ENERGY TRANSITION HUB
an Australian-German innovation partnership

Enabling Digital Energy Entrepreneurship

A comparative analysis of German and Australian digital energy entrepreneurial opportunities

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Executive summary

Enabling clean energy entrepreneurship is an important component of building climate change responses and strong economies, and entrepreneurs are playing increasingly important roles in providing new technologies and new business models to help achieve emissions reductions. Digital energy as an industry category is emerging in response to the proliferation of Internet of Things (IoT) technologies, the opportunity to disrupt existing systems with access to new data streams, and the application of blockchain and artificial intelligence (AI) to the energy industry. Entrepreneurs are taking these opportunities seriously and pose both a threat to existing business models, and an opportunity for economic growth, to incumbents. This report focuses on 1) the context for clean energy entrepreneurship; 2) technology focus in digital energy; 3) investment patterns; and 4) ecosystem development.

Context: emerging energy entrepreneurship opportunities

Entrepreneurs often bear great risk in bringing innovation to market through startups (Shane and Venkatamaran 2000). Entrepreneurs accept this risk because of the potentially high rewards for building a successful business. The entrepreneurial journey is an especially risky and challenging in clean energy because of the magnitude of complexity in decarbonising the economy with the aim to achieve peak emissions in 2020 and reach net-zero by 2050. This journey requires new business models and technologies, significant risk-tolerant capital deployed *both* widely and deeply, socio-cultural conditions to enable and incentivise individual behavioural change, and a broad-based ecosystem to support systemic change. Germany and Australia have shown strong growth in clean energy entrepreneurship, with significant opportunities for clean energy cross-cutting entrepreneurial activities. The profit incentive, and material liquidity events that have been seen in the non-energy digital technology landscape, mean that digital innovation for clean energy entrepreneurs holds strong incentives for high risk time and sweat equity investment (CSIRO 2018).

Although in very different regulatory, climate, and energy management systems, both Australia and Germany show strong opportunities for clean energy entrepreneurial development. Despite the lack of national policy certainty, Australia's renewable energy resources have opened up significant opportunities for distributed energy resources (DERs) and opportunities to use renewable energy in heavy industrial processes (Beyond Zero

Emissions 2018). Australia's deregulated electricity retail markets, the highest per capita penetration of rooftop solar in the world, and grid stress due to extreme temperatures and high electricity demand are opening up significant entrepreneurial opportunities in solar optimisation, grid balancing, and customer engagement (International Energy Agency 2016; CSIRO 2018; ClimateWorks 2018).

In Germany, a progressive regulatory environment, strong renewable feed-in-tariffs, vibrant community energy cooperatives, and successful rollout of renewable energy are contributing to the country's *Energiewende* (energy transition). Several changes in the political and social power constellations, as well as endogenous policy measures and exogenous events, have shaped the processes (Kuttinen and Velte 2018). The German *Renewable Energy Sources Act* enabled the steady growth in the share of renewables in electricity consumption over the last few years – from around 6% in 2000 to around 36% in 2017. By 2025, 40-45% of electricity consumed in Germany is to come from renewables (BMWi 2019c).

Technology: rapidly emerging digital energy technologies and new business models

Digital energy – the ability to use Internet of Things technologies, new energy data streams, and apply optimisation software to energy generation, storage, distribution, and use – is experiencing significant growth in early stage enterprises (Bumpus and Comello 2017). Digital approaches to energy hold particular promise for emissions reductions because of the ability to scale solutions, find new efficiencies, and deliver improved customer value through renewable energy integration. In particular, leaders in both energy incumbents and disruptive startups have noted blockchain and artificial intelligence represent high impact issues for transforming the energy industry (WEC 2018). A growing number of startups in both Germany and Australia are aiming to take advantage of these technologies and apply them to disruption in the market.

Although these technologies are being tested, production level application (i.e. commercially viable and rolling out at full scale) of both AI and blockchain currently still remain at the Proof of Concept (PoC) or pilot phase. This is evolving as the costs of fundamental hardware (e.g. production and storage of clean energy) reduce faster than anticipated, and incumbents continue their involvement with accelerators to explore digital energy solutions that show optimisation and new business model approaches are profitable.

A key challenge, however, is that the digital backbone for digital energy innovation lags in the deployment of digital infrastructure. In particular, smart meters with access to data that enable new business models to be developed. The digital infrastructure lag poses a barrier to realising the full opportunities in digital energy entrepreneurship and, even where smart meters have nearly 100% penetration (such as in Victoria, Australia), use of that data is hindered by existing political economic power dynamics.

Investment trends: Australia can learn from region-based entrepreneurial support emerging in Germany

Investment that covers the entire life cycle of entrepreneurial actors – from research and development (R&D) to seed funding through to exit – is especially critical in complex sectors like energy (Monk et al. 2015). Although dedicated innovation funds exist in Australia, including government and private venture capital co-investments (e.g. ARENA and CEFC), the German government seems to be investing more heavily in region-based entrepreneurial support (e.g. the SINTEG programme) and, importantly, bringing smart cities, digital infrastructure, and 'whole of economy' innovation and entrepreneurial opportunity together. Examples include the 'Power-to-X' approach, which could have strong positive ramifications for Australian industry (Beyond Zero Emissions 2018).

Government funding for clean energy entrepreneurs in Australia remains available, but is relatively uncertain moving into the future. In addition to investing in larger infrastructure projects, government capital through the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC) have provided venture capital finance for innovative clean energy companies that has seen continued significant growth between 2016 and 2018. Private sector capital is flowing, principally in combination with public sector support and through accelerators like Energy Lab and Startupbootcamp Energy Australia. Corporate Venture Capital, however, is still relatively low in Australia for energy entrepreneurs.

In Germany, government investment has a strong focus on showcasing regional innovation and development in digital energy. Under the SINTEG funding programme, more than €500 million will be invested in the digitisation of the energy sector. According to KPMG (2018), Germany's policies are the most favourable among advanced economies for investment in renewables due to its stable regulatory landscape and continuous development plans for renewables. Private capital is making a move to support new digital energy entrepreneurs, specifically through CVC. Utilities in the US and Europe have invested about

$3 billion into renewable energy-related businesses, including some digital business models (Greentech Media 2017).

Ecosystem support: private sector supports entrepreneurial ecosystems both within and between Germany and Australia

As a result of the challenges in clean energy entrepreneurship, ecosystems that support this discovery and commercialisation are critical foundations of entrepreneurial success (Isenberg 2010). For energy innovations to reach their full potential, new energy innovation systems coupled with intense innovation efforts are needed at all stages of the energy system value chain (Cornell University et al. 2018).

As such, ecosystem support structures such as accelerators, incubators, hackathons, and bootcamps are emerging and helping generate new digital energy businesses. Networked incubators in particular play an important role in enabling connectivity between startups and incumbent companies, regions (Chesbrough 2003), and act as conduits of knowledge, capital, and human resources flows.

A relatively new structure are international accelerators jointly formed by utilities that are enabling more specific and active international entrepreneurial activities with and between utilities. For example, Innogy from Germany and Origin Energy from Australia have opened a joint office in Silicon Valley to scout for mutually beneficial investments in clean energy (AFR 2017; Innogy 2017). Although Australia seems to lag in Corporate Venture Capital (CVC) deployment to startups compared to Germany, vehicles like the Free Electrons accelerator are enabling CVC and piloting opportunities for entrepreneurs across both countries.

At a national level, policy in Germany has principally focused on supporting clean energy generation and supporting regions that can build locally focused entrepreneurial ecosystems, such as the SINTEG programme. In Australia, the focus has been on supporting entrepreneurs through an emerging network of incubators (supported by both corporate and state government), and public-private finance from the federal level in specific investment vehicles such as the Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency (ARENA).

Policy scenarios are outlined that highlight the opportunity for Australia to take a stronger lead in clean energy entrepreneurship given the deregulated nature of the electricity markets, strong entrepreneurial spirit, and abundant clean energy resources.

1. Introduction: clean energy entrepreneurship

In a complex and rapidly changing world, innovation and entrepreneurship drive economic development. Opportunities rely on multiple interrelated socioeconomic factors that influence how technology ecosystems emerge and sustain entrepreneurial opportunities. For imperative opportunities like the clean energy response to climate change, entrepreneurs and system innovators face significant scientific, policy, and social complexity. As such, although entrepreneurs are playing an increasingly important role in providing new technologies and new business models to help a new energy ecosystem evolve, there remain significant challenges to enabling a fully-fledged entrepreneurial energy ecosystem. At the same time, countries and regions see economic opportunities for differentiating and advancing their environmental entrepreneurial capabilities and are approaching this in different ways to strengthen their economies as we aim for a net-zero carbon world by 2050.

To support the understanding of entrepreneurial energy ecosystems in Australia and Germany, this report highlights the technology, investment, and ecosystem opportunities and challenges that are emerging to drive economic growth through clean energy entrepreneurship and innovation.

1.1. Focus of the briefing

The focus of this briefing is on the role of digital energy entrepreneurship, and how these new companies are being supported in the Australian and German ecosystems. These startup companies pose threats and opportunities to the incumbent energy system.

This briefing has three main points of focus that are essential components to entrepreneurialism: technology forms, the role of capital, and entrepreneurial ecosystems.

Firstly, **entrepreneurs associated with digital energy technologies and business models** are on the rise. Most hardware solutions obviously also include some digital assets (i.e. software), however digital energy is more focused on software being the principal driver of value in the enterprise. In particular, and given the concern and opportunity identified in global surveys of clean energy innovation, the focus here is on the role of companies using distributed ledger (i.e. blockchain and post-blockchain) technologies and artificial intelligence.

Secondly, the **role of capital** in enabling clean energy entrepreneurship is important in understanding how new ideas are developed, commercialised, and sustained in the market. Early stage capital, that is normally relatively risk tolerant, has been traditionally difficult for sectors like ‘cleantech’ which has seen large boom and bust periods in the mid-late 2000s. Some experts have suggested that venture capital is simply not right for cleantech (Gaddy et al. 2016), while others have suggested that venture capital plays an important role in placing many early stage bets (Islam et al. 2018). Government funding for early stage cleantech is also an important component for supporting entrepreneurs, with startups securing government grants using them as an important avenue to early-stage private capital (Islam et al. 2018.). Others note that given the difficulty in navigating the deep ‘valleys of death’ for clean energy entrepreneurs, multiple-stage capital sources need to be intermediated and aligned (Bumpus and Comello 2016; Monk et al. 2015).

Thirdly, technology development, capital provision, infrastructure and market access, and cultural conditions are enabled and brought together in **entrepreneurial ecosystems.** Social and cultural conditions enable entrepreneurialism when they support partnerships and coopetition (cooperation within and between competitive entities), levelling of the playing field or tilting it to the entrepreneurs, and broader understanding and acknowledgement in the public and senior decision makers (public and private sector) of the importance of both the topic (clean energy) and the mechanism (entrepreneurship).

The ecosystem, therefore, provides the petri dish in which entrepreneurial activities occur. They enable interactions between entrepreneurs, capital providers, government support, customers, incumbents, and importantly, markets. Innovation ecosystems have been shown to be important determinants in regional entrepreneurial success. Networked incubators and accelerators are increasingly important components of clean energy ecosystems as conduits of flows for capital, knowledge, and social networks. Understanding the focus, maturity, and effectiveness of entrepreneurial ecosystems enables a better understanding of how innovations are brought to bear in the market. Much of these opportunities can be seen through open innovation platforms that enable interactions between entrepreneurs and the market: i.e. through hackathons, incumbent-entrant innovation forums, inward and outward entrepreneurial investment platforms, and support mechanisms (Chesbrough 2003).

The focus is on these three main commercial issues in this briefing and primarily on national policy, with reference to state policy where relevant.

1.2. The Australian and German contexts

Climate responses, innovation, and economic development are tightly intertwined. The OECD (2018) notes that countries that harness innovation and entrepreneurship as engines for new sources of growth will be more likely to pull out of, and stay out of, recession, and reach their climate goals. Australia and Germany pose distinctly different but complementary economies for clean energy entrepreneurs. Australia has abundant renewable energy resources associated with electrification of residential, commercial, and even heavy industrial opportunities (Beyond Zero Emissions 2018); deregulated electricity retail markets; and the highest penetration of rooftop solar in the world. Germany has a progressive regulatory environment, strong renewable feed-in-tariffs, vibrant community energy cooperatives, and successful rollout of renewable energy. Both countries have strong incumbent electricity companies that are taking smaller or larger steps toward decarbonisation, and both countries have thriving startup scenes.

The top five high-income economies in the quality of innovation in 2018 are Japan, Switzerland, the US, Germany, and the United Kingdom (UK) (Cornell University et al. 2018). Both Australia and Germany score higher than the global average in the Global Innovation Index (GII) according to GDP and innovation outputs across the economy, however, Germany overperforms on innovation outputs as related to its inputs, and Australia underperforms on the same metrics. For cleantech innovation, when comparing Australia and Germany for example, we see that both are advanced innovation economies, but Australia lags in terms of outputs and impact (see Figure 1).

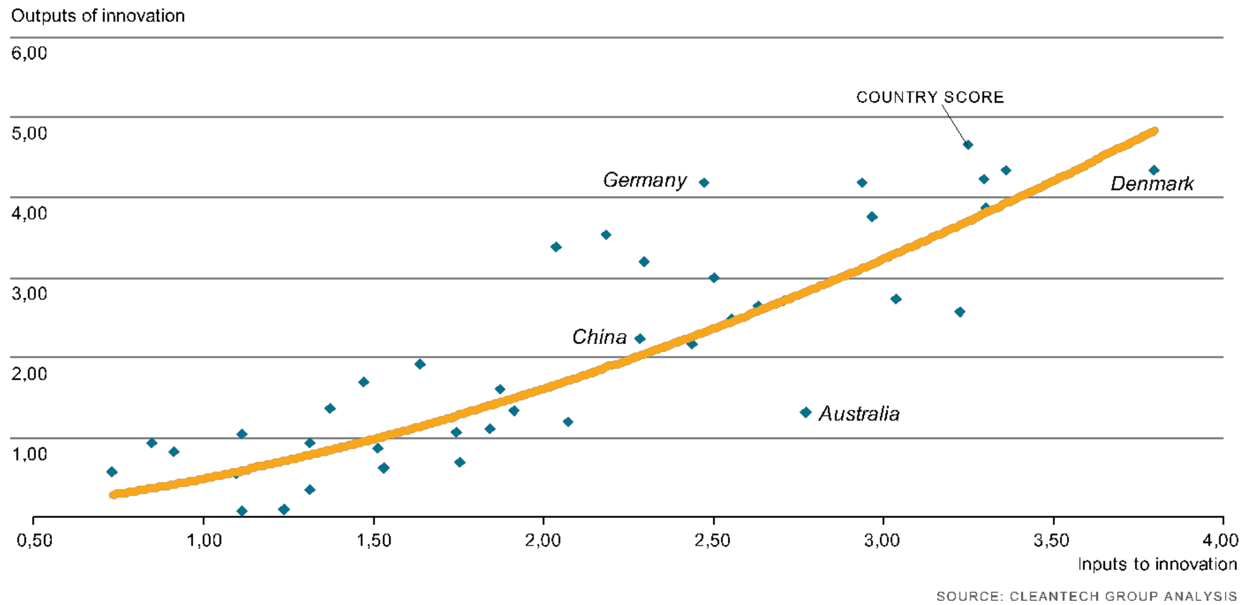

Figure 1: Cleantech innovation efficiency according to inputs to and outputs of innovation (WWF 2017).

Context - Australia

Internationally, Australia is a signatory to the Paris Climate Agreement, and a member of Mission Innovation, which seeks to drive decarbonisation through an innovation agenda. Nationally, federal agencies such as Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC) are financing clean energy innovation and entrepreneurial activities at different levels and are complemented by state-level support for clean energy innovation. In addition, digital innovation is seen as a key driver for Australia's economic growth, adding a potential $315bn to the economy: "the world is entering a new phase of economic development as *every sector of the economy* is re-defined as a result of digital science and technology and the extensive use of data." (CSIRO 2018, emphasis added).

Climate and energy policies in Australia have a tempestuous history. Policy has, at times, helped spur distributed household and utility-scale renewable energy development by setting targets, identifying organisations to act, and creating support mechanisms for deployment. In 2017-18 the government's proposed National Energy Guarantee (NEG) set a target of 36% renewable energy generation in the grid. However, following the collapse of the proposed NEG policy, there is no post-2020 renewable energy target. Instead, Australian states have announced targets for renewables; Victoria, for example has a renewable energy generation target of 25% by 2020 and 40% by 2025, while Queensland's target is 50% renewable energy by 2030.

