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Jumping into the Future: The Transition Towards a Decentralised Energy System in Australia

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Abstract

Australia is facing a critical energy crisis with its Centralised Energy System failing to provide reliable, sustainable and affordable energy. This dissertation identifies a paradigm shift in the drivers for energy which enables a new path to be taken towards a Decentralised Energy System that will provide a more secure and sustainable energy future. This study employs path dependence theory in analysing the legacy of coal-fired generation to determine whether this carbon lock-in can be broken. Multi-Level Perspective framework is used to evaluate the extent to which actors in government, the energy market, and energy communities will influence this transition. This dissertation identifies dynamic changes occurring with the rise of Distributed Generation coinciding with the ageing of coal-fired generators, and this, coupled with favourable economics, will diminish the dominance of the Centralised Energy System. Despite inherent conflicts with the bottom-up approach of technological niche and energy community actors providing more competition, energy market actors are changing their business models with a move towards decentralised energy assets. The energy sector would normally look to the federal government for certainty in policy for confidence to invest, but instead, state governments have taken the initiative in driving their own policies that has involved collaboration with actors on decentralised energy projects. The South Australian state government has provided a pathway to this transition with their long-term Renewable Energy Targets which have attracted investments including the collaboration with technologist actor Tesla in developing the world's largest Virtual Power Plant. The transition will not be linear due to the high conflict potential linked to the legacy of the existing energy system; however, landscape factors with the need to solve the 'energy trilemma' along with the binding COP21 emissions targets, will likely push actors to cooperate and thereby enable Australia to transition towards a Decentralised Energy System.

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Table of Contents

List of Acronyms

ALP	Australian Labor Party
BES	Battery Energy Storage
CCS	Carbon Capture and Storage
CES	Centralised Energy System
CET	Clean Energy Target
COAG	Council of Australian Governments
COP	Conference of Parties
DES	Decentralised Energy System
DG	Distributed Generation
ETS	Emissions Trading Scheme
EV	Electric Vehicle
FIT	Feed-In-Tariffs
GHG	Greenhouse Gas
HV	High Voltage
LCOE	Levelised Cost of Electricity
LNP	Liberal National Party
MLP	Multi-Level Perspectives
NEG	National Energy Guarantee
NEM	National Electricity Market
NSW	New South Wales
PM	Prime Minister
PS	Power Station
PV	Photovoltaic
SA	South Australia
T&D	Transmission and Distribution
TIC	Techno-Institutional Complex
VPP	Virtual Power Plant

Introduction

On September 28, 2016, a storm billed by the Bureau of Meteorology as a "once in fifty years event" (Waldhuter, 2016) caused significant damage to multiple High Voltage (HV) transmission lines and as a result plunged the state of South Australia (SA) into complete darkness (Figure 1). The state-wide blackout disrupted communities and businesses as it took several days for full restoration of electricity along with resulting in damages to the state's economy with an overall financial loss of $367m (Owen, 2016). This prompted the Prime Minster (PM) of Australia, Malcolm Turnbull, to declare that the number one rule had to be keeping on the lights with secure and reliable energy and only days after the SA blackout, an emergency meeting was called upon by the Australian federal government[1] requiring the attendance of all state energy minsters to address Australia's power system security (Starick, 2016). The agreement between the federal and state governments was that an independent review[2], chaired by Australia's Chief Scientist Dr Alan Finkel, would be commissioned by the Council of Australian Governments (COAG)[3] to provide a blueprint of Australia's energy security and reliability.

Figure 1. *Satellite image of Australia taken on September 28, 2016, shows the blackout across the state of South Australia and the aftermath of the Storm that damaged Transmission Lines which trigged the blackout* (RNZ, 2016)

[1] Australian Federal Government is run by the Liberal National Party (LNP)
[2] Independent Review into the Future Security of the National Electricity Market also known as the "Finkle Review"
[3] The COAG is made up of federal and state government members with its role to provide policy leadership for the Australian gas and electricity markets (see Appendix A for the COAG relationship with various energy institutions in Australia).

Energy is the lifeblood of a modern society and without the reliable supply of energy, all other sectors of the economy can be halted which is why Australians expect and fully depend on a secure, robust and dynamic energy system (Bradley, 2003). Considering that energy security and reliability are key priorities for Australia, could a transition towards a Decentralised Energy System (DES) [4] contribute to stabilising the supply of energy and avoiding such dramatic blackouts? With the DES relying on Distributed Generation (DG), this greatly increases national energy security by eliminating the serious risks inherent to long transmission lines such as severe weather events, and the reliability gain of diverse DG avoids potential power failures of centralised baseload generation (Guevara-Stone, 2014).

Although the Finkle Review's initial focus was on energy security, there were other pressing concerns in relation to energy. This was, namely the requirement to reduce emissions and access to affordable electricity (Nance, 2017, p. 8). Indeed, Poudinesh and Jamasb (2012) show that in most countries, energy policies are designed to create an energy sector that supports the security of supply as well as sustainability and provides affordable energy to consumers. However, even the most ideal energy sector faces the challenge of meeting those objectives simultaneously as achieving any of them involves trade-offs with the other two (p. 2). This creates an 'energy trilemma' (Figure 2) which represents a major challenge as the energy sector transition leads to an increase in the complexity and the dynamics of managing the three trilemma dimensions (World Energy Council, 2017, p. 23).

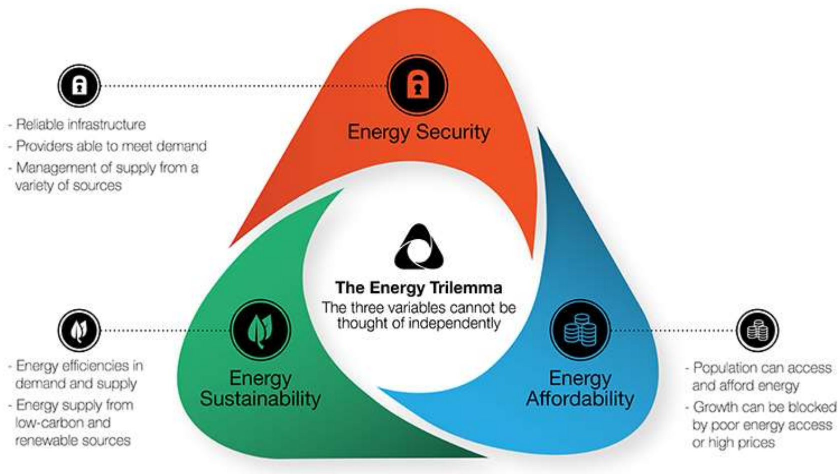

Figure 2. *The Three Dimensions of the Energy Trilemma* (Energy Post Weekly, 2017)

[4] This dissertation uses the term "Decentralised Energy System" (DES) which encompasses a diverse array of generation, storage, energy monitoring and control solutions incorporated in a smart grid that allows for the bidirectional flow of energy (see Appendix B for more on the DES).

The Current Energy Situation in Australia

Over the past decade in Australia, energy has been the most divisive topic in the political landscape between the two biggest parties, the Liberal National Party (LNP) currently holding office and the Australian Labor Party (ALP) currently in opposition. However, there is no argument on either side of politics about how the nation should address the 'energy trilemma'.

