URGENT: Education and skills	STRATEGIC: Capabilities	STRATEGIC: Export
Report 1 framing questions		
What are the critical new skills that will be needed for the transition, are there any structural barriers to them being met (time, place, quantity) and, if so, what are the appropriate policy responses?	To what extent should Australia be self-reliant in clean energy industry capability (both manufacturing and services)? What are the costs, benefits and potential policy responses to a range of self-reliant scenarios?	What opportunities are there for Australia to export clean energy industry capabilities and skills?
Further questions from this report		
How can clean energy industry training systems be improved so that existing workers are upskilled quickly, and new workers are best prepared to meet clean energy industry needs effectively?	How can Australia increase self-reliance in clean energy industry capability while remaining attractive to international investment?	What are the emerging opportunities to strengthen and export Australia's clean energy industry capabilities and what is the corresponding demand for these exports in overseas markets?
How can the government, industry, and other stakeholders, especially the education sector, better prepare and support workforce transition from emissions-intensive to renewable energy jobs?	How can Australia benefit from greater self-reliance in clean energy industry capabilities with a clearly identified competitive advantage?	What support mechanisms (policies, strategies, etc.) can be put in place to promote the international growth of Australia's clean energy industries?
How can Australia establish more inclusive formal consultation processes to ensure that the voices of all key stakeholders, and specifically the workforce, are heard during energy industry transformation?	What is value of and challenges involved in improving the domestic renewable energy industry capability?	What are the export-oriented clean energy skills and capabilities that Australia can strategically invest in that cross over various industries (e.g., hydrogen, renewables, batteries), and how can these be developed?

5. Action

The research questions identified in section 4 above represent the most pressing questions in the transition dynamics of the energy transition. The research areas identified, and the research questions posed, reflect big-picture concerns regarding the institutional governance system of Australia's energy transition. Such governance will determine whether the transition ahead is optimised for national benefit, or slow and fragmented as seems likely from current conditions. International case comparisons offer rich insight, and Australia should collaborate with other nations in order to further understand the effects of institutional governance on transition outcomes and on other questions regarding self-sufficiency and industry capabilities. It is also imperative that further research is conducted into the resilience of the Australian energy system in the wake of future chronic stresses and extreme events.

By undertaking research in the areas identified through the literature assessment, the energy transition is likely to progress with greater individual and community support, supported by effective policies and regulatory architecture, within a supportive and engaged socio-political climate.

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