A number of studies have highlighted the different pathways to decarbonisation in Australia; many of which relate to entrepreneurial opportunities to enable new products and business models to enter the market. Climateworks (2018) note that Australia is not yet on track to meet its Paris commitments and net-zero emissions by 2050 (Figure 2). Australia needs to double its emissions reduction progress to achieve the federal government's target of 26-28 per cent below 2005 levels by 2030 and triple progress to reach net-zero emissions by 2050. The report shows that progress has stalled in most sectors and reversed overall.

Industry, buildings, and transport sectors are increasing in emissions, but significant entrepreneurial opportunities exist. For example, the electricity sector is reducing emissions and emissions intensity with electricity emissions projected to fall to 21% below 2005 levels under existing and proposed policies with renewable energy reaching 31% share. Further potential is available for electricity sector emissions to fall to 68% below 2005 and for renewable electricity to reach a 70% share. Increased clean energy generation and efficiency would also positively impact the industrial and buildings sector, which need to be supported by improved sector-specific regulation and technologies for industry, and proposed improvements to building and appliance standards for buildings. Transport emissions have risen to 19% above 2005 levels due to activity outpacing emissions reductions but could be reduced with improvements in low-emissions fuel standards and a more rapid switch to electric vehicles.

Despite the lack of national policy certainty, Australia's renewable energy resources have opened up significant opportunities for distributed energy resources (DERs) and opportunities to use renewable energy in heavy industrial processes including becoming the first country to produce emissions-free steel without coal, exporting renewable ammonia – a zero-carbon fuel, and zero-carbon production of energy intensive materials such as carbon fibre (Beyond Zero Emissions 2018). Given the opportunity for DERs in Australia, optimisation of the current grid is also emerging as a critical entrepreneurial opportunity.

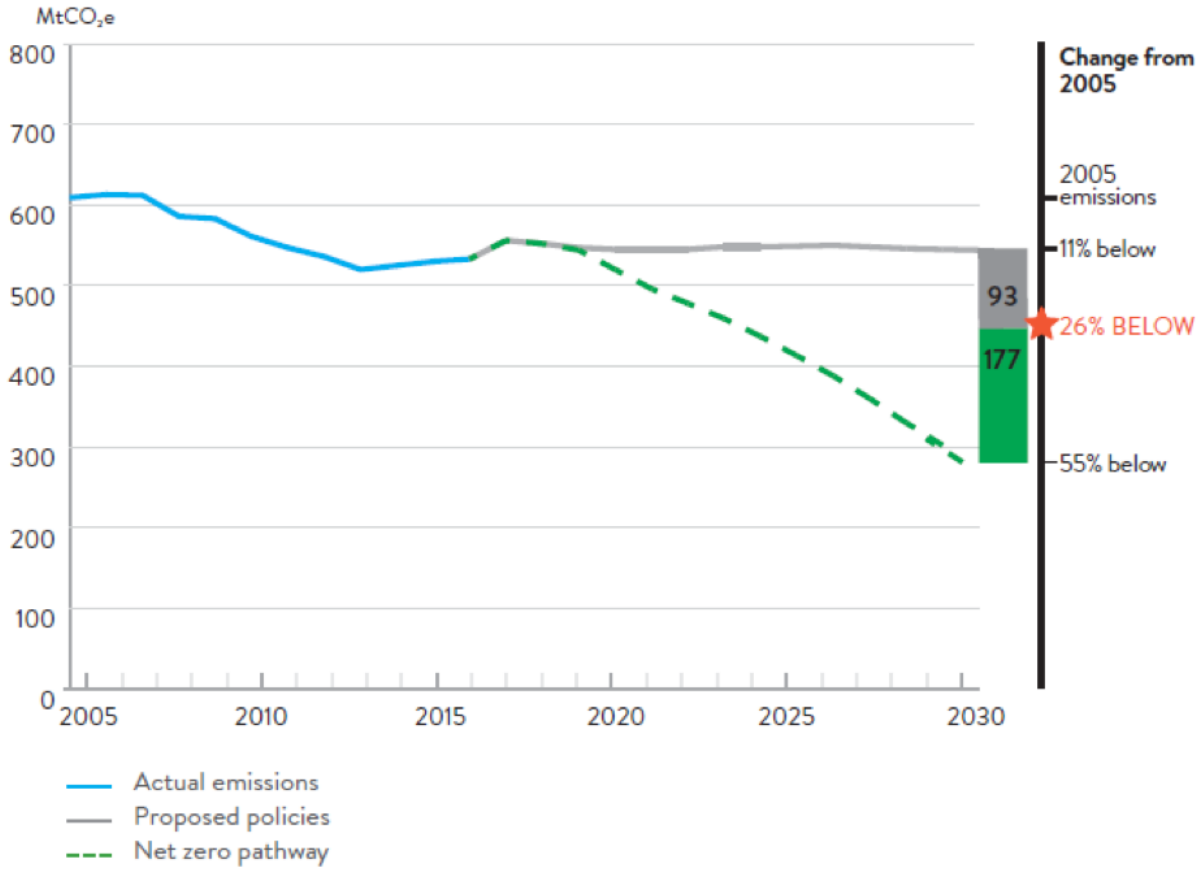

Figure 2: Total emissions since 2005, projected emissions to 2030 under proposed policies scenario and the net-zero pathway and gap to target (ClimateWorks 2018).

As a result, the Australian clean energy entrepreneurial ecosystem has been developing over a number of years as private sector actors responded to state and federal government tariffs and support for wind and solar farm development, rooftop solar delivery, and commercialisation of deep technology from universities. A wider, more actively incubated startup ecosystem for energy entrepreneurs has subsequently gained traction since 2015/16. In comparison to a few, rather siloed, deep technology points of focus (e.g. wind, rooftop solar, research and development (R&D) for energy materials commercialisation), the broader ecosystem has so far taken on the form of a shallow, but wide lake: many different ideas but without investable substance (Bumpus and Comello 2016).

The University of Melbourne and Stanford University report, Acceleratenergy (Bumpus and Comello 2016), found that incubators and accelerators are playing a vital linking role in the huge opportunity space for clean energy entrepreneurship in Australia; that building effective technology and commercial teams with guidance from elders is critical; and that investor resources and funding models need to be better developed. Finally, the report concluded that communicating and celebrating the success stories of clean energy entrepreneurs is lacking but is needed to build and engage a vibrant clean energy startup community.

A critical part is finance for new technologies and companies; ARENA and the CEFC continue to make investments in clean energy innovation. However, Acceleratenergy highlighted that the clean energy entrepreneurial ecosystem in Australia faces two compounding fundamental challenges: 1. the digital energy entrepreneurial industry is new, with high uncertainty as to how it will evolve; and 2. new enterprises attempting to access, and thrive in, this emerging industry face technological, business model, economic, and policy barriers that continually threaten to leave them in the 'valley of death'.

	1 Pathway 1: Energy productivity plus	2 Pathway 2: Variable renewable energy	3 Pathway 3: Dispatchable power	4 Pathway 4: Unconstrained
Buildings, industry and transport	Ambitious energy productivity improvements	Business as usual energy productivity improvements	Business as usual energy productivity improvements; Hydrogen for transport and export	Ambitious energy productivity improvements; Hydrogen for transport and export
New build electricity generation	**Existing low emissions technologies:** wind, solar PV (45% limit) plus gas	**Cheap, mature, low emissions generation:** mainly wind and solar PV **plus enabling technologies** e.g. batteries pumped hydro	Wind and solar (45% limit) plus **low emissions, dispatchable generation:** • Concentrating solar thermal with storage • High efficiency, low emissions fossil fuels with carbon capture and storage • Nuclear • Geothermal	**All low emissions technologies allowed, with no limit on wind and solar PV**
Fugitive emissions	Uptake of cost-effective technologies			

Figure 3: CSIRO pathways for decarbonisation in the Australian economy (CSIRO 2018).

The good news is that several studies notes that the power sector will be at the heart of Australia's energy system transformation (IEA 2016; CSIRO 2018; ClimateWorks 2018). CSIRO's (2018) report highlighted four low-emissions pathways that enable new technology development (see Figure 3). And that this can support broader economic emissions reductions through abundant clean electricity as improved industrial, commercial, residential, and transport technologies take advantage of the cleaner grid.

For entrepreneurs, the Australian context provides ample opportunity for innovation. High-emissions sectors, the opportunity from increasing levels of renewable grid electricity, the relatively deregulated nature of energy retailing, all pose opportunities to develop new technologies and business models to seek profit in decarbonisation.

Context - Germany

Germany's *Energiewende* (energy transition) is well underway. The *Energiewende* dates back over three decades and has evolved from grassroots environmental activism to a politically-steered process. Several changes in the political and social power constellations, as well as endogenous policy measures and exogenous events, have shaped the processes (Kuttinen and Velte 2018).

Germany's digital revolution is also taking place, guided in large part by government direction. The digital strategy of Germany's Ministry for Economic Affairs and Energy, BMWi, explicitly includes systematic use of the digitalisation potential in the fields of energy, transport, health, education, and public administration. This is encapsulated in the Smart Networking Strategy that was adopted by the cabinet in September 2016:

"Products and services increasingly contain digital value added and are getting "smart" by incorporation into intelligent and networked systems. New business models are arising in the digital environment. Completely new ecosystems with value added chains are being created in which data are an important resource. The use of digital (data) technologies gives rise to new areas of knowledge and industry: we are now seeing data-supported health services (e-health), using data-driven financial services (Fin-Techs) and have the first applications of intelligently networked energy production and supply (smart home)." - BMWi 2017, p. 15.

Germany is well equipped to make this transformation given the country's starting position as an established innovation and production location. Germany has already made its mark on the development. "Industry 4.0" has long become an internationally accepted term to describe the current challenge: the networking of people, machines, plant and processes to form an intelligent whole. BMWi estimates that digitalising industry will open up potential additional cumulative added value of €425 billion by 2025 in Germany alone. Projections put productivity gains at up to 30%, annual efficiency gains at 3.3% and cost reductions at 2.6% annually (BMWi 2017).

Germany's digitalisation opportunities build on its deep technological and engineering history, and its strong guidance, policy support, and economic incentives from government for the installation of renewable energy across the country. Indeed, Germany has been considered "the world's first major renewable energy economy" (Renewable Energy World 2009). Until 2014 it had the highest capacity of solar installation of any country in the world, until overtaken by China and the US. The *Renewable Energy Sources Act* enabled the steady growth in the share of renewables in electricity consumption over the last few years – from around 6% in 2000 to around 36% in 2017. By 2025, 40-45% of electricity consumed in Germany is to come from renewables (BMWi 2019c). Wind and solar are the biggest contributors, followed by biomass. In 2017, solar PV installations, for example, generated 43 GW of electricity, and in the first half of 2018, renewables provided for 41% of the country's energy needs (Fraunhofer ISE 2019).

By mid-2018, coal in Germany generated 35.1% of the country's electricity. In comparison, renewable sources, such as solar, wind, and biomass, generated 36.5%. At the half-year mark, it is the first time in Germany's history that renewable sources have generated more electricity than coal. Germany has technological leadership and pioneering work in renewable energy technologies but is experiencing challenges with grid infrastructure capacity and digitalisation of energy transmission.

The electricity grid in Germany is also becoming smarter with the advent of the SMARD grid system, enabling improved visualisation of the energy mix across the German grid (Bundesnetzagentur 2018). This improvement of visualisation of the grid enables entrepreneurs to explore market opportunities at the intersection between variable grid prices, baseload configurations, and interconnectedness with other jurisdictions. The Energy Transition Hub's 'OpenNem' project is enabling a similar view in Australia (OpenNEM 2019).

In January 2018, the German coalition government raised its clean energy target to 65%, up from 50%. Germany already reached its 2020 target and is progressing at pace to become 100% renewable by 2030 (Renew Economy 2018). The policy shift helps maintain momentum for private sector players and keep up with market realities. As noted above, this is considerably higher than the 36% target previously set by Australia's proposed National Energy Guarantee, and even the Opposition Labor party's aspirational target of 50% by 2030.

The *2014 Amendment of the Renewable Energy Sources Act - EEG* noted that renewable energy source consumption share is set to increase to 40-45% by 2025, to 55-60% by 2035, and to 80% by 2050. RES technology expansion corridors are expected to be: onshore wind energy – 2.5 GW of net additions annually; offshore wind energy – 6.5 GW to 7.7 GW additions by 2020 (800 MW per year); solar PV – 2.5 GW annual additions; biomass – 100 MW annual additions (IEA 2016).

The success of renewable energy in Germany has been in large part due to the dedication of the Government of Germany to support a number of platforms and fora to enable technological opportunities in key areas of climate and energy innovation (BMWi 2016):

- **Research and Innovation Platform:** Aimed on the one hand at enhanced coordination between Federal Government, the Länder, and business and scientific communities and on the other hand at a strengthened approach in transforming R&D results to innovation, the central action areas of this platform are development of energy research policy, development of new approaches (such as strategic energy system analysis), the system integration of individual technologies (particularly smart ICT systems), and the role of startups in the innovation process.
- **Energy Transition Research Forum:** In this forum, key players from the Länder, the business community, academia, and civil society have been meeting since 2013 to drive forward the effective coordination and long-term direction of energy research.
- **Copernicus projects:** The aim is of these projects is to better bridge the gap between basic research and practical applications in key areas of the energy transition. The first funding phase is focused on power grids in the context of a high share of renewables in the energy mix, storage and conversion, realignment of industrial processes to intermittent energy supply and sector coupling. The projects are set for three years and planned funding is up to €120 million.
- **Energy Systems of the Future Academies project:** The purpose of this project is to bring together 120 representatives from German science academies to develop systemic policy options for the area of basic research with a focus on the energy system of the future. This is expected to provide a scientifically sound basis for society-wide debates on *Energiewende*-related issues.
- **Sustainable Power Grids research initiative:** This joint initiative of the BMWi and the Federal Ministry of Education and Research (BMBF) exists to create a necessary technological framework for the future electricity transmission and distribution infrastructure.

- **Energy Storage research:** This joint initiative of BMWi and BMBF exists to support the entire research chain from fundamental R&D work to practical application in the field of energy storage. So far, the initiative is formed by around 250 projects and €200 million of funding (2012-2016).
- **National Innovation Program for Hydrogen and Fuel Cell Technology:** This program is designed to accelerate hydrogen and fuel cell technology development and the process of producing marketable products. So far, more than 200 research projects with a budget of around €1.4 billion for 2007 to 2016 have been initiated.
- **Collaboration Program**: Known as the Energy Transition Research Alliance at the German Federation of Industrial Research Associations (AiF), this joint initiative of energy research and industrial collective research launched by BMWi is designed specifically to strengthen the innovative capacity of non-research-focussed SMEs in the development of energy solutions. The first projects started at the end of 2016 with a total funding of €18 million.
- **Carbon2Chem research initiative:** This is a consortium from industry and science (including Thyssenkrupp, Linde, BASF, Covestro, AkzoNobel, Max Planck Society, and Fraunhofer Gesellschaft) that is trialling the conversion of smelting gas from steel production into base chemicals using renewable energy, with funding of €62 million in 2016- 2020.
- **Renewable Resources funding program:** This is an initiative of the Federal Ministry of Food and Agriculture for the promotion of research, development and demonstration projects in the use of renewable resources as a material and for energy purposes. In 2016, combined funding from the Federal Ministry of Food and Agriculture (€61 million) and the Energy and Climate Fund (€24.6 million) was made available.
- **Biomass Energy Use funding program:** This program is practically orientated and has a focus on R&D, on forward-looking technologies and the optimisation of bioenergy processes to contribute to energy supply security. The program was launched in 2009 and since then 300 projects have been carried out with funding amounting to around €44 million. In 2016 €61 million was available with an additional €24.6 million provided from the Energy and Climate Fund.

Challenges for clean energy entrepreneurship

Critical to entrepreneurship is how services are discovered, evaluated, and exploited; the sources of opportunities and the set of individuals who discover, evaluate, and exploit them (Shane and Venkatamaran 2000). As such, the ecosystems that support this discovery and commercialisation are critical foundations of entrepreneurial success: according to Isenberg (2010), it is not due to the heroics of one person or even one idea but the collective vision of a group of stakeholders committed to the promotion of entrepreneurship, creating an ecosystem to actualise their vision.