Energy security entails Australia's ability to provide sufficient energy to support economic and social activities along with ensuring reliability with minimal disruptions to supply (Yates & Greet, 2014). The current energy supply faces pressures with expected closure of ageing coal-fired power stations (PS), risk of supply of gas along with the variable extreme climate that can damage energy infrastructure (AEMO, 2017). A DES would improve Australia's energy security by covering the energy demand with its diverse and decentralised DG (Dustan et al., 2011, p. 52). In addition to the energy security issue, the sustainability of the energy sector requires attention. Australia has the highest per capita emissions in the OECD (Nance, 2017). The emissions intensity is high primarily due to the electricity sector contributing a third of Greenhouse Gas (GHG) emissions, with coal making up the majority of Australia's energy generation mix at approximately 78% (Figure 3). The need to reduce emissions for energy sustainability has seen Australia make an international commitment to reducing global emissions at the Paris Conference of Parties (COP) 21 where it pledged to reduce GHG emissions to 26-28% below 2005 levels by 2030. Reduction of GHG emissions could result in the implementation of DES with low-emissions DG, the integration of energy storage along with reducing energy consumption through digitalisation measures (iGrid, 2011, p. 10).

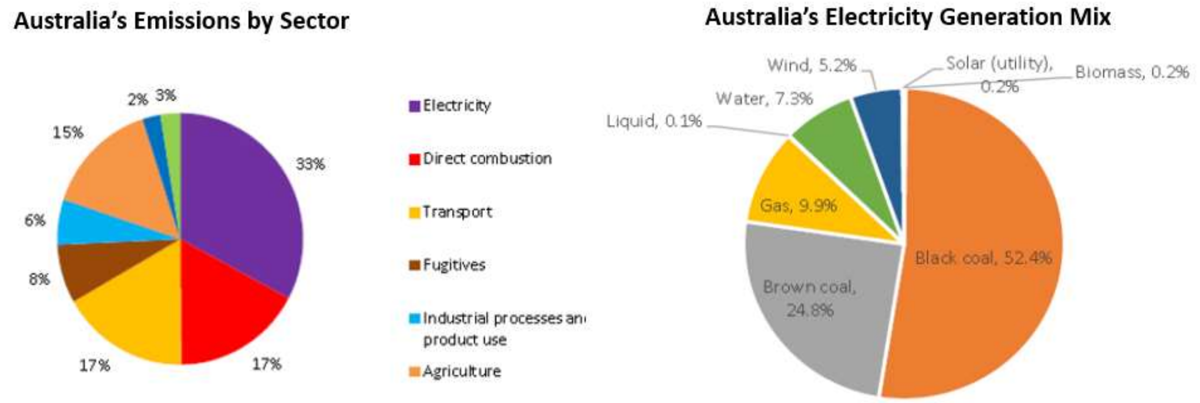

Figure 3. *Australia's Greenhouse Gas Emissions by Sector & Electricity Generation Mix* (Commonwealth of Australia, 2017, p. 4)

Moreover, Australia has experienced a rapid electricity price rise over the last decade (Figure 4), where average prices have increased by 63% which has prompted the Australian Competition and Consumer Commission to note that there is a severe electricity problem. This price increase in electricity has not matched the wage growth over the period and has placed economic pressure on consumers (Murphy, 2017a). The network costs which consist of the Transmission and Distribution (T&D) of electricity are the primary reason why there is an energy affordability issue as this represents approximately 45% of the average electricity bill (Nance, 2017, p. 13). Shifting peak load by demand response through shifting consumers' energy consumptions can be implemented by a DES that could result in reducing electricity pricing (W. Priest[5], personal communication, February 27, 2018).

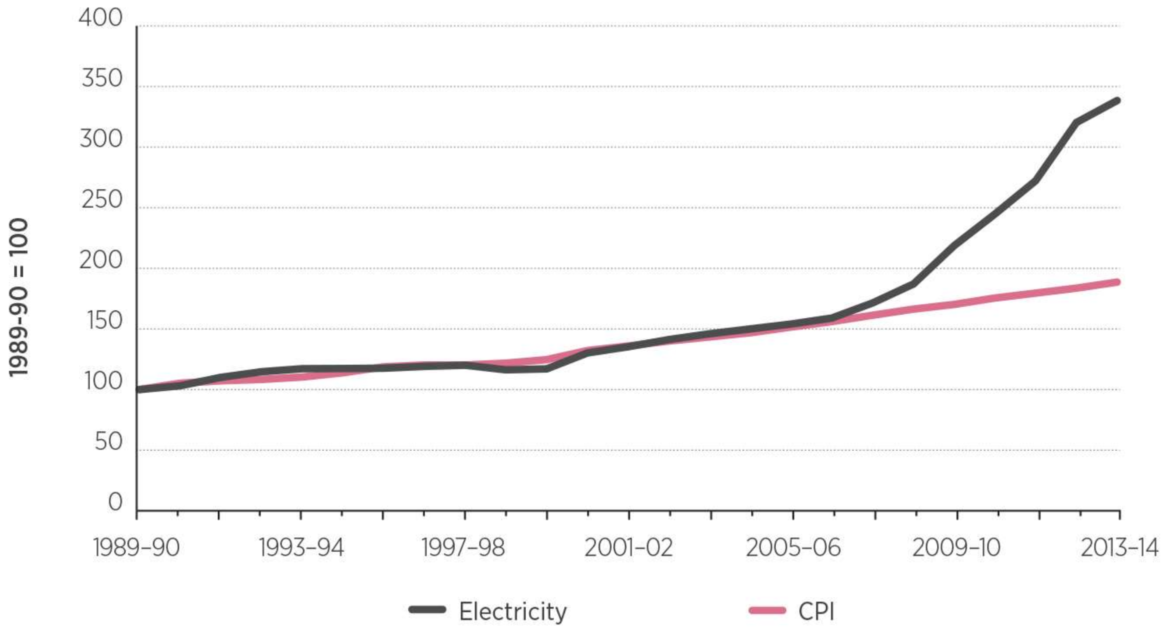

Figure 4. *Australia's Retail Electricity Price Index* (Australian Bureau of Statistics, 2014, p. 22)

PM Turnbull posed the question of how energy can "deliver the trifecta of secure and affordable power while meeting our emission reduction commitments" (Hewson, 2017). This dissertation argues that the answer is for Australia to transition towards a Decentralised Energy System. A DES can be deployed to solve the 'energy trilemma' (Figure 5), in the view of Dustan et al. (2011), by securely and reliably meeting the nation's energy needs whilst reducing GHG emissions and saving on energy costs for consumers (p. 20).

[5] Interview with Warner Priest, Head of Emerging Technologies, Siemens Australia