The World Economic Forum white paper Accelerating Sustainable Energy Innovation (WEF 2018), noted that six principle ideas need to be addressed to assist in the global clean energy transition:

1. Establish an **independent international sustainable energy innovation accelerator fund** to finance innovative energy technology projects, blending public and private sources of capital
2. Develop **instruments for public-private co-investment** at the national or regional level to support and **finance deep-tech energy innovations**, reduce risks and improve the effectiveness of available public and private funding; if properly designed, such instruments would not only **stimulate more private money into breakthrough energy** projects but would also significantly **improve the success rate and impact of public research, development, and deployment (RD&D) grants**
3. Mainstream energy innovation through strategic public procurement to **use the power of public procurement to accelerate development and commercialisation** by providing first markets for innovative energy technologies and solutions
4. **Create strong national institutions** for energy innovation acting as a single voice for public support in energy innovation, bundling responsibilities as the main public funding authority, overlooking and steering the overall sustainable energy innovation process
5. Co-define **energy technology roadmaps** through public-private collaboration to align global policy and industrial innovation efforts and create a credible road to scale for technology areas of high potential currently advancing slowly

6. Ensure super-transparency of government RD&D spending to **improve the efficiency of the public RD&D funding process** and increase the transparency of opportunities and volume of public funding available for entrepreneurs and investors

Within the broader innovation ecosystem, entrepreneurs often bear great risk in bringing innovation to market through startups. This high level of risk for entrepreneurs is accepted because of the potentially high rewards for building a successful business. They work hand-in-hand with private and institutional investors to raise capital or 'bootstrap' through client and customer contracts to fund progress. This is especially hard in clean energy given the complexities of the sector and difficulties in commercialisation; as the boom and bust of clean energy technologies in the first 15 years of the 21st century showed.

Consider the principal components of the entrepreneurial challenge required for the decarbonisation goal peak emissions in 2020, and net-zero by 2050: new business models and technologies, significant risk-tolerant capital deployed *both* widely and deeply, socio-cultural conditions to enable and incentivise individual behavioural change, and a broad-based ecosystem to support systemic change. These components pose high castle walls to climb, but significant riches for entrepreneurs that can successfully scale them.

New energy technologies face specific challenges to adoption. Five key messages emerged from the Cornell University et al. (2018) Global Innovation Index (GII) survey:

1. Innovation has a key role in meeting increasing global energy demand.
2. Energy innovations are happening globally, while objectives differ across countries.
3. New energy innovation systems need to emerge, with efforts along all stages, including energy distribution and storage.
4. Obstacles to the adoption and diffusion of energy innovations remain numerous.
5. Public policy plays a central role in driving the energy transition.

The GII (Cornell University et al. 2018) highlights that for energy innovations to reach their full potential new energy innovation systems coupled with intense innovation efforts are needed at all stages of the energy system value chain. Higher levels of technological and non-technological innovation are required on supply side (i.e. production of energy through cleaner sources). But innovation is also critically needed on the demand side (i.e. the consumption and use of energy). Digital energy entrepreneurship therefore is part and parcel of emerging smart cities, intelligent homes and buildings, energy efficient industries, and transport and future mobility. At a systemic level, enabling technologies for the optimisation of intelligent energy systems, including smart grids and advanced storage technologies, will be important in supporting secure, affordable, clean energy.

1.3. Why *digital* energy entrepreneurship?

Digital energy on the up: innovation and investment trends

Technology trends are important indicators and determinants of how entrepreneurial ecosystems are developing, and how sociotechnical transitions, for example in clean energy, take place. Entrepreneurs in clean energy have evolved alongside other industries developing hardware solutions, from generating clean energy to storage to mobility; and alongside software industries, including evolving from software to enable renewable generation, through to blockchain-enabled clean transactive grids.

Illustrative shifts exist in financial trends and ecosystem development. For example, Bumpus and Comello (2017) noted an increasing development of global early-stage investments for software led companies over the last 15 years, increasing first investments by early-stage capital providers, and increasing prevalence in US-based technology business incubators.

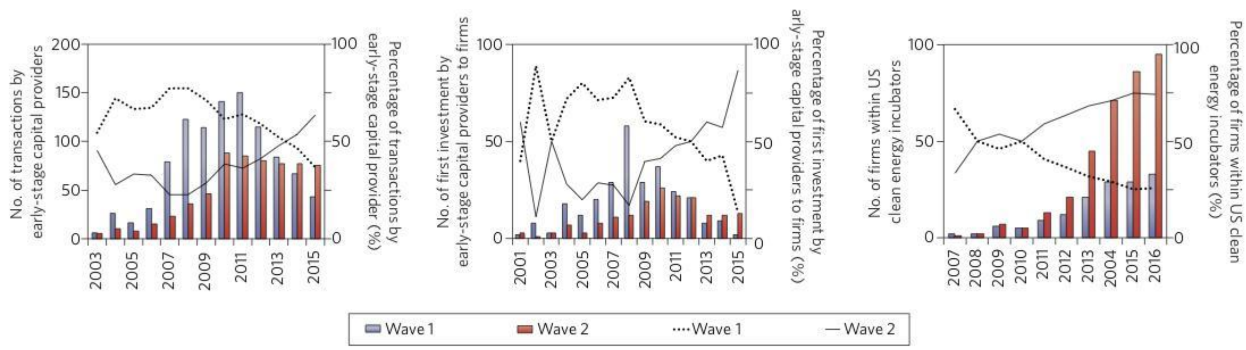

Figure 4: Early stage support for energy startups in Wave 1 (hardware and generation technologies) and Wave 2 (software, optimisation, efficiency technologies). (Bumpus and Comello 2017).

The role of 'Wave 2' (see Figure 4), digital clean energy innovation should not be underestimated in the goal of decarbonisation: it provides an opportunity for capital-light experimentation, optimisation and increased efficiency of existing clean energy generation assets, and an opportunity for entrepreneurs suited to software technology development to apply learnings from successful digital innovation into the clean energy issue.

Similarly, the GII (Cornell University et al. 2018) showed relatively steady proportions of investment in specific types of clean energy innovations that patent numbers record, however growth exists in 'other' technologies (see Figure 5).

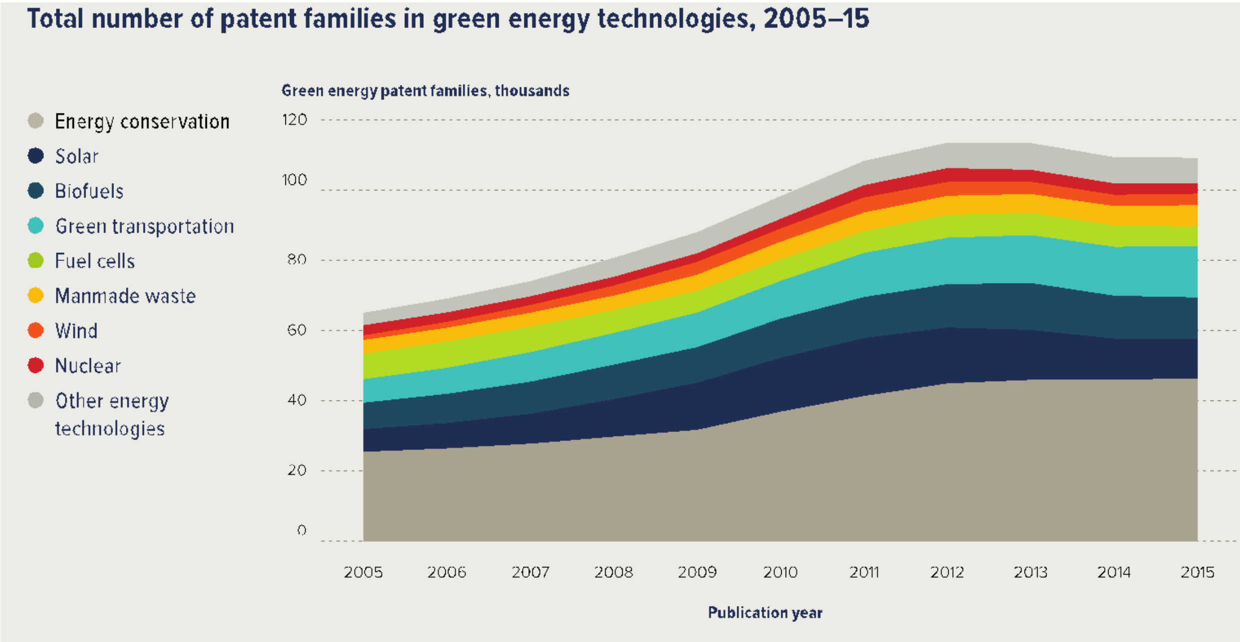

Figure 5: Total number of patent families per specific green energy technology. (Cornell University et al. 2018).

Within this bracket, new business models are emerging as a result of software and IoT technologies that are being adapted and used in new ways. It is the emergence of this *digital energy* that provides interesting and important system disruption opportunities for energy entrepreneurs.

Within digital energy: artificial intelligence and blockchain

Importantly, digital energy provides significant 'stick and carrot' incentives for clean energy entrepreneurship and innovation. Technologies and business models that have high uncertainty and high impact are fruitful places for entrepreneurs to seek profit opportunities. First, digital energy encompasses the critical elements that energy managers and executives worry about most: the rise and disruptive capability of digital tech in blockchain, IoT, augmented reality/virtual reality (AR/VR), and artificial intelligence/machine learning (AI/ML). Second, it can be applied in myriad ways to existing clean energy generation and hardware systems to help optimise, creating economic and environmental value faster from idea conception to pilot and product rollout. Third, digital innovations are often lighter on capital needs and have a faster time to market. The profit incentive, and material liquidity events that have been seen in the non-energy digital technology landscape, mean that digital innovation for clean energy entrepreneurs holds strong incentives for high risk time and sweat equity investment (CSIRO 2018).

The focus on this sector from both incumbent and entrepreneurial points of view is summed up in the World Energy Council Issues monitor of 2018 (WEC 2018). In the WEC report, blockchain appears with the same level of high impact and high uncertainty in both SET100 and Global Perspective Maps (see Figure 6 a-c). This suggests that the increasing pace of innovation is difficult for both startups and energy leaders to understand. Data and artificial intelligence (AI), energy efficiency, renewable energy in general, storage, and finally the climate framework were all common concerns (with digitalisation added in for incumbent energy leaders as a catch-all issue).

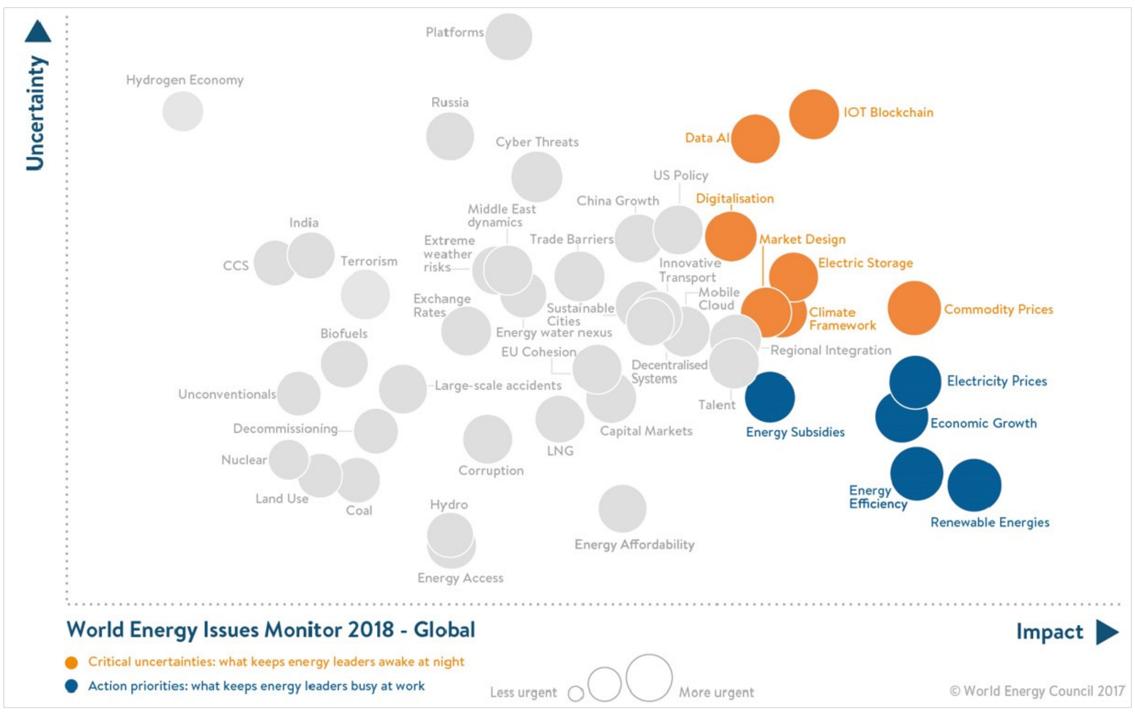

Figure 6a: What keeps energy leaders awake at night as voted by national energy leaders (incumbents)

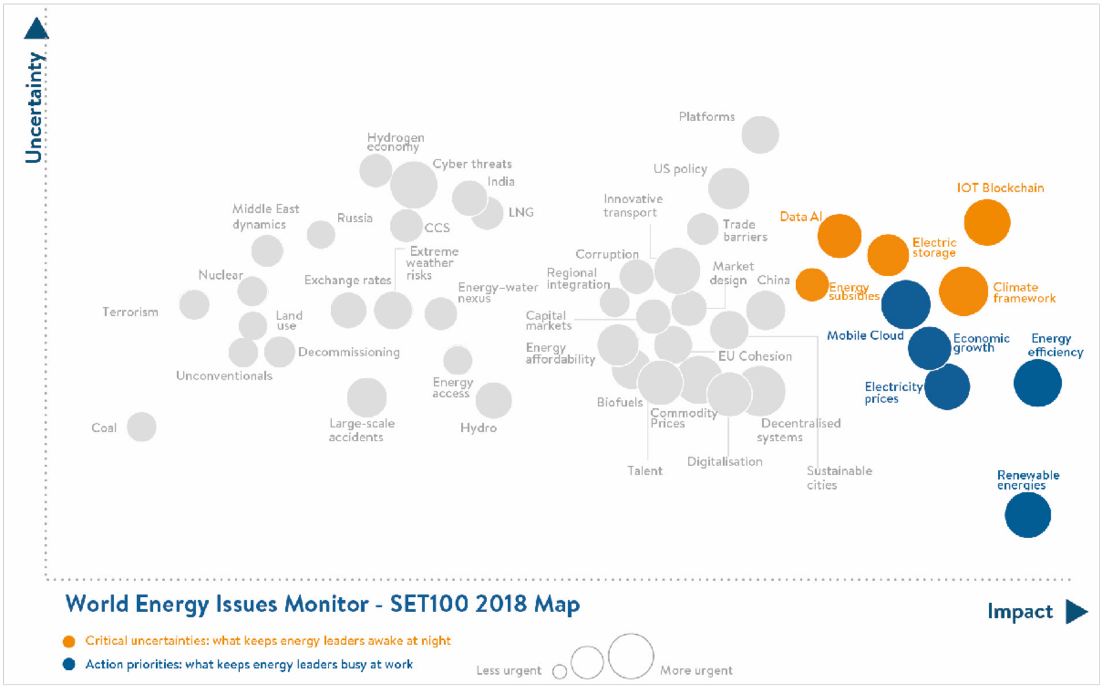

Figure 6b: What keeps energy leaders awake at night as voted by the Sustainable Energy Transition Awards (SET100) community (startups)

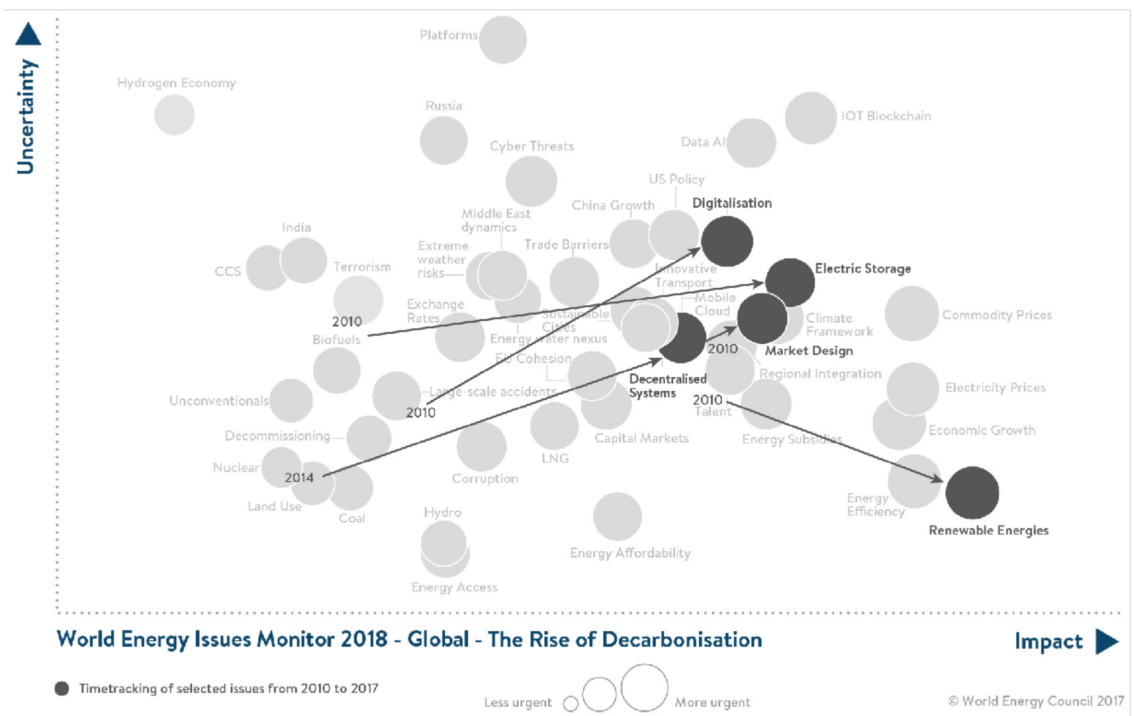

Figure 6.c The rise of decarbonisation on the energy agenda, and concomitant uncertainty in digitalisation technologies.

The trends highlighted by Bumpus and Comello (2017) and in the WEC (2018) report note the importance of considering decarbonisation, the compounding role of digital energy, and the importance of the high uncertainty opportunity for entrepreneurs.

Interestingly, considering the context of digital energy within the broader energy innovation landscape, an even more complex, but compelling, landscape is evident. For broader 'green energy technologies', there has been a decline in patent applications in energy innovation since the peak in 2012 (Cornell University et al. 2018). Combined with the data from Bumpus and Comello (2017), this trend may relate to the shift toward Wave 2 technologies that rely less on hardware patent applications and more on new, innovative business models or software applications that enable existing hardware technologies but that are not patentable (cf Wainstein and Bumpus 2016).

Taking AI and blockchain as examples, new use cases and opportunities for energy companies can be envisaged. While AI provides a new interface for the customer to interact with different services provided via internet, the blockchain technology changes the way data are exchanged and transactions are executed.

"We could think of a system in which AI learns to meet your preferences with respect to energy consumption and the willingness to pay for this service. Based on this knowledge, the AI could make it very convenient for you to actively participate in the data exchange and related services, like flexibility provision from your photovoltaic power plant, battery storage, heat pump or electric vehicle, to an extent that we do not imagine today. Additionally, blockchain technology offers the potential to operate a distributed data exchange system that executes transactions within seconds at low costs. Based on the blockchain technology, micro-transactions could become profitable within the future, allowing us to exchange and trade energy on a local level, e.g. with our neighbours." – Enerquire 2017b

To date, cleantech has been limited to production, or in some cases consumption, assets like power generators. Now, with smart metering and other intelligent network assets data becomes available on energy consumption, production, and the network infrastructure. Startups can make use of this data to develop new business models. Thereby, innovation moves from technologies with high investments towards less expensive digital applications. The telecommunication sector has demonstrated that a switch from capital-intensive innovation process towards data-driven business models can accelerate the innovation process. Maybe a similar dynamic market development will emerge within a digital energy economy. For now, it is clear that the on-going digitalisation of the energy sector helps to address two key challenges for cleantech startups in the past and two main reasons for the 'valley of death' for cleantech startups: long development time and high upfront investments into production facilities (Enerquire 2017a).

To refine even further, this approach demonstrates the opportunities and threats that are posed by IoT blockchain and AI. In addition, recent work with the Free Electrons international accelerator has shown that these categories are gaining traction with both incumbents and startups as opportunities for the evolution toward net-zero carbon by 2050.

1.4. The state of play in clean energy entrepreneurship and innovation

The 3Ds of energy disruption

A critical element of clean energy entrepreneurship is to assist in the development and diffusion of clean transportation technologies, augmentation of ecosystem services that sequester and process greenhouse gases, and the rapid decarbonisation of the electricity system. At a structural level, to enable emissions reductions and create economic opportunities, the decarbonisation of the electricity system poses the most important immediate challenge. It is also the system currently facing the most rapid disruption *from* technological and social disruption; the so-called 3Ds of the new energy landscape: decarbonisation, decentralisation, and digitalisation[1].

Decarbonisation is being driven by climate change responses, and the socially accepted norm that carbon emissions must be rapidly reduced. From the Paris Climate Agreement down to the municipal level, regulations, standards, goals, incentives, and support mechanisms are reducing the carbon intensity of electricity grids. Decentralisation is also taking place as DERs, such as residential and commercial solar and storage, emerge to support existing renewable energy sources such as utility scale wind farms that are already at grid parity. Digitalisation of the energy system, through the rapid increase of IoT technologies, improved understanding of the role of data in driving economic value in

[1] Deregulation and democratisation of energy are also 'D's that fall into this list but are left aside for now.

energy systems, and new digital trading paradigms such as blockchain, emerge to capture value in the current traditional electricity systems.

As a result, across the globe, traditional energy and electricity frameworks are witnessing a fundamental shift in how they operate and generate value. Entrepreneurial ecosystems are then emerging to take advantage of these shifts. New technologies are being enabled by both public and private-sector investment, and traditional utilities—some of which are seeing this new way forward as an opportunity rather than as disruption—are experimenting with how to work with startups and entrepreneurs developing and applying new technologies in the renewables space (Cornell University et al. 2018).

However, the rate of commercialisation and application of clean energy entrepreneurial activities is not well understood, and traditional measurements for entrepreneurial success – capital raising, rapid growth, and exits – are not particularly well-suited to the complex landscape of energy. Better understanding of entrepreneurial ecosystems is, therefore, important to further enable the commercialisation of basic research, collaboration between emerging companies and incumbent players, and to facilitate effective deployment of domestic and international early-stage capital. For energy entrepreneurship, a sector characterised by high levels of incumbency, deep 'valleys of death' for startups, and limited traditional early-stage capital provision, supporting entrepreneurial ecosystems is a critical component of their development.

Energy innovation ecosystems

"Sustainable energy innovation flourishes in virtual networks and physical systems that cross national borders and involve multiple actors, from established companies and start-ups to academic and government institutions. Catalysts for innovation, such as regulatory policies, public funding programmes and innovation alliances, regulate and influence the system's enabling frameworks, which also contain inherent deficiencies or weaknesses that create barriers for sustainable energy innovations."

- *World Economic Forum 2018, p. 11*

Clean energy entrepreneurship is a response to the opportunity to create business models that address the challenge of climate change. Entrepreneurs in clean energy seek out profitable opportunities in the production or generation, transmission, and retailing of clean energy technologies, business models, and applications.

Entrepreneurs play a critical role in the formation of an effective innovation ecosystem. Startup companies as entrepreneurial vehicles are the engines of innovation and commercialisation of breakthrough ideas, alongside larger commercial entities, taking technology from Technology Readiness Levels (TRL) 3 (proof of concept) to 7 (full scale demonstration in a relevant environment). Energy entrepreneurs, therefore, emerge and work within an ecosystem of established companies and startups, academic and government institutions, financiers and grant making institutions. Government initiatives, like Mission Innovation[2], and private sector financing, like the Breakthrough Energy Coalition[3], aim to financially support new energy entrepreneurs and innovative technologies and business models. Accelerators and incubators, like InnoEnergy[4] in Europe, Elemental Excelerator[5] in the USA, and Startup Bootcamp Energy Australia[6] and Energy Lab[7] in Australia, aim to provide hubs for entrepreneurs to develop and further commercialise their ideas. Large existing energy companies develop open innovation platforms, like Free Electrons[8], to bring startup companies together with utility innovators to scale up and deploy new technologies. Yet recent global analysis, including research on the inner workings of emerging incubators and accelerators, highlight that these ecosystems are still embryonic, with significant challenges for their optimisation, connection, and effectiveness (WEF 2018).

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[2] http://mission-innovation.net/

[3] http://www.b-t.energy/coalition/

[4] http://www.innoenergy.com/

[5] https://elementalexcelerator.com/

[6] https://www.startupbootcamp.org/accelerator/energy-australia/

[7] https://energylab.org.au/

[8] http://www.freetheelectron.com/

2. Digital energy technologies and entrepreneurship

2.1. Digital energy in Australia

Policy context: constraints and opportunities

"The power, control and responsibility for generating and managing energy is fast moving into the hands of the consumer." - Parsons 2017

The digital technology-related sector is exploding on a global scale, surpassing most other business segments over the recent two decades, and this development is steady and continuous. Not surprisingly, digital industry is the most important growth sector for startups (Startup Genome 2017). Digital energy companies are also on the forefront of the business model-technology interface for innovation and may offer a new opportunity for entrepreneurial commercialisation in Australia. From a policy context, Australia's strongest opportunities are in focusing R&D investment and applying digital innovation to existing industry strengths, where key drivers of competitiveness are already in place: strong domestic markets and high-quality basic research.

Digital innovation could deliver $315 billion in gross economic value to Australia over the next decade (CSIRO 2018) but use cases for digital energy innovation are only now emerging from the periphery of the innovation landscape. Bumpus and Comello (2017) note that 'Wave 2' Digital energy technology companies (e.g. more software driven innovations such as 'digital twins' of existing systems, IoT technologies, optimisation algorithms etc.) differ to the previous 'Wave 1' traditional hardware companies which are more focused on generation of clean energy (e.g. solar, wind, and other renewable energy materials and hardware development and production), and in some ways differ to the participants in the traditional support systems for hardware technology development.

To date, these activities have been undertaken through university commercialisation arms and industry support mechanisms like the Clean Energy Council, who have worked hard to support manufacturing and clean energy generation (e.g. rooftop solar) installations. Their focus has been more technical hardware: bioenergy, cogeneration and trigeneration, energy efficiency, energy storage, geothermal, grid, hydroelectricity, large-scale solar PV, marine energy, and off-grid renewables. 'Digital' energy has not yet factored significantly in these support mechanisms. Instead, digital energy technologies incorporate technologies that are cross cutting, such as AI and blockchain (e.g. with data-driven financial services in the 'fintech' sector) and span not only energy, but other cleantech technologies and themes including water, 'agtech', etc.

Opportunities for digital innovation in the Australian energy landscape is also being supported by changes in regulation for the electricity markets. Key opportunities include the proposed Australian Electricity Market Commission (AEMC) rule changes that make it easier for consumers to be paid for delivering capacity to the electricity market whether that capacity is megawatts from solar PV and batteries, or 'negawatts' from reduced demand. Aggregated demand response and opening up opportunities for consumers to engage multiple retailers/aggregators at the same connection point (multiple trading relationships), promote competition between retailers, supporting new business models for demand response and providing consumers with greater opportunities to engage in wholesale demand response with parties other than their incumbent retailer (Murray-Leach 2018). This increased opportunity and complexity opens up large opportunities for new digital energy business models based on blockchain and AI technology.

Supporting future entrepreneurs is the underlying cost of fundamental renewable energy technologies (Wave 1). CSIRO (2017a) analysis shows that by 2050, the 2017 cost projections for wind and rooftop PV are lower than were projected previously in 2015, indicating that the costs are more rapidly decreasing than previously assumed. For rooftop solar PV, the recent cost estimate reductions have also improved the longer-term outlook, together with CSIRO's new assumption that learning for both the panel and balance of system can continue at faster rates for longer (CSIRO 2018, p. 11).

The projections (CSIRO 2017a) highlight the role of multiple forms of renewable energy, including new forms of solar panels, and their ability to be integrated into structures are potentially game changing. Free floating offshore wind technologies could open up a wider area of ocean resources if proven cost-effective and robust (CSIRO 2018). These new technologies require data analytics and integration software into the smart grid of the future.

Wave 2 energy entrepreneurs are well positioned to take advantage of, and push through, these new, Wave 1 technologies. This has important implications for the development of digital energy optimisation technologies that will enable panel integration and improved balance on the grid toward cost savings in the future.

Beyond Wave 1 (hardware-based renewable energy generation technologies), and even Wave 2 (software and hardware-software integration and grid optimisation technologies; cf. Bumpus and Comello 2017), energy storage technologies, as well as clean energy export technologies, will play an increasingly important roles from now to net-zero, and beyond. The CSIRO (2017b) electricity generation technology cost projections report noted that strong learnings can be provided from the transport sector given the faster uptake of storage technologies (i.e. in electric vehicles), making this sector the strongest source of learning and thus cost reductions. The updated projections indicate the trend seen in the last few years in which solar PV, wind, and battery storage technologies reduce in cost at a faster rate than most other technologies. However, although Australia has strong basic research and development, it is the *deployment and commercialisation* of technologies that has suffered (as highlighted above).

As such, between 2030 and 2050, energy entrepreneurs will need to continually evolve technologies in line with climate threats and modelling. To limit to 1.5°C, the sequencing involves rapidly decarbonising the grid, enabling all fossil-based combustion to be converted to electricity (i.e. electrification), and then deploying sequestration technologies to reduce temperatures from +2°C to +1.5°C. This is in the context of projections that indicate that by 2040 the world will require up to 30% more energy than today (Cornell University et al. 2018).

New business models for sharing the benefits of solar electricity production across building tenants and owners will also enable integrated solar. This is already happening in 2018 with blockchain-based technologies and entrepreneurial companies like Powerledger and LO3, and emerging trading systems using distributed AI, like RedGrid One. Although no future projections are infallible, the CSIRO analysis points to the continued decrease in the cost of renewable energy. In combination with the squeezing of the business models of traditional fossil-based energy generators and retailers, the opportunity is emerging for advancing the support for *smart digital energy as a connector, stabiliser, and enabler of new business model value.*

Supporting new energy entrepreneurship in the context of digital disruption is highlighted in the CSRIO report:

"As a mid-sized market, it is critical that Australia defines its own path to success at digital innovation, rather than attempting to emulate the breadth of Silicon Valley or the scale of China. Australia is most likely to succeed if it focuses on producing new digital products and services for industries in which it already has a global competitive advantage — thanks to its natural resources endowment, strong institutions, diverse and highly skilled workforce, and existing infrastructure and customer base." - CSIRO 2018

Digital energy entrepreneur examples

Although it is difficult to assess the total opportunity for startups in energy due to their diffuse profiles and difficulty of categorising startup/entrepreneurs (out of 100 'startups to watch in 2018' only two focused specifically on energy: Powerledger and Wattblock – see Holderness 2018), startups are moving into the digital energy space due to the opportunities that are brought about by the 3Ds of the energy transition. The IoT, AI and machine learning, cybersecurity, and blockchain are enabling software technology companies to move into the energy space. In particular, digital energy entrepreneurs are aiming to improve customer experience and optimising existing DERs, and thus enable optimisation, automation, and control of the existing electricity system. Examples of instances in which companies have engaged with new digital energy business models include:

1. Consumer engagement through **new business models** running on web2.0; e.g. Powershop, DC Power Co
2. **IoT** hardware and software integration for behind the meter control and grid integration; e.g. Greensync, Zen Ecosystems, WattWatchers
3. Enabling new transactive opportunities through **blockchain** and web 3., including peer to peer trading; e.g. Powerledger, Enosi
4. **AI/ML** that integrates the physics of the energy system with markets, including aggregated demand management and response; e.g. Reposit Power; Relectrify, RedGrid One

Disruptive startups achieve this by picking off a piece of the incumbent's business model and redesigning it in a way that is highly customer-centric, aiming to give customers 'more of what they want and less of what they don't' by delivering value it in a way that is fast, digital, and pain-free (AFR 2017).

This will only increase over time. By 2020, there are expected to be 200 billion IoT devices (up from only 15bn in 2015). Already, Australian startups and scaleups, such as WattWatchers, are enabling IoT for new clean energy opportunities (see Table 1). From 2020 onwards, current retailed will need to change their business models in relation to digital energy technology. The most successful retailers will be those that understand their new role as both enablers of consumer-led electricity generation and management, and partners to customers who are now key players in the generation and trade of stored energy between homes, businesses, retailers, and the grid (AFR 2017).