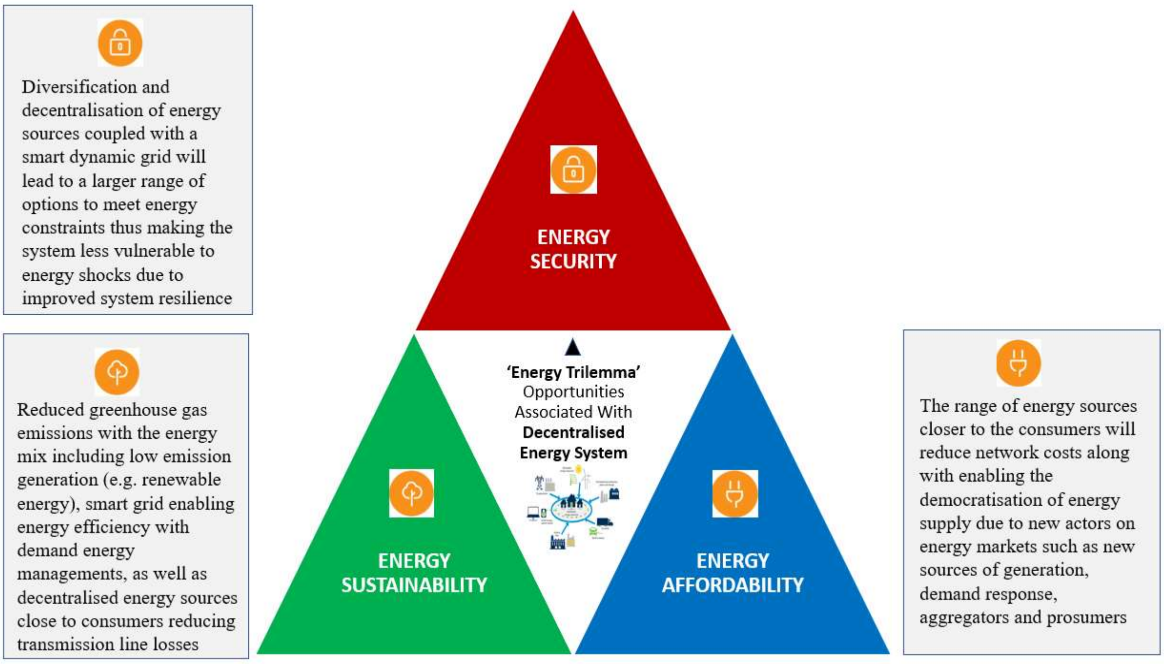

Figure 5. *The 'Energy Trilemma' opportunities associated with a transition towards a DES* (elaborated by the author)

A Country Relying on Centralised Energy System

For decades, Australia's electricity sector, just like most across the world, has operated on a model of large-scale centralised thermal-based generators (e.g. coal-fired PS) that are co-located with the major sources of fuel (e.g. coal) to distribute the energy supplies to consumers through HV transmission lines. Over the years, the Centralised Energy System (CES) has provided quality electricity supply for Australia. However, due to the high level of T&D integration, CES can be vulnerable to disturbances within the network such as blackouts. In addition, they can be costly as T&D power losses equate to $4.5 billion nationally (Dunstan et al., 2011, p. 55). The once clear advantages of CES are quickly declining primarily due to the impact of climate change from the GHG emission intensive fossil fuels, insecurities of an ageing coal-fired PS fleet, and high costs of the expansive electricity grid.

Long-term drivers mean, firstly, that the energy market is now changing with the demand for energy growing in Australia with a rise of 2.3% between 2015-16 and on average energy consumption has been growing by 0.6% over the past decade which is a trend that is expected to continue considering the Australian population has an average annual growth rate of 1.2-1.4% (Department of Environment and Energy, 2017, pp. 8-12). Secondly, there is the pressing need for sustainability of the energy system. This can be achieved by replacing Australia's ageing energy infrastructure which is illustrated by the Climate Council (2014) noting that half of Australia's coal-fired PS beyond 2020 will be too outdated, inefficient and carbon intensive to be retrofitted with emissions-decreasing technologies such as Carbon Capture and Storage (CCS) (p. 70). Thirdly, with the emergence of innovative, smarter technology, consumers are now more informed about their energy usage and can become energy producers and storers themselves, that is being 'prosumers[6]', resulting in a bidirectional flow of power (Mouat, 2016). To handle all these drivers, there needs to be a systematic optimisation of the energy system. This is where the DES with its diverse and decentralised low-carbon generation, smart grid infrastructure and distributed energy management systems will be essential (A. Pears[7], personal communication, October 3, 2017).

A Switch Towards a Decentralised Energy System?

DES is a broad term that is used widely in differing contexts. In this dissertation, DES refers to an energy system where the electricity is generated at or close to the point of use and is connected to the local network (Figure 6) (Greenpeace, 2010, p. 15). The components of DES are depicted in Figure 7. DES encompasses DG from low-carbon such as renewable sources. Energy storage allows for a smooth energy profile along with enabling the DES to be resilient when there is a lack of resource. The management of the diverse energy generation to the consumer is done by smart grid where, in turn, prosumers can contribute to the energy mix due to the bidirectional flow. Digitalisation unlocks the management systems in managing peak energy demand and increasing energy efficiency, thus creating a smooth energy profile to enable less stress on the network which allows for the reduction in emissions and electricity pricing.

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[6] To ensure reader comprehension, "consumers" will be defined here as users who consume electricity and "prosumers" as users who both consume and produce electricity (European Parliament, 2016)

[7] Interview with Alan Pears, Senior Industry Fellow (Environment and Planning) at RMIT University, member of the Advisory Board for the Climate Alliance and co-director of Sustainable Solutions (environmental consultancy)

Figure 6. *Decentralised Energy System generates electricity close to the consumers* (Arup & Siemens, 2016)

Figure 7. *Decentralised Energy System Technologies* (Arup & Siemens, 2016, p. 14)

With the traditional CES, generation follows load, but to meet the drivers for the future energy system a DES is required where instead load will follow generation (Figure 8). One prime example, elaborated by Siemens, are Electric Vehicles (EVs) that can be charged or operated at night drawing on cheap wind power. There is a paradigm shift towards leaving the unidirectional CES energy flow behind for a bidirectional DES energy flow (R. Apel[8], personal communication, March 16, 2018). Energy consultant actor Poyry states that "the world is moving towards decentralised energy" (Bradbury, 2017). This dissertation examines whether Australia can transition towards a Decentralised Energy System.

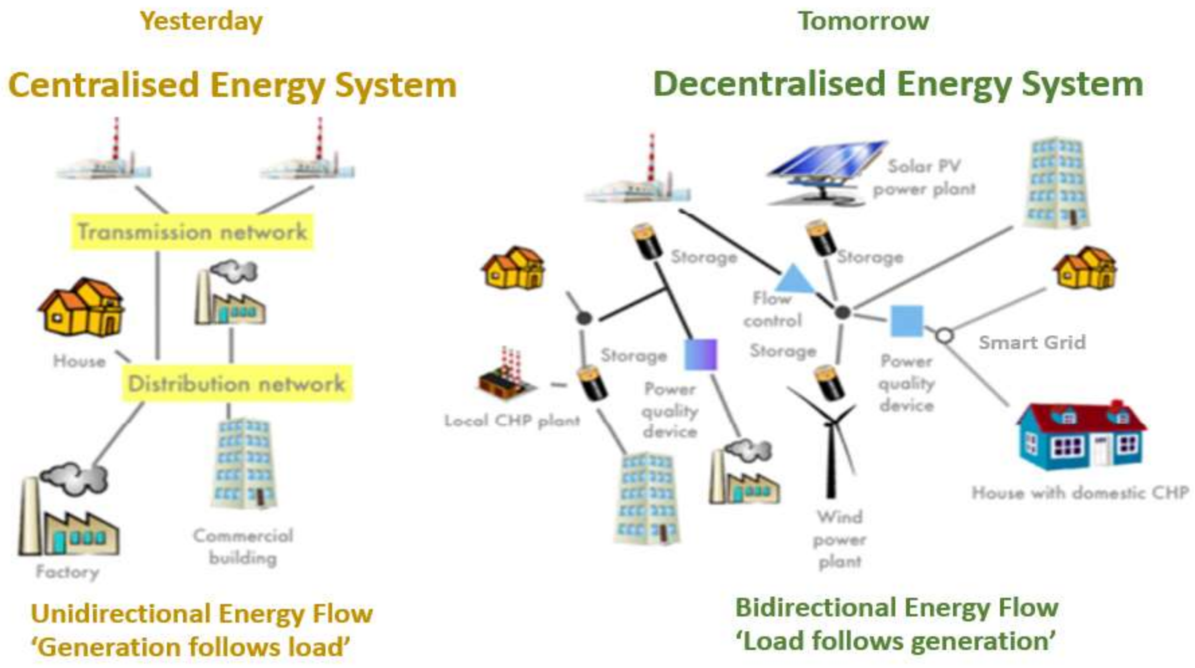


Figure 8. *The paradigm shift from a CES comprising of large-scale generation & transmitted over HV network to a DES which enables local clean energy generation & storage* (Farrell, 2011)

To answer this question, the first chapter expounds on Australia's dependence on coal as an energy resource using path dependence theory to formulate the extent of the carbon lock-in effect of the CES. The chapter further explores the dynamic changes that could break the lock-in and would allow Australia to change paths towards a DES. The second chapter introduces the Multi-Level Perspective (MLP) analytical framework to identify and analyse the actors' conflicts and collaboration in this transition. Moreover, this chapter examines the influence of actors in government, the energy market, and energy communities will have in transitioning towards a DES.