Table 1: Examples of digital energy startups in Australia (Source: Author analysis).

Technology Sector	Name	Activities	Digital Focus
Energy management (HWSW)	Allume Energy	Allume Energy is a renewable energy technology company focused on grid sharing and solar as a service for Australian communities.	IoT and AI
Finance	Brighte	Finance for clean energy upgrades, increasingly using AI	AI
Finance	Encoin	Blockchain technology to accelerate adoption of renewables	Blockchain
P2P trading	Enosi	Blockchain energy management	Blockchain
P2P trading	Powerledger	Blockchain technology to enable embedded grid transactions	Blockchain IoT
Solar and Storage Optimisation	Redback technologies	Battery storage and management	IoT and AI
Energy management (HWSW)	RedGrid One / Tility Labs	Uses decentralised artificial intelligence and blockchain to enable grid energy optimisation	Blockchain IoT & AI
Storage	Relectrify	Battery storage	IoT and AI
Solar and Storage Optimisation	Reposit Power	Intelligent solar and battery management that connects and sells to the grid.	IoT and AI
Energy management (HWSW)	Thinxtra	Energy monitoring devices	IoT and AI
Energy management (HWSW)	Wattwatchers	Retro-fittable energy management device, the startup allows users to see real-time energy data, and to identify which devices are consuming the most power in their home, at any given time	IoT and AI
Finance	WePower	Blockchain technology to enable small scale investment in renewable generation	Blockchain

Case Studies in AI and blockchain: Tempus Energy and RedGrid One

Two startup companies working on these issues in the Australian market are, the predictive market AI company, Tempus Energy from the UK, and, the Australian 'internet of energy' company, RedGrid One, which is bringing together AI and IoT control through blockchain.

Tempus Energy provides software that unlocks demand flexibility in connected customers. Using AI and smart algorithms they can control and optimise when flexible assets use energy. By predicting volatility in carbon intensity and market prices, they allow customers to reduce their energy costs while simultaneously enhancing their use of renewables. Tempus is active in the Australian market working with the gentailer, Origin Energy, and delivering a pilot in South Australia that will then be rolled out nationally (Origin Energy 2018). The Free Electrons accelerator enabled Tempus to move from the UK to Australia, highlighting the importance of the global digital energy entrepreneurial ecosystem that is emerging.

RedGrid One, a startup based in Melbourne, provides a solution that enables energy producing and consuming assets to trade independently with each other, shifting load, and enabling responses to micro and macro electricity demand (i.e. from different local demands for electricity up to responding to the spot price in the market). Partnered with Holochain - the global decentralised software-hardware and agent-based 'post-blockchain' solution – RedGrid is building what they call the 'internet of energy' – an open source platform that will allow all IoT connected devices to trade and make independent decisions working on behalf of optimising electricity and maximising renewable energy take-up and use. The company has delivered work with Free Electrons 2018 winner SOLShare (RedGrid 2018). The company has also taken advantage of the energy entrepreneurial ecosystem, winning places in the ARENA A-Lab incubator (2018) and a place in the top 11 global energy startups at Startup Bootcamp Energy Australia 2019 to deliver pilots across the Australian market.

2.2. Digital energy in Germany

For the *Energiewende* to be completed, digitalisation will be an increasingly important component of new technologies and business models. Germany's current focus on digitalisation is testament to this direction: Germany's digitalisation strategy highlights the opportunity for digitalisation by exploiting its existing high industrial competence in the new digital economy. To do this, platform and network-based approaches will need to combine Germany's existing product portfolios and customer contacts with the network effects of a platform. This creates an ecosystem for additional value added – with new technologies, new customer interfaces, new partners, and, most importantly, new services. Entrepreneurs are well suited to take up the challenge.

Policy context: constraints and opportunities

Germany's Digital Strategy for 2025 notes that the digitalisation of energy is an explicit goal alongside developing the digitalisation of other sectors:

"Our aim is the comprehensive and systematic use of the digitalisation potential in the fields of energy, transport, health, education and public administration; we expect this to generate considerable efficiency gains and to stimulate macroeconomic growth. The Smart Networking Strategy was adopted by the cabinet in September. Since then, a lot of information policies have been rolled out. For example, a "Smart Networking Initiative" centre of excellence has been set up, and roadshows set in motion." - BMWi 2017, p. 33.

However, similar to Australia, and alongside some other European nations, Germany is lagging behind digital leaders in the world. The US is exploiting 18% of its digitalisation potential and leads the global field, whereas Europe is only capturing 12%, and Germany only 10% (McKinsey 2016). So far, only one in four manufacturing companies in Germany believes itself to be well prepared for digitalisation. The government notes that it needs to significantly boost funding for research and development in the area of digitisation of the economy. In most areas of trade and industry, this funding is only one-tenth the amount of that provided for energy or aerospace.

The BMWi notes that in the medium term it is not sufficient for Germany to be a digital efficiency champion. More investment in digitalisation required but that "a change in corporate culture is necessary: openness and courage to use digital technologies and qualified employees so as to develop new business models" (BMWi 2018, p. 28). This builds on the opportunity emerging in digital energy and the ability to add value by moving away from products to data platforms, and how completely new value-added potential is arising by networking customers and cooperation partners.

From 2014 to 2017, the BMWi also implemented the 'Digital Agenda'. In particular the agenda included the formation of 12 'hubs' (Figure 7). SMEs will be key driving forces for digital innovation:

“The aim is to help SMEs to succeed and grow in the rapidly changing conditions of a global data economy. In some sectors, such as the services sector, this initially involves measures to raise awareness of scope for digital development and resulting new value chains.” – BMWi 2017.

By developing a network of ‘Mittelstand 4.0 centres of excellence’ across the country, the government is raising awareness for the deployment of digital solutions among SMEs. Ten of these hubs and one centre of excellence for digital skilled crafts have been established, and more are to follow. Some of these hubs support the crossover between energy and digital innovation in Germany. Of particular relevance to energy, for example, is the Leipzig-Dresden hub that focuses on smart systems, IoT, and energy, smart city, and e-health sectors as particular focal points (de:Hub 2018). While the Leipzig hub focuses on promoting smart infrastructure, in Dresden the focus is on developing the hardware, software, and connectivity components needed to facilitate smart systems. The aim is to become a platform for application-based solutions for leading industries, and consequently facilitate the IoT.

BMWi’s (2017) Digital Platforms paper notes that products and services increasingly contain digital value added and are becoming ‘smart’ by incorporation into intelligent and networked systems. New business models are arising in the digital environment. Completely new ecosystems with value-added chains are being created in which data are an important resource. The use of digital (data) technologies gives rise to new areas of knowledge and industry, including data-supported health services (e-health) and fintech, and have the first applications of intelligently networked energy production and supply (smart home).

Germany’s digital Agenda 2025 sets out even more ambitious objectives. By 2025, Germany has goals of establishing a viable gigabit network (with gigabit speeds for uploads and downloads, reliable real-time transmission, and high-quality secure internet services). The government’s view is that companies and business parks must be connected to gigabit networks as soon as possible by rolling out optical fibre network nationwide, because this is a key prerequisite for introducing 5G networks (5th generation mobile phone standard). Similar to the beleaguered roll out of the National Broadband Network (NBN) in Australia, infrastructure investments in Germany are seen to be critical to avoid a situation where a lack of infrastructure holds back digitisation innovation opportunities.

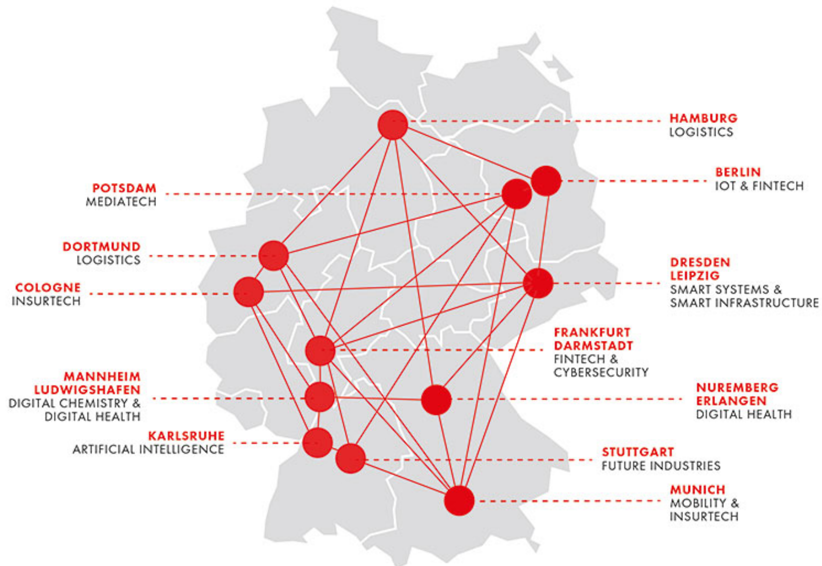

Figure 7: Digital ecosystems interconnected hubs in Germany (de:Hub 2019)

Leipzig has steadily built its reputation as an attractive, aspiring location for startups. Several research institutions covering a wide range of research projects serve as the driving force behind the Digital Hub. At the same time, the site is home to strong businesses that are - often in collaboration with startups - increasingly opening up to innovation. The energy, smart city, and e-health sectors are particular focal points in Leipzig, allowing the Hub to connect the scientific community, businesses, and startups. An accelerator programme focussing on smart infrastructure, various regional cluster organisations, numerous events, and innovation formats all play a supporting role in enabling this exchange. For example, partners in Leipzig include: AOK PLUS, VNG Group, Leipziger Gruppe, European Energy Exchange, enviaM, Porsche, and Arvato Systems (de:Hub 2018).

One of the main problems for digital energy entrepreneurship in Germany is the lack of a smart energy infrastructure backbone — smart metering. Challenges include:

1. Under the current rollout of smart meters, only large consumers (and small producers) will have the equipment to participate in digital business models

2. Even these large consumers will only be equipped until 2028 with the necessary smart meter infrastructure

3. The annual costs of €100-200 per customer for the smart meter infrastructure will be relatively high in Germany (compared to for example US$25 in the US – see Greentech Media 2010), which increases the customers' expectations for high returns from any digital service or product to recover these costs.

Full rollout of smart meters in some European countries is progressing (e.g. 80% rollout in Sweden and Italy); the US has about 50% of all households covered; Canada has nearly a full rollout completed; and patchy coverage in Australia is improving (the state of Victoria is at 100% rollout, but the country as a whole has approximately 25% coverage). For Germany, however, by 2028 about 10%-15% of all network users will be equipped with intelligent metering systems. Larger consumers (annual demand of more than 6000 kWh) and producers above 7 kW will be covered in the rollout, but until 2032 households will only be equipped with metering systems that cannot communicate data outside the households. Given that German households spend about €830 annually on electricity, the business case for rolling out smart meters needs to recover over 10% of the average electricity bill to recover rollout costs. It is currently unclear which entities will carry these costs.

Despite this approach, there are also fundamental opportunities in Germany that support digital business models. Enerquire (2017b) points out some strong opportunities:

1. The metering market in Germany is market-based, allowing every interested party to enter the metering business (i.e. to become a meter operator). In addition, the German market for meter operation along with the UK market is the only one in Europe not limited to the regulated Distribution System Operators.
2. German law allows every metering operator to provide customers with modern measurement systems and intelligent metering systems, as long as the annual costs do not exceed the limits defined by law. If a company creates a business case, it can provide customers with metering systems. Evidence from other digital platform businesses (e.g. Amazon) suggests that platform providers are willing to sell hardware for prices lower, or at least not above, production costs by adopting business cases that require access to consumer data. Companies with similar business models for electricity consumption might start a market-based rollout of intelligent metering systems or modern measurement systems on their own.
3. A meter operator that sells a modern measurement system to customers needs to ensure that the data from the measurement system is externally accessible via the standardised interface (smart meter gateway). It is possible to use one smart meter gateway to access a larger number of measurement systems, which offers potential for cost reduction.

Germany's digital energy transformation may, therefore, focus beyond top-down rollout of smart meters and instead rely on *network effects* of digital business models. Most of these models that currently challenge global markets are digital platform businesses (Facebook, AirBnB, Uber, Amazon, Google). The success of digital platforms is particularly relevant to positive network externalities as a result of a growing network (Enerquire 2017b).

Digital energy entrepreneur examples

Network effects are supported by IoT, blockchain, and network-based AI. As such, a number of blockchain and AI startups are emerging to enable new digital innovation for the energy sector (see Table 2).

Table 2: Examples of German blockchain and AI energy startup companies (source: Author analysis)

Technology Sector	Name	Activities	Digital Focus
Energy management (HWSW)	Car eWallet	Car eWallet will make your car function as an autonomous financial entity. It will pay for parking, charging, toll, without the need to manage multiple accounts. Runs on blockchain Hyperledger.	Blockchain and Electric vehicles
P2P trading	Conjoule	This Innogy spin-off provides a blockchain based platform to enable PV owners within the same region to interact with each other.	Blockchain and P2P trading
Energy management (HWSW)	Freeelio	Develops AdptEVE, an energy app that uses AI to optimise the costs and the use of solar power. AdptEVE uses blockchain to account for energy value in a building with different tokens of different purposes: feed-in, shifting, saving, storing, and sharing of electricity.	Blockchain and P2P trading
Behind meter data	JungleAI	Maximise the performance of your electrical assets with tailored AI models	AI
P2P trading	Lition Energy	A blockchain project that brings affordable clean energy to German households.	Blockchain and P2P trading
Finance	Oursolargrid	Oursolargrid aims to restore the incentives to invest in solar power by allowing producers and consumers to share or trade energy within the community. The decentralised, tamper-resistant and efficient characteristics of blockchain make this technology an ideal fit for this p2p sharing.	Blockchain and P2P trading
Storage	Oursolargrid /TenneT / IBM/ Vandebron/Sonnen	In Germany, Sonnen has joined a pilot in which decentralised battery storage systems are used for congestion management, eliminating the expensive need to cut down the supply of wind turbines in case of supply surpluses.	Blockchain and grid management
P2P trading	Ponton	PONTON is the driving force behind the "Enerchain" project, a decentralised energy trading platform for the OTC wholesale energy market, which is supported by more than 30 of the leading European Energy Trading companies.	Blockchain and P2P trading
Energy management (HWSW)	Share&Charge	Allows people to share their charging stations, parking spots, and, eventuall,y their EVs. The payment system is based on blockchain.	Blockchain and Electric vehicles
SW/HW combined	Slock.it	Slock.it aims to revolutionise the Sharing Economy by making it possible to rent, sell, or share any smart object through the blockchain	Blockchain and P2P trading
Finance	StromDAO	STROMDAO develops and operates a consensus system for decentralised energy markets.	Blockchain and P2P trading
Retailer management	SwitchUp	Optimise clients' energy plans and make sure they're never overcharged for electricity or gas again.	Platform as service
Storage	Tesvolt	TESVOLT specialises in battery storage for commercial enterprises. They produce lithium-ion-based electricity storage units that can be connected to all renewable energy producers in the low-voltage grid: sun, wind, water, and combined heat and power.	Intelligent storage

Case Study: Lition (www.lition.io)

Working with global technology giant SAP, the Lition platform was developed to connect consumers directly with green energy producers and provide more choice over where energy is provided from and how much it costs. Lition uses blockchain to enable a better understanding of the provenance of the electrons that a customer is using, and the smart contracting that blockchain can enable to make the process of buying energy directly from producers much easier and transparent by eliminating third party brokers.

Lition argues that current energy delivery arrangements are inefficient and expensive, and the consumer does not have a good understanding of what is being purchased from official grid systems. "We want to give 'power to the people,'" he says. "Current power delivery systems are too complex and there is no transparency for the consumer. It's not possible with today's delivery systems to know what exactly you're buying. Even dirty coal energy can be packaged as 'green' and sold at premium prices" (NewsBTC 2018).

Lition is working to address the complex issues created by fluctuating demand versus intermittent supply given the Lition platform works with smart appliances, enabling users to monitor and track how they use their energy. Lition is also one of the few platforms that has a vehicle charging application layer that will become crucial as the market moves to electric vehicles. The company has customers in 11 cities in Germany, accessible to 41 million households.

3. Investment trends

3.1. Investment trends Australia

Public sector support

The stark reality of clean energy investment is that US$2.4 trillion per year is needed to keep the world on a path to a safe climate under 1.5°C (IPCC 2018). For comparison, the first half of 2018 only saw $138.2 billion of renewable energy investments (BNEF 2018b). Investment in Australia continues to face the challenge of an ever-shifting landscape of climate and energy policy.

Despite this uncertainty, investment in clean energy has led to 6553 MW of capacity from renewable energy projects under construction or already built by May 2018; this is above the 6400 MW of capacity required to meet the previously set, Renewable Energy Target (RET). The RET requires 23.5% of Australia's energy – or 33,000 GWh– to come from clean energy sources by 2020, with key investments to keep flowing out until 2030. However, the RET finishes in 2020, and 97% of emissions reductions mandated will be achieved through business-as-usual activities. The previous Turnbull government's proposed NEG, supported by the Finkel Review (Commonwealth of Australia 2017), was pronounced "dead" by the subsequent Prime Minister, Scott Morrison, in September 2018 (AFR 2018), with no federal renewable energy target in its place. State governments are therefore going alone in their policies to achieve emissions reductions in line with, or beyond, Australia's Paris Agreement commitments.

At a federal level (the focus of this briefing), investment in clean energy innovation must, therefore, come from existing sources: ARENA and the CEFC. ARENA and the CEFC work to drive the development and uptake of clean energy technologies in Australia. ARENA provides research, development, and deployment grant funding to improve the affordability and supply of renewable energy in Australia. The CEFC focuses on investing commercially to increase the adoption of clean energy technologies and to facilitate the flow of funds into the clean energy sector.

In 2016 the Government provided $800 million in funding to ARENA to 2022, and as of 30 June 2017, ARENA had committed approximately $1 billion to more than 320 renewable energy projects. This has been matched by $2.5 billion in co-funding, making the total $3.5 billion. It is unclear if ARENA will receive funding post-2022. According to former CEO, Ivor Frischknecht, ARENA would no longer be needed if battery storage and demand management matched the rapid uptake of wind and solar in the National Electricity Market, essentially providing the backup for intermittency in renewables (AFR 2017).

The CEFC was funded with $10 billion in public funds. Over five years of investing, CEFC commitments have contributed a total project value of $19 billion to clean energy projects Australia-wide. The CEFC has directly invested in more than 110 individual transactions and delivered finance for more than 5,500 smaller-scale projects. Each dollar of CEFC investment commitments has been matched by more than $1.80 of private sector finance.

In the 2018 financial year, the CEFC invested in 10 large-scale solar projects, and four wind farms, to deliver an additional 1,100 MW in clean energy Australia-wide. There are now more than 20 large-scale solar projects and more than 10 wind farms financed Australia-wide, including the most recent investment in Tasmania's largest wind farm, at Granville Harbour, which closed just after year-end. Together these projects target more than 2,400 MW of additional renewable energy, sufficient to power more than 800,000 homes (CEFC 2018).

In addition to investing in larger projects, the CEFC's venture capital finance for innovative clean energy companies has seen continued significant growth between 2016 and 2018 (CEFC 2018, Figure 8). A significant component has been in the Clean Energy Innovation Fund, which has provided over $56 million in finance to nine companies, and in combination with ARENA, a total of $140 million in project value.

An example of the CEFC's investment in digital energy is its debt finance of $35 million to intelliHUB (http://intellihub.com.au/); a subsidiary of the global smart metering company, Landis+Gyr, aiming to accelerate the use of smart meters, extending the benefits of distributed clean energy to Australian households and businesses.

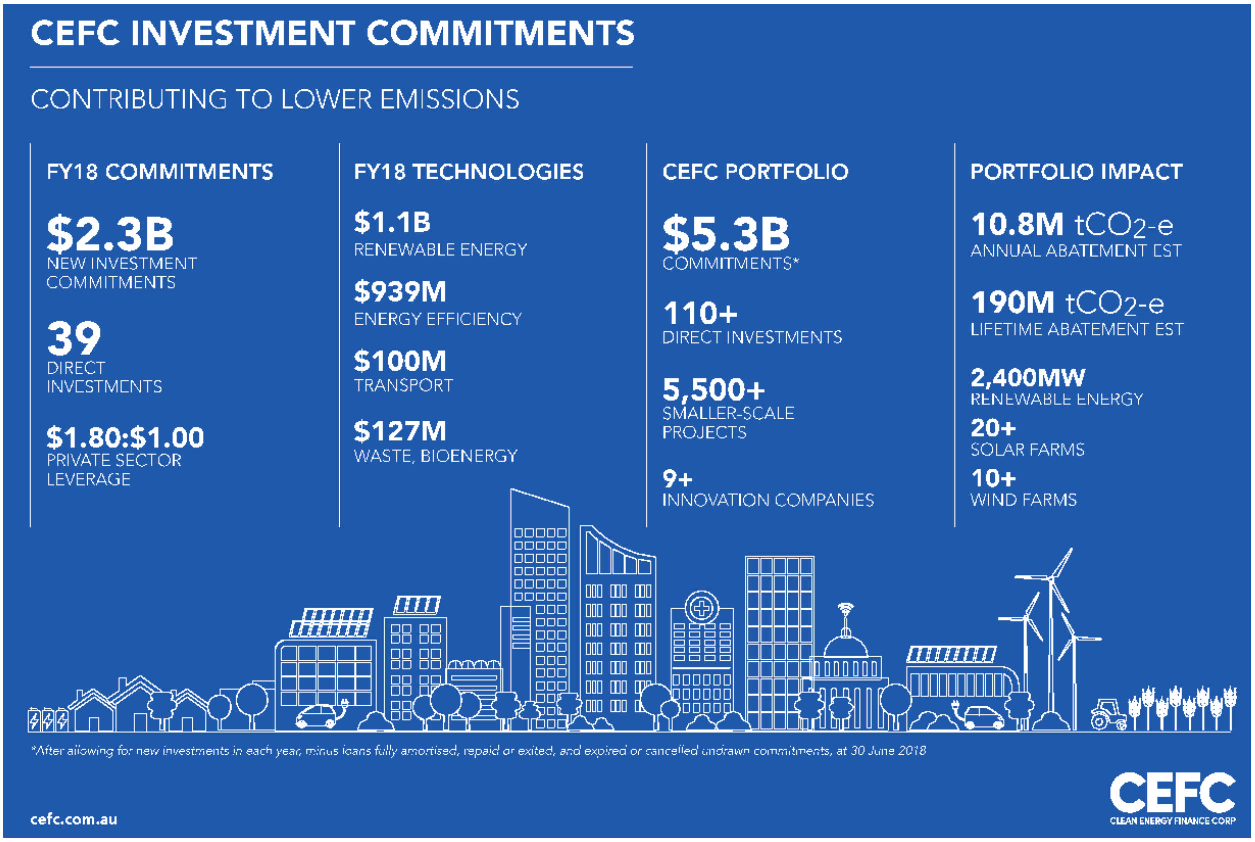

Figure 8: CEFC FY18 commitments (CEFC 2018).

Private sector support

Large-scale renewable energy investment is increasingly covered by project finance from mainstream banks and corporate power purchase agreements. A clear sign of the maturity of investment in this market is the role of corporate finance investing in renewable energy project portfolios. Although Australia is a nascent market, activity is beginning to pick up, due to expensive wholesale power prices and strong renewable resources (BNEF 2018a).

Cost declines have made renewables cost-competitive with wholesale power prices and more traditional sources of electricity, and as a result, corporations are locking into fixed, long-term clean energy contracts to hedge against volatile prices in the wholesale market. Investors are ‘voting with their money’ and backing more than $20 billion in renewable projects as Australia moves to a less carbon-intensive economy. As of October 2018, for the 73 large-scale projects in construction, there is currently $18.6 billion in investment, adding 11,586 MW of new renewable energy capacity to the system (Clean Energy Council 2018).

Private sector financial engagement with clean energy startups also comes in the form of venture capital and corporate venture capital. Two prominent venture capital funds in Australia have official ties into clean energy entrepreneurship policy: Southern Cross Venture Partners with ARENA's Venture Capital Fund (https://arena.gov.au/funding/programs/venture-capital-fund/), and Artesian Venture Partners, with the CEFC's Clean Energy Seed Fund (https://www.cefc.com.au/case-studies/clean-energy-seed-fund-taps-into-innovation/).

The Southern Cross Renewable Energy Venture Capital (REVC) Fund looks for opportunities to partner with renewable energy entrepreneurs with global aspirations. It has committed capital of up to $120 million with 50% Softbank China Venture Capital (SBCVC) and 50% from ARENA. The fund managers note the equity investment is followed by targeted support to enable catalysing the right connections, bringing the lessons of experience, acting as a trusted partner, and sharing in the vision of co-founders to build commercially successful companies.

What does this context mean for digital energy technologies and entrepreneurs? Firstly, it means that early-stage support through government finance that would otherwise be placed into generation technologies, can now be deployed in the next wave of innovative technologies that aim to optimise the existing generation assets already being deployed. Secondly, it shows that startup clean energy entrepreneurs have less opportunity to compete with existing generation technologies due to cheap costs, and instead must focus on disruptive business models (e.g. new retailers), software and IoT plays, and the confluence of data analytics and energy. However, despite growing interest in private sector capital deployment to clean energy startups, there is still a dearth of capital associated with large ideas that are potentially highly transformative: "We have more good deals than capital available" (Senior VC investor, A-Lab Incubate 2018). Thirdly, it means that capital institutions are starting to enable a linked investment chain from very early stage to later stage companies.

The Clean Energy Seed Fund (CESF) attracted $26 million in finance, including a $10 million cornerstone commitment from the CEFC through the Clean Energy Innovation Fund. The CESF targets scalable, high growth potential startups, encouraging innovation and creating opportunities in the development of clean technology. It will invest in startups at seed stage via dedicated clean energy accelerators such as EnergyLab, which is supported by Climate-KIC Australia. To have successful startup outcomes in the form of a material liquidity event (e.g. IPO, or acquisition, i.e. 'exit'), there needs to be a pipeline of quality, investable ideas that are placed in a structured programme geared towards commercialisation. It is estimated that of 10,000 applicants to an incubator program, 1,000 will be accepted and just 50 will exit with a viable business (Bumpus and Comello 2016).

Corporate venture capital (CVC) is strong in the US and Europe, with companies like ABB having CVC arms, like ABB Technology Ventures, and utilities like Innogy investing (see below) who invest in early stage clean energy startups. CVC is still relatively small-scale, but seems to be increasing in Australia with companies like Energy Australia making equity investments in clean energy tech companies like RedBack Technologies, and Origin piloting demand response opportunities with companies like Tempus Energy.

However, Australia still lags regarding material liquidity events – where investors invested in technology companies recoup their financial interests. These are seen to be much stronger in Germany than Australia. In a KPMG survey, 40% respondents noted that Germany would see the biggest increases in mergers and acquisitions (M&A) activity expected in 2019, as compared to only 5% who viewed Australia as the most attractive (40% also viewed China, 26% the UK 21%. and India 15%).

For long-term investment, a lack of stable energy policies is still a barrier for long-term transformative investment according to Ted Surette, a partner with KPMG Australia:

"There have been multiple changes in policy over the past 10 to 15 years. The industry, the federal government and most market participants in Australia are all of the view that we need a nationwide energy policy that brings together federal and state requirements. This is the number one issue facing the country right now." (https://home.kpmg.com/jm/en/home/insights/2018/01/great-expectations.html)

Australia's growing levels of utility and residential renewable energy is also providing challenges for grid integration. Coal is down 20% since 2008 and wind power up 325% in the same time period according to the Australian Energy Market Operator. The increase in intermittent renewables and requirements for flexible demand for grid stability are causes for concern for those basing business models on more renewable energy generation. However, while integrating such a complex energy mix can be challenging for end users and government policy-makers, it gives investors opportunities. According to KPMG, "Investors want to take advantage of this disruption — they're looking at sophisticated service models, blockchain applications and fringe-of-grid solutions because of the geography," (Ted Surette, KPMG Australia). Digital energy technology companies in blockchain and AI therefore may find opportunities in solutions that enable improved optimisation and integration but are still suffering from a lower level of ambition and size of investment tickets than similar companies in Europe and the US.

3.2. Investment trends Germany

Public sector support

A steady policy environment for renewables has laid the foundation for well-integrated renewable energy generation. To support regional integration through digitalisation, the government is rolling out "Smart Energy Showcases - Digital Agenda for the Energy Transition", also known as the SINTEG programme (BMWi 2019b). The projects seek to develop blueprints for a smart renewables-based electricity supply that can then be rolled out on a wider scale and build the smart digital energy economy of the future.

Under the SINTEG funding programme, more than €500 million will be invested in the digitisation of the energy sector. The SINTEG funding programme aims to set up large-scale showcase regions for developing and demonstrating model solutions that can deliver a secure, efficient, and environmentally compatible energy supply with electricity being generated to a large extent from volatile sources such as wind or solar. The solutions developed are to be rolled out on a wider scale.

The program places a clear focus on building smart networks linking up the energy supply and demand sides, and on the use of innovative grid technology and operating strategies. It thus addresses key challenges of the energy transition including the integration of renewables into the system, flexibility, digitisation, system security, energy efficiency, and the establishment of smart energy systems and market structures. The project makes an important contribution to moving forward the digital transformation and the energy transition (BMWI 2019b).

A key enabling factor is regulatory; in order to make it possible for the participants of the SINTEG programme to test new technologies, procedures, and business models in practice without facing financial disadvantages, BMWi has developed a fixed-term ordinance, this provides participants with room for conducting experiments. The change in regulation aims to enable learning from practical tests so that the existing legal framework can be updated.

The SINTEG programme includes five digital energy related activities:

1. The ‘C/sells’ showcase is based on an energy system organised into ‘cells’, varying in size from individual sites to networks, and organised through energy exchanges between areas of high and low demand and supply, including incentives for improving flexibility in distribution grids and balancing energy via the heat and transport sector.
2. Data from some 140,000 meters is to be used in the ‘Designnetz’ model region which showcases the optimised use of flexibility options that benefit the market, the grid, and the overall energy system.
3. The ‘Enera’ showcase is experimenting with decentralised installations to provide regional ancillary services, to improve the reliability of the electricity supply, and use a data and ICT framework to enable electricity trading.
4. The ‘NEW 4.0’ showcase brings together the city of Hamburg – a large centre of demand – and the state of Schleswig-Holstein – a key centre for the generation of wind energy. by using state-of-the-art technology and improved market rules, supply and demand are to be balanced in the best possible way.
5. The ‘WindNODE’ showcase aims to efficiently combine renewable energy generation, electricity grids and energy users through digital networking. The project focuses on the use of flexibility options at all levels. The clear goal of the project is to develop innovative products and services that complement the traditional business of selling volumes of energy, and to introduce consumer protection and data security standards so that people and companies that are part of the interconnected energy system are effectively protected against misuse of their data, and so that the highest possible level of data security is guaranteed.

Germany is well placed for private sector energy funding toward 2030. According to KPMG’s Great Expectations report (KPMG 2018), 60% of respondents say Germany’s policies are the most favourable among advanced economies for investment in renewables due to its stable regulatory landscape and continuous development plans for renewables. Respondents expect the country to see the biggest rise in M&A activity in the next 12 months, ranking it the western European country where they are most likely to invest.

Progressive energy policies are the key to Germany’s highly anticipated M&A activity — it takes the top spot as the western European country most respondents (43%) are likely to invest in over the next 12 months. Germany’s approach, as stated by BMWi, is to “fundamentally alter Germany’s energy supply: away from nuclear energy and fossil fuels and towards renewable energy. By 2025, at least 40 to 45 percent of our energy is to be sourced from renewable energy, and we want to raise this to at least 80 percent by 2050." (BMWi 2016).

For digital, however, broader infrastructure requirements exist: between 2018 and 2025, around €10 billion in public funding – and more in private investment – will be needed. Part of the funding will come from the new 'fund for future investment in digitisation' which will be established soon. To stimulate demand, Germany needs to provide small and medium-sized companies and other social and economic organisations based in rural and underserved areas that use innovative solutions with 'gigabit' vouchers – fixed-term grants for getting gigabit connections (BMWi 2019a).

For long-term ambitions to 2050, Germany is the clear winner among advanced economies in promoting investment in renewable energy, according to 60% of respondents. "The German government and its long-term support for renewables is what got them where they are today," says the finance director of an Indian utility. "In this sector, it's extremely important to have government support and Germany has that."

Solar PV, in particular, is undergoing something of a renaissance, particularly in Germany, according to KPMG's Annette Schmitt:

"There wasn't a very favourable subsidy regime for large-scale solar PV in Germany for a long time. It was mostly smaller-scale rooftop installations. Now, with the transition from FITs to an auction-based support regime, larger-scale projects are coming back and, contrary to onshore wind, there are still many sites where larger solar PV can be put into operation."