[8] Interview with Dr. Rolf Apel, head of technology and innovation strategy, Siemens AG

This dissertation employs a deductive approach in the first chapter to analyse the legacy of the CES in Australia by using path dependence theory to understand the carbon lock-in effect. To investigate the dynamic changes in changing paths along with the role of different actors in the transition towards a DES in the second chapter, this dissertation focuses on an inductive approach. The data used for this dissertation was both qualitative and quantitative and took the form of interviews with energy actors and meta-research from both national and international sources respectively.

Building on this analysis, the third chapter then addresses the challenges and opportunities in the energy system shift. Here, a comparison between the two energy systems is used to determine the best solution for the Australian context. Finally, this dissertation concludes by expanding on the finding and providing recommendations that will allow Australia to transition towards a DES.

Chapter 1. Energy Systems: Legacies and Changes

"The Lucky Country" a term often used to describe Australia, was first coined by the Australian writer Donald Horne (1964) due to a multitude of factors including its nature and wildlife, the sun to enjoy its white sandy beaches, enough space for a small population, a strong and growing economy, no hostile neighbours and opportunities for all (pp. 13-27). This term is also applicable in terms of energy since the country is blessed with an abundance and diversity of energy resources (Figure 9). Nethertheless, Australia's self-sufficiency for electricity is heavily reliant on coal. The nation's first coal-fired PS, Yallourn, was built in 1924 when the state of Victoria utilised its vast lignite coal deposits in the Latrobe Valley (CIGRE, 1996). Electricity was produced and transmitted along long distance HV transmission lines to the city of Melbourne. Since then the growth of coal for the use to generate electricity has significantly increased, so much so that coal currently makes up the majority of the Australia's energy mix

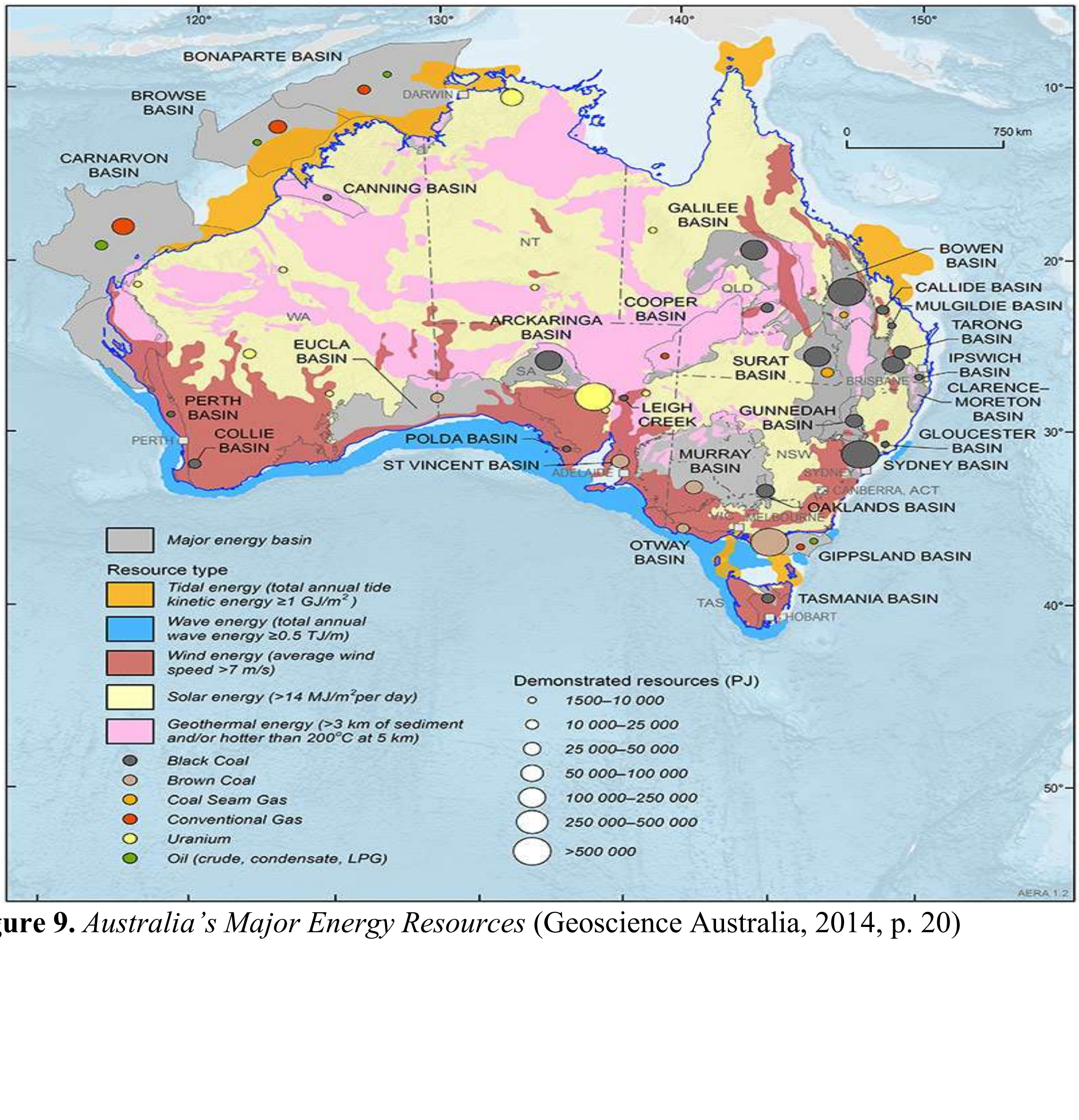


Figure 9. *Australia's Major Energy Resources* (Geoscience Australia, 2014, p. 20)

The most prevalent explanation for the dominance of coal in the Australian energy sector is based on the location and quantity of the energy resource. Australia's existing electricity generation is derived from coal-fired PS that were built next to coal reserves which makes coal cheap to exploit as it is cheap to mine (Marar, 2018). Most of the coal reserves are located on the east side which is in correlation to where the greatest demand for electricity resides as although Australia is a vast land it has heavily urbanised areas with 80% of its population residing on the eastern seaboard (Australian Bureau of Statistics, 2016, p. 46). There is an abundance of coal with Australia being the third-biggest producer of coal globally (Geoscience Australia, 2015). This dissertation argues that the reason why coal dominates the Australian energy sector is its path dependence which causes carbon lock-in of the CES using coal-fired PS for its electricity generation. Perry (2012) defines path dependence as "current technologies and systems depend on historical circumstances and not necessarily efficient resource allocations" (p. 3). The path dependence argument suggests that the decision to build these coal-fired PS reflects the accumulation of historical events to which over-time is a greater factor rather than just the location and quantity of the energy resource in coal (Meng, 2014, pp. 1-5). This has led to a carbon lock-in of CES in Australia that may explain why a change to DES can only be incremental as it is dominated by interests deeply rooted in the reliance of coal for its energy generation.