The favourable policy position taken by Germany for investors has created a firm foundation on which future investment toward 2030 and 2050 can be built. The KPMG survey results bare out the global sentiment on the strong leadership of Germany for clean energy investment, as compared to Australia (see Figure 9). This is a major opportunity for Australia to learn from Germany.

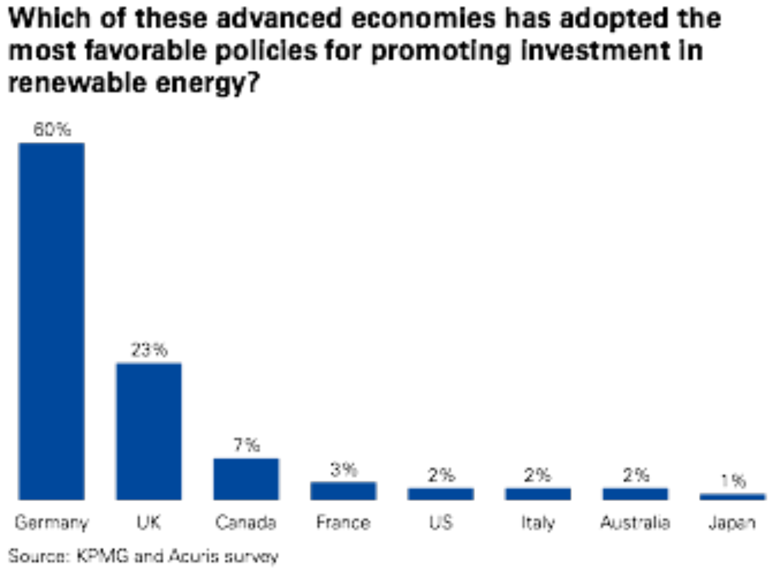

Figure 9: Survey results of which countries have the most favourable policies for promoting investments in renewable energy.

Germany has supported renewable technologies through its *Energiewende* policy framework for more than seven years. However, Annette Schmitt from KPMG in Germany considers that investors should take heed of the changing subsidy landscape: "Strike prices and tenders across all technologies are coming down, so it is a much tougher market these days. Everyone who is playing in the German market, or wants to play in the German market, has to think about how to respond."

Private sector support

Private capital is making a move to support new digital energy entrepreneurs, specifically through CVC. For example, German utilities have increased venture capital and acquisition activities since 2015. Utilities in the US and Europe have invested about $3 billion into renewable energy-related businesses, including some digital business models as well (Greentech Media 2017).

Some incumbents are actively involved in the development of new digital business cases. For example, Innogy invests and co-runs (alongside Australian utilities Origin and Ausnet Services) an accelerator program (Free electrons). Innogy's innovation hub cooperates with startups like slock.it to apply – among other things –blockchain technology to the billing of electric vehicle charging. Other incumbents in Germany, e.g. E.On with the agile accelerator, are developing similar approaches. Furthermore, large demonstration projects like the Enera project by EWE try to develop new business cases based on digitalisation (https://www.energymeteo.com/projects/enera.php).

In 2018, Innogy New Ventures LLC, the Silicon Valley based arm of the Innogy Innovation Hub, led the CVC Series A round for Free Electrons 2018 winner SOLshare – the Bangladeshi company delivering clean energy minigrids across Southern Asia – raising US$1.66M, alongside Portuguese utility firm EDP, and the IIX Growth Fund from Singapore.

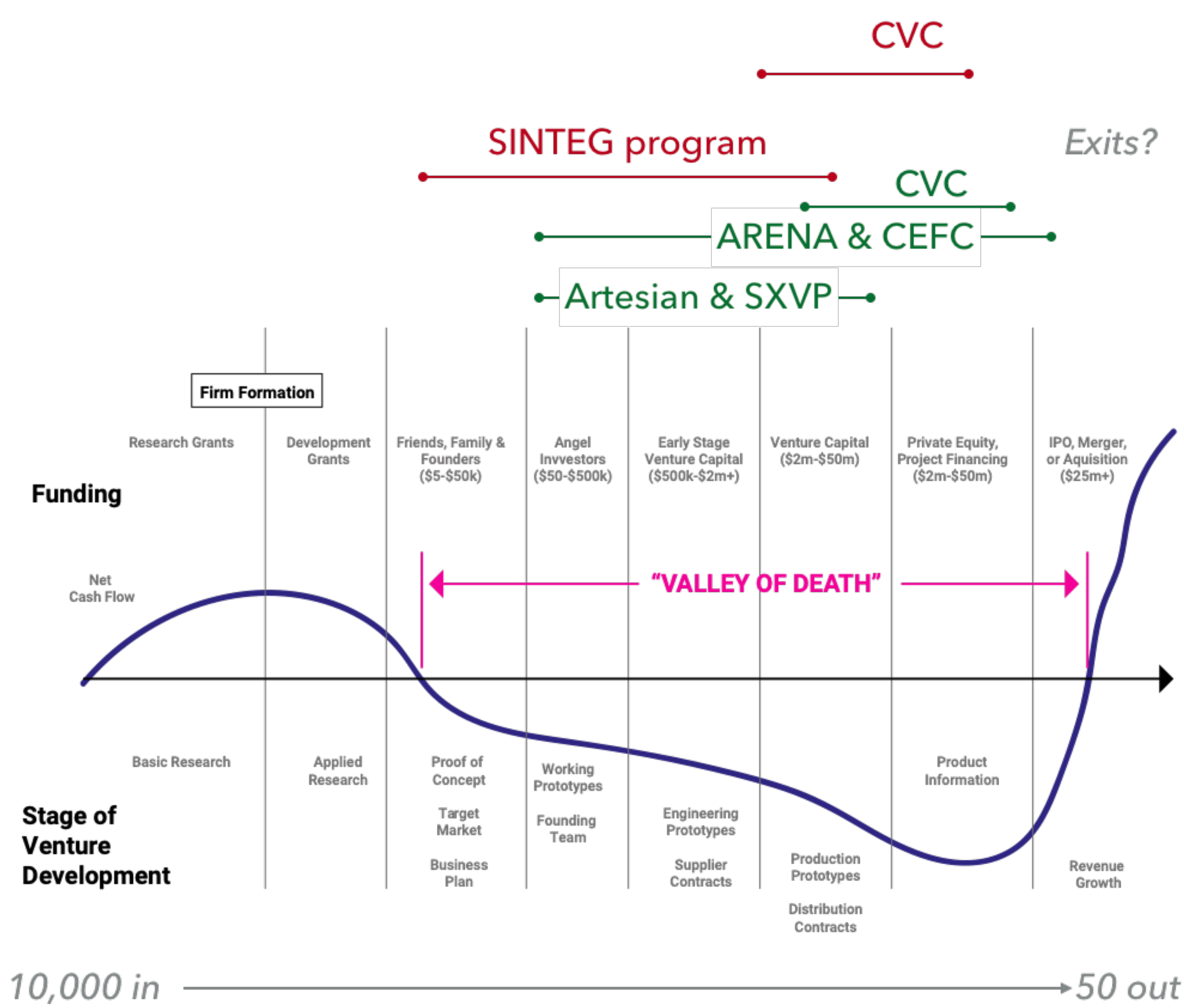

Figure 10: Capital providers assisting clean energy startups in Australia (green) and Germany (red) as startups navigate the valley of death (Bumpus and Comello 2016)

In comparison to Germany, Australia is not seen as an attractive opportunity for global investors in solar PV. Germany is at the heart of investor activity due to its stable regulatory landscape and continuous development plans for renewables. 32% percent of respondents saw Germany attracting the most investment in the near future, compared to only 1% for Australia (KPMG 2018).

As a result, bridging the ‘valley of death’ for clean energy entrepreneurs in Germany and Australia needs a combination of both public and private investors that are full scale – i.e. that are strategically aligned without gaps for startups as they move along their journey. Both Australia and Germany have existing public investment systems, and the private sector is emerging in the form of VC and CVC for clean energy. The material liquidity events (exits), however, of these startups are yet to be fully realised (see Figure 10).

4. Ecosystem support

Finally, technology advancements, and investment and market trends, are supported by a broader entrepreneurial ecosystem that binds incumbents, startups, financiers, markets, and society. A rich history of literature shows that without entrepreneurial ecosystems, broad-based systemic innovation opportunities are difficult to enable and sustain.

Startup ecosystems are complex and multi-dimensional. Supporting startups can bring multiplier effects to the economy and, in the case of critical landscape issues like climate change and the need for cleaner energy, enable future-proofing of positive socioeconomic conditions. These ecosystems to support digital energy entrepreneurship are critically important to incubate and accelerate startups.

To understand what makes startup revolutions possible, people tend to focus on numbers. Instead, the focus should be on the quality of life and unique specifics that each city can bring to a startup (https://valuer.ai/blog/top-50-best-startup-cities/).

In a digital world, geographic limits do not compel entrepreneurs as much as they did in the past; internationally connected accelerators, for example, enable entrepreneurs to access and reach new markets, which they can then service with their digital technologies remotely. Although local context is still important, global growth for digital energy startups is becoming a real opportunity.

Entrepreneurial ecosystems support these growth opportunities by enabling startups to gain footholds and move into markets strategically. This is a strong opportunity for policy makers. For example, the startup scene in Victoria could create AU$4 billion of economic value over the next several years. In a context where an estimated 40% of jobs could become obsolete within the next decade or so, this type of economic growth is essential to sustaining job security and economic opportunity (Startup Genome 2017). When startups become *scaleup firms* (as a few do) they create jobs both directly and indirectly. This is important as the economy transitions from value created through boom and bust cycles, including mining and real estate, to a knowledge economy driven by innovation and technology (including potentially clean energy fuelled manufacturing).

Technology jobs have a much higher multiplier effect than other sectors. Every technology job in a startup has been estimated by economist Enrico Moretti to create an additional five jobs in other parts of the economy, both skilled and unskilled. This is three times higher than manufacturing jobs. So, although technology startups may strike policymakers and others as small, especially when compared to large firms in mining and the sheer size of the real estate sector, they have a far higher reaching economic impact.

To take full advantage of entrepreneurial opportunity ecosystem, support mechanisms are needed to protect nascent business models and help startups turn into scale-ups that provide wider socioeconomic and environmental benefits.

4.1. Incubators and accelerators: Australia, Germany and international

In contrast to more traditional commercialisation ecosystem support mechanisms in the research-industry-government triangle, new digital energy innovations are emerging from a range of new innovation development forms including accelerators, incubators, hackathons, and bootcamps. These approaches can build on the existing support mechanisms for early-stage digital ventures that already exist, but enable more specialist advice, mentoring, and market engagement for the particular complexities of the energy sector.

Digital energy companies are finding homes in accelerators and incubators because of their capital light nature, ability to integrate and commercialise energy data, the ability to develop software and more generic IoT device-enabled platform technology, and their focus on customer engagement, rather than new deep technological or materials science breakthroughs.

As a result of the startup ‘thousand flowers bloom’ approach, a flurry of ideas exists. However, a far higher rate of attrition and company failure seems to exist due to unworkable business models and technologies that cannot integrate into the energy system, which is built on complex and incumbent processes with high regulation. Quality assurance in the startup pipeline is essential to achieve escape velocity for the nascent digital energy startup market and to prove to capital providers that ideas are worth allocating effort and capital.

Accelerators play an important role in enabling new ideas to turn into investable companies. Research has indicated that accelerators may enable companies to make mistakes faster, enable quicker and more effective product-market interaction, and therefore make early-stage capital investment more effective (Yu 2017). This is a critical element for a clean energy future, especially in a country like Australia where innovation inputs are strong, but outputs and commercialisation are weaker. In order to reach the Paris climate goals, emissions need to peak in 2020, and decline rapidly thereafter. The journey to 2030 needs to be, therefore, one characterised by rapid innovation and diffusion of clean energy generation and optimisation technologies.

"Digital technologies are also reshaping markets in Australia. Digital is increasing cross-sector competition, enabling larger technology players with low-cost ways of storing, transporting and replicating data to scale quickly into adjacent businesses and sectors. Apple is becoming a healthcare company and Tesla an energy company… Australia has a world-class pool of researchers, and an increasingly powerful technological toolkit, created by concurrent improvements in the performance and cost of complementary technologies such as genome sequencing, low-carbon energy, machine learning, AI, optimisation, visualisation, sensors and robotics." - Innovation and Science Australia 2017.

Incubators and accelerators have been shown recently to enable business model iteration, product-market fit, and enable coopetition between and within startup and incumbent companies. This is assisting in sociotechnical transitions associated with clean energy (Bumpus and Comello 2016).

Incubators and accelerators have, therefore, emerged to help foster a quality, investable pipeline of new energy ideas, and facilitate connection between existing incumbent energy retailers and new startup companies. As of 2018, Australian companies are connected into a number of domestic and international energy-specific focused accelerators, and both Australian and German companies are moving through a number of domestic and international accelerators (see Table 3 and Figure 11).

Similarly, cooperation with startups and innovation processes is one important aspect of the digitalisation process that utilities are adopting in Germany. Implementing new innovation processes is a topical in energy companies due to prominent examples from other sectors where new digital business models (uber, AirBnB etc.) currently challenge, in some cases even disrupt, existing business models. Innogy's Innovation Hub is an example of structures that enable utilities and startups to cooperate in pre-competitive scenarios to establish co-created opportunities for business model development. These networked incubators and accelerators enable connections between incumbent utilities and startups in different locations (e.g. startups from Australia interacting with utilities from Germany), access to markets through connections and specifically targeted events (e.g. modules that enable cross-collaboration), and facilitate capital raising (e.g. by 'vetting' startup quality and introductions to venture capitalists).

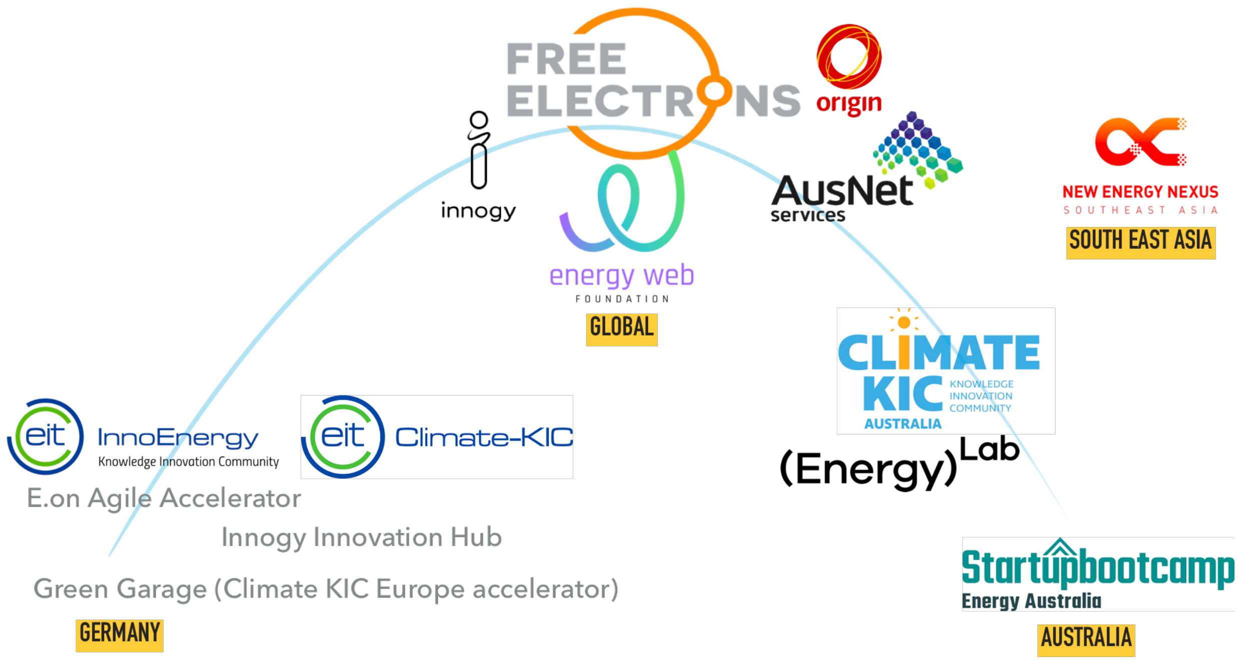

Figure 11: Examples of startup accelerators and incubators in Germany and Australia, and potential pathways for startups to link between accelerators in Germany and Australian through accelerators (e.g. Free Electrons) (Source: author).