1.1. Australia's Path Dependence: Centralised Energy System

The theory of path dependence was originated in economics to explain technology adaptation processes and industry evolution (Arthur, 1989; David, 1985). There are numerous connotations related to the concept of path dependence however, the consensus amongst scholars is that the expression "history matters" relates to path dependence in that there are dynamic processes that can be described as evolutionary (David, 2000). There have been many technological developments that have experienced path dependence and lock-in effects such as the steam train, Alternating Current, and the QWERTY keyboard (Arthur, 1989; Unruh, 2000).

To understand the path dependence of Australia's current CES, this dissertation analyses the initial driving factors for the demand of CESs since path dependence as suggested by Sewell (1990) means that "what happened at an earlier point in time will affect the possible outcomes of a sequence of events occurring at a later point in time" (p. 16). The driving factor for the demand of CES in Australia was its reliability whilst there was an increase energy demand. The inability to install new generating capacity during World War II to meet the increased energy demand during post-war years contributed to significant power outages across most of Australia. Meanwhile, the energy demand rose steeply as analysed by Butler (2017) due to the government aggressively pushing the expansion of industrial capacity were established to underpin Australia's industrialisation, as well as to guarantee Australia's economic security in the Cold War period (pp. 61-67). At the same time, Australia's population grew rapidly, and households were using the relative wealth of the post-war boom to purchase devices like washing machines and refrigerators that had previously been beyond their reach. Following the need to address the issues of reliability and increase in demand for energy, Australia saw one of the most rapid expansion phases in the history of its energy sector with the construction of generators, coal-fired PS, and the expansion of the electricity grid from the 1950s to 1980s. Therefore, most of the coal-fired generation that is being used to power Australia today was built during those four decades.

1.1.1. Increasing Returns

During the early phase of the technological adoption of a system like CES, the notion of increasing returns that is a condition of path dependence can lead to a technological lock-in. Pierson (2000) states that in an increasing return process "the probability of further steps along the same path increases with each move down that path" (p. 252). The increasing returns process incorporates positive feedback (ibid.) which occurred during the expansion period of the CES in Australia where a supply chain including the local manufacturing and construction industries continued to support and develop this system to build on their economic gains. The positive feedback effect on coal being used for energy can be further illustrated where the Australian Mining Industry in 1965 spent $22 million on the exploration of coal and by 1982 this had increased many-folds to $576 million as the CES became locked-in the energy sector (Australian Bureau of Statistics, 2001).

The increasing returns process is further illustrated by Unrah (2000) where the S-curve model in Figure 10 represents the evolution of the performance and cost in relation to the technology scale of adoption (p. 820). In economics, there is a focus on the upper curve placing an importance on long-run equilibrium returns. However, path dependence is developed in the lower curve where increasing returns are most influential during the early implementation. Positive feedback can give a technology the right conditions of favourable timing or historic conditions that can lead to technological lock-in (Arthur, 1994). In Australia both those favourable conditions have played a part in the lock-in effect of the CES. Australia's population doubled between 1955 and 1985 whilst CES was being integrated where coal-fired generation capacity expanded more than ten-fold (Butler, 2017, p. 62). The "energy boom" of the 1970s and 1980s was largely driven by the energy sector as this was related to the second oil price shock in the late 1970s which increased the cost of energy globally (Battellino, 2010). Australia capitalised on these shocks by increasing its energy-intensive activities in industries such as aluminium which enabled it to become competitive on the global market due to the prominent use of coal for generation.

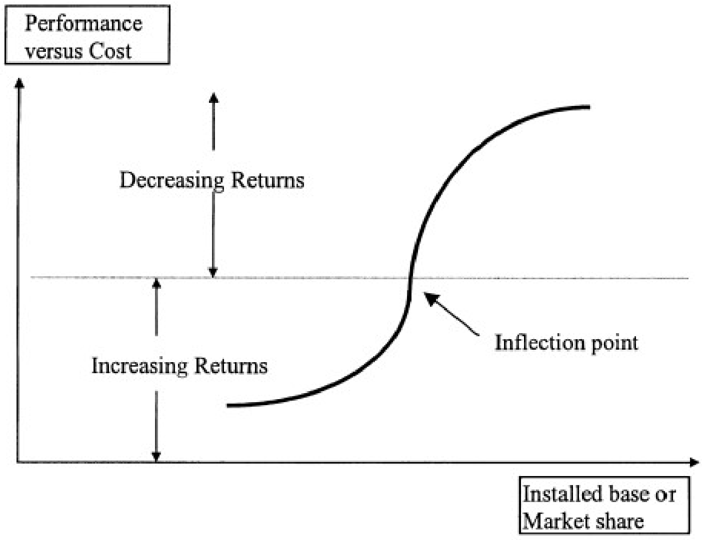


Figure 10. *S-Curve Model of the performance-to-cost ratio as a function of the level of adoption. Once a technology reaches a critical mass in the early stages of adoption, there are increasing returns that provide positive feedback leading to a technological lock-in* (Unruh, 2000, p. 820)

Another form of increasing returns for the CES is that this is an economy of scale[9]. This is a core feature with increasing return for the current CES model which is based on the Edison-Insull model[10]. This concept saw electricity price reduction through the economy of scale where it is most economical for a single entity to provide all services in a geographical area (Pechman, 2016, p. 6). In the context of the Australian CES there was further economy of scale where consumer power prices almost halved over the period from 1955 to 1980 (Butler, 2017, p. 63).

[9] Economy of scale is a mechanism that arises from increasing returns, in that unit production costs decrease as fixed costs are spread over increasing production volume (Mansfield, 1988).

[10] The Edison-Insull model is the concept of centralised generation providing electricity over poles and wires to an allotment of consumers (Butler, 2017, pp. 62-63).

1.1.2. Carbon Lock-In Effect

The Australian energy sector has become locked into a CES that is reliant on coal and transmitting electricity over long distances to consumers through a path dependent process driven by increasing returns to scale. The carbon lock-in effect is derived through a combination of systematic forces that prolong fossil fuel-based infrastructures that form the basis of CESs regardless of the environmental impact due to its intensive emissions and existence of other technological and cost-effective alternatives (Unrah, 2011, p. 817). Unrah (2011) presents the concept of Techno-Institutional Complex (TIC) to capture the idea that carbon lock-in can be born from combined interactions amongst technologies and institutions (p. 818).

In the Australian context, TIC arises in a technological system like CES as this involves the energy market[11]. This involves a range of institutional actors such as the power producers, coal-mining industry along with their lobbying and financial backing of governments, labour unions and the subsequent industries involved in the supply chain of CES (Perry, 2012, p. 3). The TIC involves positive feedback that fosters lock-in of the energy system (Figure 11).

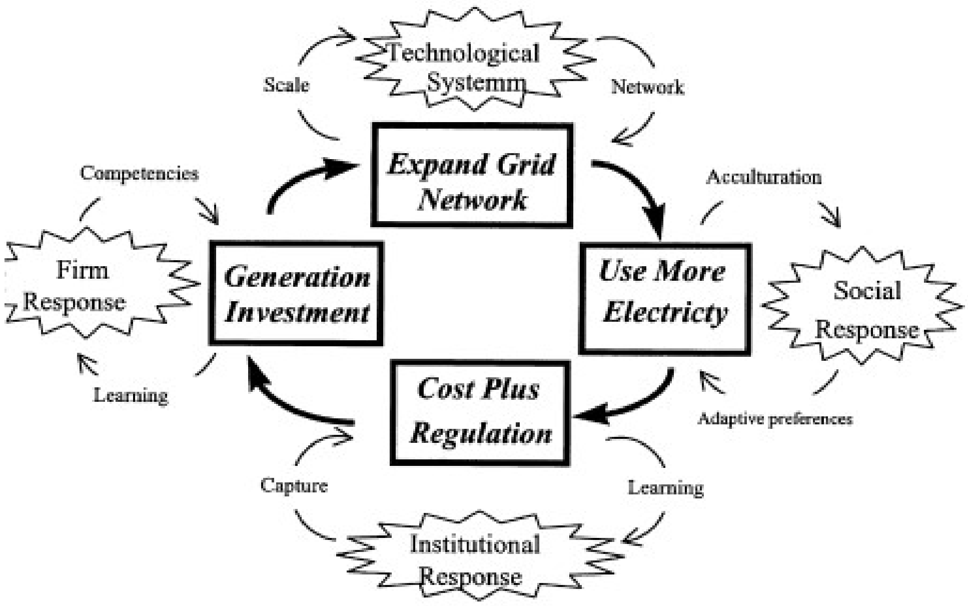


Figure 11. *TIC is a continuous loop reinforced by the increasing returns to foster lock-in of the energy system* (Unruh, 2000, p. 826).

[11] Energy market consists of generator, transmission, distribution and retailer of electricity

The inherent carbon lock-in of CES with coal-fired generation in Australia is further illustrated by the political interference with the assertion that energy security can be compromised by alternatives such as renewable energy sources. This is exemplified the day after the SA blackout with the federal government nominated energy security in ensuring the "lights stay on" as its number one priority (Keneally, 2017). PM Turnbull stated in the aftermath of the blackout that a heavy reliance on intermittent renewables places pressure on the grid and that reliability comes in the form of traditional baseload power such as fossil fuels (Farr, 2016). Further political interference that feeds into the carbon lock-in is exemplified with the decision by generator actor AGL to close the Liddell coal-fired PS by 2022. The federal government is pushing AGL to extend the life of the power station for a further five years beyond 2022 with energy security being the driver as MP Frydenberg stated that dispatchable baseload power "is the absolute key to the reliability of the system" (Grattan, 2017). This is a prime example of political interference in the market with the federal government providing formal justification in delaying closure of a coal-fired PS that further feeds into the carbon lock-in of CES without recognition to address the other dimensions of the trilemma being energy sustainability and affordability.

With CES in Australia locked-in, it can be difficult to displace and can lock-out alternative systems such as DES for extended periods. This is even when the DES demonstrates the ability to address the 'energy trilemma' whilst the established CES has proven that it cannot balance the three trilemma dimensions that is currently plaguing the Australian energy sector. Although paths can be discontinued through an "exogenous force" to induce such a significant level of disruption (Summerfield, 2018).

1.2. Breaking Paths: The Dynamic Changes in Shifting Towards a Decentralised Energy System

To explain the break in path dependence in the context of Australia's CES, it is essential to consider the concept of critical junctions. Critical junctions are framed by Kingdon (1997) as events that galvanise the policy community to consider change where the catalyst is on an external shock that can break the technological and institutional lock-in. Building on the idea of critical junctures as providing opportunity to break existing path dependences, Birkland (1997) defines disasters as exogenous shocks that affect the public and policy world as a trigger of critical junctions (Figure 12). The storm in SA that resulted in a state-wide blackout can be related to an exogenous shock that triggered critical junction in questioning what changes were required to Australia's existing CES. Kingdon (1997) depicts disasters as mechanisms that push problems to the forefront and can lead to policy change. This was the case with the state-wide blackout that resulted in proposing a new energy policy called the National Energy Guarantee (NEG). This energy policy will require electricity retailers to make a certain amount of dispatchable power available at all times, to reduce the electricity sector GHG emissions to meet the COP21 target, and to decrease the average household electricity price, all whilst ensuring reliability (A. Pears, personal communication, October 3, 2017). The critical junction has been set with a DES providing a pathway in solving the 'energy trilemma' and satisfying the requirements of the NEG, thus breaking the carbon lock-in of the CES.

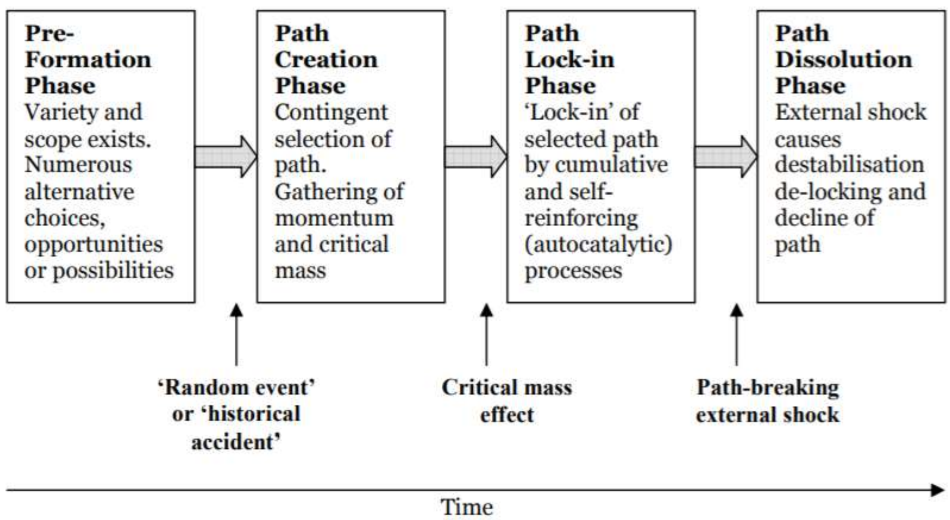


Figure 12. *Technology system evolution over time depicting the path breaking of a lock-in is caused by an external shock* (Martin & Sunley, 2006, p. 6)

For a change in the Australian energy system, what is required is to assess how this change is occurring. Moving from a CES to a DES pathway can be related to Lovins (1976) advocating for a change from a "hard path" to a "soft path". The hard path involves large-scale centralised fossil fuel generation where Lovins (1976) argues that this path suffers from infrastructure costs involved in transporting electricity over long distances which involves a costly expansive grid. The Australian CES is considered a hard path as it has a limited amount of coal-fired PS that are co-located next to coal resources. Subsequently, the T&D costs account for almost half the cost of consumer's electricity bills. In contrast, the soft path is diverse and providing energy in smaller quantities from decentralised low emission generation. Lovins (1976) declares this soft path, which is the basis of a DES, is inherently more flexible and appropriate than the hard path (i.e. CES). The dynamic change in how Australia's energy system would adjust from a hard path, CES, towards a softer path in a DES will be explored in the following section.

1.2.1. The Increase in Distributed Generation

Australia is an expansive land, being the world's sixth largest country, but with only a population of 23 million people (Australian Bureau of Statistics, 2016). This has corresponded in the Australian electricity grid system uniquely characterised by its length, thinness, and its predominant overhead lines (Butler, 2017). Australia's grid is susceptible to extreme weather conditions such as storms and bushfires (Engineers Australia, 2016). To mitigate against damage to the grid to ensure energy security there will need to an investment in a DES consisting of DG which is, as stated by Ogunjuyibe et al. (2016), small-scale generation, that is not directly connected to the transmission network and is not centrally dispatched (pp. 94-95). This has allowed for an increase in local generation from households and businesses.