Table 3: Examples of clean energy ecosystem accelerators and incubators in Australia, Germany, and international networked accelerators that link both jurisdictions. Note the list is non-exhaustive (source: author analysis).

Accelerator Name	Domestic/ Int'l	Year Started	Energy Specific	Location	Type of accelerator	Stage of companies	Sponsors	Capital provided	Business Support	Length of accelerator	Equity Taken	Examples of Startups involved
Energy Lab (also acts as accelerator for Climate KIC Australia)	Australia Domestic	2016	Yes	Melbourne, Sydney, Canberra, Brisbane	Non-profit	Early, pre-revenue, but with solid business plan	Origin Energy, Gov NSW, Artesian Venture Capital	AUD$50,000	Mentoring, workshops, resident desks	12 months	1-9%	Power Pal (Australia, Everty (Australia) Evolte. (Australia)
eighteen04	Australia Domestic	2015	Yes	Newcastle	Non-profit	Early, pre-revenue, but with solid business plan	TBC	Unknown	Desk space mentoring	Variable	0%	SwichedIn (Australia)
Victorian Energy Incubator	Australia Domestic	2018	Yes	Melbourne	Non-profit	Early deep tech hardware companies	TBC	Unknown	Engineering space	Variable	TBC	N/A
StartupBootcamp Energy Australia	Australia Domestic (but with international startups)	2017	Yes	Melbourne	Corporate	Early, but post-revenue	Energy Australia	AUD$25,000	Mentoring, workshops, resident desks	3 months	5%	WePower (Estonia), RedGrid One (Australia), Keewi (USA)
Climate KIC accelerator	Germany and EU	2010	Yes	Europe	Non-profit	Various but mostly early	EU and corporate	€20,000-50,000	Mentoring, workshops, resident desks	Variable	Unknown	N/A
E.on Agile Accelerator	Germany Domestic	2016	Yes	Essen	Corporate (internal)	Various	E.On	TBC	Desk space, mentoring, piloting within company	Variable	Unknown	
Innogy Innovation Hub	Germany Domestic	2016	Yes	Essen	Corporate (internal)	Early, but with focus on AI, machine learning, blockchain	Innogy	TBC	Desk space, mentoring, piloting within company	Variable	Leads investment rounds for startups	

Accelerator Name	Domestic/ Int'l	Year Started	Energy Specific	Location	Type of accelerator	Stage of companies	Sponsors	Capital provided	Business Support	Length of accelerator	Equity Taken	Examples of Startups involved
Green Garage (Climate KIC Europe accelerator)	Germany Domestic	2013	Yes	Berlin	Non-profit	Various but mostly early	EU and corporate	TBC	Mentoring, workshops, resident desks	Unknown	Unknown	
New Energy Nexus	International	2016	Yes	California; SE Asia	Hybrid	Various	CalCEF	Unknown	Network connections for startups.	N/A	N/A	N/A
Energy Web Foundation	International	2016	Yes and blockchain	International locations based on sponsors	Not accelerator, but supporting business development	Able to provide at least USD$25,000 joining fee (startups), $250k (coporates)	Multiple	N/A	Business development piloting with utilities	N/A	N/A	
Free Electrons	International (1 x 2 week bootcamp; 3 x 1 week modules)	2017	Yes	International locations based on sponsors	Corporate consortium		Origin Energy, Ausnet Services, Innogy (GER), SP Group (Singapore), TEPCO (Japan), CLP (China), EDP (Portugal), ESB (Ireland), DEWA (Dubai), American Electric Power (USA)	All travel expenses covered	Business development piloting with utilities	8 months (3 x modules)	0%	Jungle AI (GER); Fresh Energy (GER), Tempus Energy (UK), Simple Energy (USA)
Elemental Excellerator	International (based in Hawaii)	2013	Yes (but with other sustainability themes)	Hawaii	Non-profit	Scale ups	Emerson Collective; US Office of Naval Research			Variable		Allume Energy (Australia); Solar Analytics (Australia)

4.2. Challenges for the future

Although evidence suggests that accelerators for clean energy are helpful in supporting clean energy entrepreneurs, this remains largely anecdotal. Utilities are engaging with startups in accelerators, however, deployment of entrepreneurial business models at scale post-acceleration remains slow on the uptake. Government funding for accelerators (e.g. LaunchVic) and capital for startups (e.g. ARENA/CEFC) is helping to support the ecosystem, but challenges remain in fully connecting the research and commercialisation work of universities with entrepreneurial opportunities. More traditional entrepreneurial locations such as Silicon Valley continue to attract the majority of venture funding and opportunity (CB Insights 2018).

Ecosystem support to encourage the fundamental infrastructure to enable clean energy entrepreneurs, such as universal smart metering, rule changes to enable increased market competitiveness, and increased early-stage small scale financing for startups will be important to support the ecosystem actors (i.e. the accelerators and incubators) that in turn provide quality control and real market opportunities for the best ideas in digital energy innovation. Digitalisation often changes business models within several years, not decades. Planning in decades might therefore not be the right strategy for digitalisation in the energy sector, and faster movement of policy to enable entrepreneurs to take advantage of this, especially within the context of reducing emissions to net-zero by 2050, is essential.

5. Scenarios and recommendations

Following the analysis above and understanding the differences and opportunities for Australia and Germany in energy entrepreneurship, this section proposes potential scenarios and recommendations for supporting clean energy digital entrepreneurship. The focus here is on Australian scenarios for clean energy entrepreneurs and recommendations, which are highlighted in **Error! Reference source not found.**, under four scenarios:

1. Australia continues with current business as usual
2. The world follows the Paris Agreement but Australia does not
3. The world and Australia follow the Paris Agreement and strive to limit warming to 1.5°C
4. Australia decides to take a world-leading approach

Table 4: Recommendations for Australian clean energy entrepreneurship under four scenarios.

Digital energy technology context	Investment opportunities	Clean energy entrepreneurial ecosystem support
1. Business as usual		
• Participant but not particularly active in Mission Innovation • Some reform of energy markets to enable improved digital innovation but slow to implement • Smart meter roll-out remains at approximately 25% • Backbone of digitalisation and connectivity remains slow paced in growth (e.g. NBN)	• Limited capital investment from private sector: only two funds active in the space, and for 'swing for the fences' ideas entrepreneurs still need to go to USA or Europe • Accelerators continue to play a role in early stage seed capital • International VC capital can be approached but access is difficult • Initial Coin Offerings subsiding but remain an option for blockchain companies • IPO opportunities remain the same	• Government agencies (e.g. ARENA and CEFC) continue to fund limited work in the clean energy entrepreneurship space (e.g. A-Lab and innovation fund) • State and regional governments continue to support limited activities in startup ecosystems (e.g. LaunchVic) • Access to international accelerators (e.g. Free Electrons) as a result of Australian competitiveness remains the same

2. World follows Paris Agreement but Australia does nothing		
• Rollout of IoT and digitalisation technologies to support connected grid continue but not linked to energy nor at scale • Clean energy digital entrepreneurs gain foothold in other countries to enable experimentation and rollout of new technology and business models. Australian based tech experiments fall behind. • Other countries gain knowledge and use case testing advantage	• Improved investment continues to move ahead for international competitor, early stage Australian startups fall behind or leave for overseas • VC remains small scale in Australia due to lack of broader support for startup quality and quantity • Other countries' entrepreneurs tap into emerging structures of green finance	• International accelerators continue to engage with Australian utilities and business, enabling overseas startups to apply technology in Australia, but limited policy certainty hinders growth • Australian startups fall behind due to stagnant building of the entrepreneurial ecosystem • Entrepreneurial activities remain piecemeal
3. Australia follows the Paris Agreement		
• Leading by example for entrepreneurship that supports 1.5°C ambition, i.e. active member of Mission Innovation • Enables faster market reform to assist in digital energy business model development • Broader communications activities with industry and public on the opportunities for clean energy entrepreneurship to overcome 'tall poppy' syndrome • Australian startups are able to follow, keep pace, or effectively compete with international startups working in the Australian landscape	• Improved incentives (e.g. tax credits, more accessible innovation funds) targeting the intersection of digital and clean energy innovation • Connect investment directly with entrepreneurial activities/ courses/bootcamps/hackathons in TAFE and higher education • Improved opportunities for discussion and action to connect institutional investors (e.g. superfunds) to digital clean energy entrepreneurs • Australian startups better able to engage international markets through increased use of smart money	• Government and energy actors recognise the problem in early stage clean energy support • Government support to early stage ecosystems ramps up to include effort to coordinate research institutions, universities, corporate innovation, and entrepreneurial activities (business creation, product-market fit, PoCs, and pilots) • Enables potential clean energy entrepreneurs from different fields to see a pathway to commercialisation through the ecosystem
4. Australia takes a world leading approach		
• Supporting multiple but differentiated regions to support entrepreneurial activities • Full reform of energy markets at a faster pace to enable more digital business model experimentation (C4NET in Victoria becomes leading model for engaging smart meter data) • Complete penetration of smart meters and encouragement of multitude of smart IoT devices through experiments • Pathways to market with incumbents encouraged through pro-entrepreneurial regulation	• Development of special purpose government early stage investment fund to create opportunities for startups, associated and building with existing finance mechanisms • Support existing and new classes of early stage investors through government co-investment with Angel Investors and dedicated tranches of institutional investors to support entrepreneurs with high realised potential • Takes on world leading tax credit opportunities for all stages of entrepreneurs	• Significant capital investment in early stage formation of energy entrepreneurial ecosystems • Top Australian financial, energy, and startup mentors collaborate to assist the growing ecosystem • Multiple connected ecosystem players enable ideation-to-commercialisation startup scaling • Strong participation from states, cities, and incumbent energy companies means that the startup energy ecosystem in Australia becomes the 'Clean Energy Commercialisation Capital' of the world. Rivals Silicon Valley in terms of capital deployed, talent retained, and innovations commercialised

6. Conclusions

Both Australia and Germany are beginning to enable a sustainable context for clean energy entrepreneurial activities. The ecosystems that are developing bring together the opportunities from both digital and clean energy innovation and entrepreneurship. Both countries, however, face challenges in enabling new entrepreneurial activities to scale up at the time frame needed to (a) keep startups alive and (b) reduce emissions to enable a safe climate. Drawing on the above analysis of Germany, the conclusions and recommendations here are focused on the Australian market.

6.1. Conclusions

From 2019 to 2030

Digital energy technologies and new business models are emerging rapidly. Key issues that concern incumbent energy company executives are AI and blockchain. Although these technologies are being tested, production level application (i.e. commercially viable and rolling out at full scale) of both AI and blockchain currently still remain at the Proof of Concept (PoC) or pilot phase. This is, however evolving, as the costs of fundamental hardware (e.g. production and storage of clean energy) reduce faster than anticipated, and incumbents continue their involvement with accelerators to explore digital energy solutions that show optimisation and new business model approaches are profitable.

The digital backbone for digital clean energy in Australia, like Germany, lags in the deployment of digital infrastructure; in particular, smart meters with access to data that enable new business models to be developed. Alongside complicated privacy regulation, ownership, and difficulty for access to smart meter data, the digital infrastructure poses a barrier to full opportunities in digital energy entrepreneurship. These opportunities are evolving, however, in a changing landscape where consumers can choose their own smart meters, and retailers face the pressure of instant switching at the smart meter level and the challenge to look for new business models to take advantage of more nuanced data. The Default Market Offer (DMO) mandated by the Australian Federal Government in 2019

(AER 2019) highlights the push to enable customers to be better informed on their energy provider, and combined with the Power of Choice legislation in 2017 (AEMO 2017), allow consumers to choose the cheapest option using their smart meter data combined with open market information.

Investment is improving to support entrepreneurs, with both Australian and German governments investing in energy entrepreneurship programs, activities, and regions that specifically target energy entrepreneurs. For example, dedicated innovation funds exist in Australia including government and private venture capital co-investments (e.g. ARENA and CEFC). The German government seems to be investing more heavily in region-based entrepreneurial support (e.g. the SINTEG programme) and, importantly, bringing smart cities, digital infrastructure, and 'whole of economy' innovation and entrepreneurial opportunity together. Australia can learn from this approach; digital energy will not just affect the electricity sector, it is the broader digital society transformations that it will enable that will further drive emissions to zero. For example, Germany's Power-to-X approach is gaining traction and holds potentially large gains for entrepreneurs with new hardware and software to optimise these systems, as noted in the electrifying industry report from Beyond Zero Emissions (2018). Focusing on the entrepreneurial opportunities across industries and building on existing regional industrial capabilities pose strong policy opportunities to support a wide range of Australian entrepreneurs.

Entrepreneurial ecosystems are developing in both Germany and Australia, and between the countries through the private sector. Ecosystems combine investment opportunities, build on the research-industry-government triangle for commercialisation, and include important intermediary actors such as accelerators and incubators. As a result, new digital energy innovations are emerging from a range of new innovation development forms including accelerators, incubators, hackathons, and bootcamps. These approaches can build on the existing support mechanisms for early-stage digital ventures that already exist, but enable specialist advice, mentoring, and market engagement for the energy sector.

International accelerators jointly formed by utilities are enabling more specific and active international entrepreneurial activities with and between utilities. For example, Innogy from Germany and Origin Energy from Australia have opened a joint office in Silicon Valley to scout for mutually beneficial investments in clean energy (AFR 2017; Innogy 2017). CVC is supported by forward thinking incumbent corporates not as a method of capture and destroy, but as an opportunity to build internal capabilities to deal with the 3Ds of the electricity system. Further connectivity and collaboration between Australian and German corporates, like the Innogy and Origin approach, will likely open up more financial and technological rewards over the next decade or so as digital energy solutions proliferate. As such, although Australia seems to lag in CVC deployment to startups as investments compared to Germany, vehicles like the Free Electrons accelerator are enabling CVC in both countries to improve access to entrepreneurs.

The digital energy entrepreneurial ecosystem will be a critical petri dish component for new energy innovations moving toward 2030. For Australia, a strong research-investment capital-industry opportunity nexus is especially important given the large differential between inputs of innovation and commercialisation of outputs. Networked incubators play an important role in enabling connectivity between startups and incumbent companies, regions, and as conduits of knowledge, capital, and human resources flows (Chesbrough, 2003). To develop commercial and economic advantage to 2030, these ecosystems in Australia need to be supported and nurtured, and *further connected* to those in countries like Germany, that are already developing differentiated by connected entrepreneurial ecosystems. Connections through large networked accelerators like InnoEnergy and Climate KIC Europe and Australia open opportunities for improved open innovation and commercialisation.

Moving from 2030-2050

Predictions toward net-zero in 2050 are harder to envisage but assumptions can be made on key attributes of the clean energy entrepreneurial ecosystem that will be in place to enable continued innovation. Clean energy entrepreneurs (who will be simply energy entrepreneurs) will look to find profits and opportunity in value-added services that benefit customers through Power-to-X energy use for productive purposes, automated transactions between variable load uses, and donation of energy value from surplus to deficit areas of the world.

Technology scenarios resemble:

- Continued march toward near-zero marginal cost electricity enabled by ubiquitous IoT technology (Rifkin 2014; Ehret and Wirtz 2016)
- Prosumers, some with storage, likely participating directly into the wholesale market that includes direct interaction through IoT technologies
- A more seamless digital energy landscape that enables the effective use of this electricity through seamless data

- AI that enables perfect information and near perfect transmission (internet of energy) leading to ubiquitous energy economic efficiency
- A proliferation of use cases for distributed ledger technology (i.e. blockchain and post-blockchain like Holochain) that enable smart asset integration and optimisation of energy technologies within a network

For investment, capital provisions will be in place from the private sector to support clean energy entrepreneurs and innovation as 2020-2030 entrepreneurial ideas become product level mainstream investments. Venture capitalists will search for 10x better opportunities targeted at continued digital innovation, value-added services, and new productive use of electricity in early-stage companies. Institutional investors will have broader portfolios that include publicly listed clean energy tech companies in addition to new economically productive companies that are built off the universal clean energy infrastructure in place.

Ecosystem support for clean energy technologies will have merged with mainstream ecosystem support for early-stage companies in general because of the cross-cutting nature of the economic structures and power availability in the future grid. Focus will be on business model development and associated lateral thinking to use electricity in new productive ways, for example across different sectors. The ecosystem will continue to enable incumbents to work with new entrepreneurs (incumbents will also be fully digital electricity enterprises), and support at a government level to ensure continued progressive reform of regulation to enable market forces to drive continual innovation toward global net-zero emissions before 2050.

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