One dynamic that is challenging the Australian energy sector is the energy revolution as described by the Australian Energy Regulator with the rise of prosumers who are consumers with the ability to generate and store their own electricity. If these prosumers are not able to fully participate in the energy market due to current constraints with the CES, then there is a risk a significant number of consumers will leave the network (Parkinson, 2014). The enabler for prosumers in Australia have primarily been various incentives for investments in rooftop solar PVs such as federal and state solar schemes and feed-in-tariffs (FIT) that have seen more than 1.5 million Australian households and businesses create a capacity of 5GW (Gui & MacGill, 2017, p. 4). Australia is leading the world in rooftop solar PV with the highest penetration rate per household at 15%. The driving reason for this as elaborated by Bruce and MacGill (2016) is the combination of the high irradiation conditions and utilising rooftop PV FIT to mitigate the continuous high electricity prices. Dr. Rolf Apel (2018), head of technology and innovation strategy from Siemens, states that the network is no longer about transporting energy from generation to consumers as prosumers are now creating a platform for not only generating their own electricity but transporting this into the grid, thus creating a platform for bidirectional trade of electricity. However, the current constraint is with the CES power flows in one direction from the coal-fired PS over HV transmission lines and to be distributed to consumers. A DES utilising a smart grid achieves bidirectional energy between the consumer and the grid which enables the participation of prosumers to generate and share with the utility or other energy consumers.

With the need for a more efficient and resilient grid, along with avoiding costly future network investments, generators and utilities are investigating how they can diversify their energy sources and reduce the need for capital investment in upgrading infrastructure respectively. The utilisation of the numerous rooftop solar PVs that exist with consumers has seen the Virtual Power Plant (VPP) as an alternative to the existing coal-fired generation in the CES. VPP uses digitalisation software to aggregate the capacities of small decentralised generation units for the purposes of enhancing power generation along with trading electricity on the energy market (R. Apel, personal communication, March 16, 2018). The incorporation of VPP in a DES can be replicated in a number of different regions across Australia as depicted in Figure 13, that illustrates how wide-spread rooftop solar PV is and the large capacity especially is as well as heavily urbanised cities on the eastern seaboard. Utilising VPP in DES is not only tailored towards cities and communities but can also act in stabilising a state’s electricity infrastructure and reduce surging electricity pricing which is what the current CES fails to do.

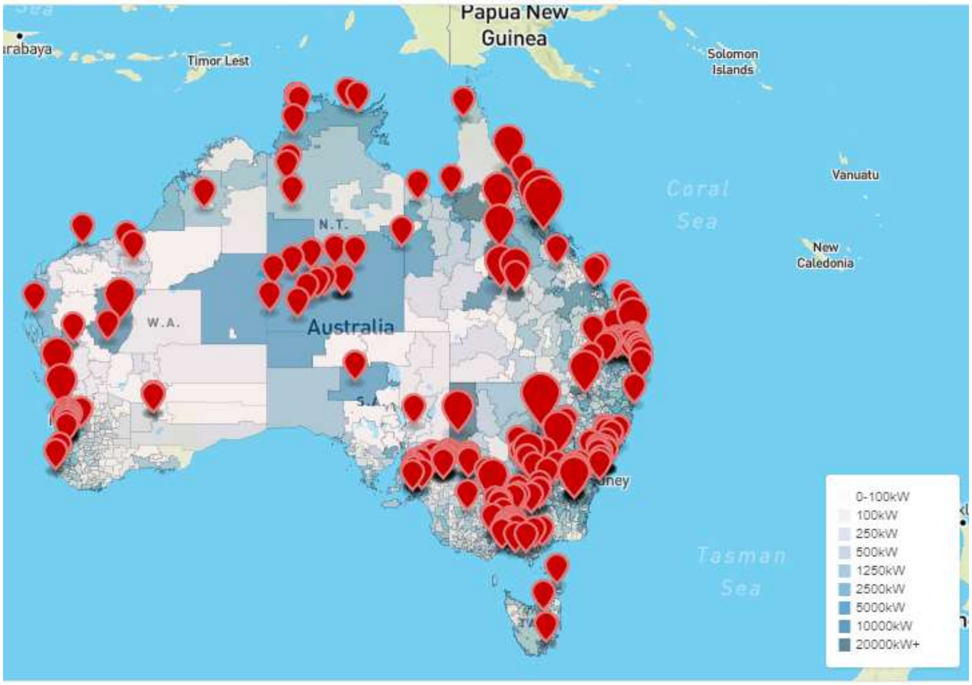


Figure 13.. *Installed rooftop solar PV capacity in Australia* (Martin, 2013)

Utilising DG in a DES offers far greater energy security than coal-fired generators used in CES, as having a number of DG decreases the impact of one generator unexpectedly shutting down as in the case of a CES having only a small number of coal-fired generators (Shah, 2012). DG can also contribute to Australia's challenge in ensuring a relatively small and sparse population living in a huge area has reliable access to electricity as one of the great advantages of DG is being utilised in isolated locations where CES is impractical or when grid extension to growing rural regions is difficult (Borges & Falco, 2003).

1.2.2. Self-Sufficient Supply of Energy

The three major trends that are driving the transformation of the energy sector are decarbonisation, digitalisation and decentralisation (E. Tuchscherer[12], personal communication, March 22, 2018). Along with the trend of the prosumer needs, there is a drive in the development of microgrids. Microgrids are small-scale, self-contained electricity networks that can operate on- and/or off grid that makes it ideal for supplying power to remote regions or locations with limited or no connection to the electricity grid. Microgrids utilise DG for their generation, storage systems, and intelligent control systems to ensure the security of energy supply, sustainability with the use of renewable energy sources, and reduce the cost of electricity through optimising

[12] Interview with Emmanuel Tuchscherer, Director for European Affairs, Engie

power usage based on demand and go off-grid depending on the utility prices (F. Nicolas[13], personal communication, March 15, 2018). There are drivers for a DES utilising microgrids in Australia due to its vast landmass and geographical distribution of communities and industries where microgrids are more equipped to meet the challenges of providing reliable, sustainable, and affordable energy compared to the existing CES with high costs of extending the grid (Handberg, 2016, pp. 8-10).

Extreme weather conditions are growing in frequency and severity, challenging Australia's dependence on electricity during and after these events. As the risks and consequences of disruption of electricity supply are growing, microgrids provide a potential solution. This can be illustrated following the earthquake and accompanying tsunami that hit Japan in 2011, where a microgrid in the city of Sendai continued to provide electricity whilst the rest of the city remained without power (Strickland, 2011). In the aftermath of the state of Victoria's 2009 Black Saturday bushfires it was found during the Victorian Bushfires Royal Commission that the start of the bushfire was due to HV line-to-earth fault (D. Marrick[14], personal communication, March 3, 2018). Drawing on lessons from microgrids such as the one of Sendai, the recommendation from the commission was energy solutions like microgrids to be implemented for Victorian communities living in high bushfire risk areas which would allow to turn off power across HV lines to these risk adverse areas to mitigate the risk of bushfire during hot weather periods and to allow for these communities to be self-sufficient once off-grid. The community microgrid project in Mooroolbark (Figure 14) is being developed by utility actor, AusNet Services, and funded by the Victorian government. The community will be able to run on and off grid on bushfire risk days with its local DG primarily consisting of solar PVs coupled with battery storage (D. Marrick, personal communication, March 3, 2018).

[13] Interview with Fabrice Nicolas, Head of Sales – Microgrids Energy Management Division, Siemens AG
[14] Interview with David Marrick, Strategists for AusNet Services Emerging Energy Markets, AusNet Services

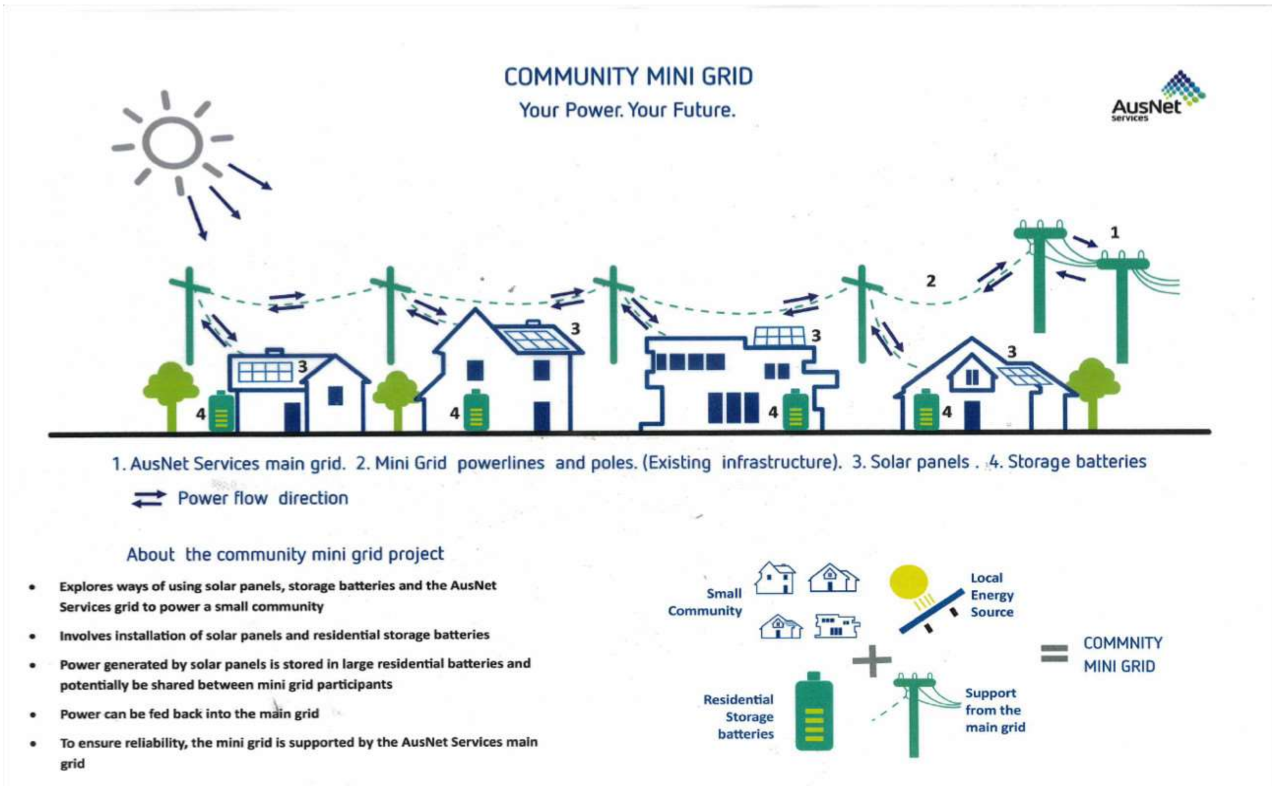


Figure 14. *Mooroolbark Microgrid provides a risk reduction approach to mitigate risk of fires from electrical faults during hazardous bushfire periods* (Hamilton, 2016)

1.2.3. The Effects of Reducing Peak Demand

Over the last decade Australians have seen electricity prices increase significantly despite the decrease in energy resulting result to the increase in DG, energy efficiency measures and reduction of demand in the industrial sector (Priftakis, 2017). This growth in electricity pricing is mainly attributed to the investment in T&D infrastructure due to a combination of population and economic growth, ageing assets being replaced and increases in peak demand (Green, 2014, p. 4). The CES coal-fired generation and grid is built to meet the very highest peak demand even if this occurs only for a few hours a year which adds significantly to electricity costs, where in Australia it is often observed that only 10% of the CES generation and network capacity is used less than 1% of the time (Dunstan et al., 2011, p. 32). Andrew Reeves chair of the Australian Energy Regulator has stated that peak demand is a function of hot days (Figure 15) with the coincident load of industrial demand and residential air conditioning demand (Grattan Institute, 2012).

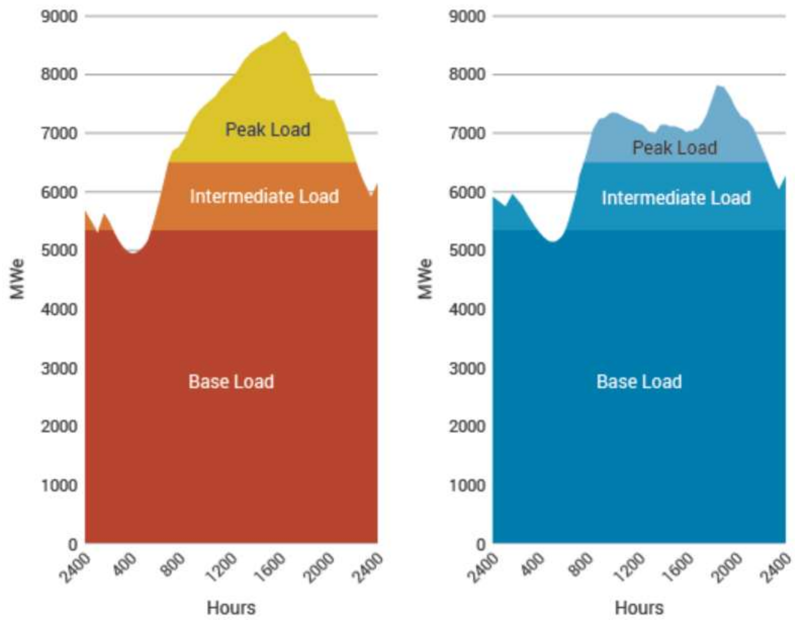


Figure 15. *Load curve of Victoria's electricity system in two peak days in summer and winter respectively. The intensity of peak loads is greatest during the warmer periods due to increase in energy demand (e.g. air conditioners)* (World Nuclear Association, 2017).

Incorporating a DES with peak load management can provide a more cost-effective approach to meeting peak demands during these short periods. Peak load management is referred to by Dunstan et al. (2011) as actions that influence the timing of energy using initiatives like demand response which aims at modifying consumer's power consumption through various approaches including direct load control and financial incentives to shed their loads at times of peak demand and shift this to times of lesser demand (p. 23).

1.2.4. Decarbonisation of the Energy System to Reduce Climate Change

Australia is a vulnerable continent and the impact of climate change on an already hot climate will be more severe than for many other nations (Butler, 2017, p. 7). Australia's premier climate agency advises the nation's land and ocean surface temperatures have risen by around one degrees Celsius since records began in 1910 (Lloyd, 2016). There is recognition globally from the 2015 UNFCCC COP21 in Paris that the long-term goal was to limit the global average temperature rise to 2 degrees Celsius as a minimum effort and then to 1.5 degrees Celsius to achieve net-zero emissions in the second half of this century. Cheung and Davies (2017) argue that "decarbonisation of the energy systems is the key to address the climate change challenge" as the energy sector accounts for over two-thirds of the global GHG emissions (p. 97). Australia's COP21 emissions target pledge is a significant dynamic in facilitating a shift from CES coal-fired generation to DES clean energy generation. Australia has ageing coal-fired generation assets where this idealised timing provides a favourable opportunity to shape a path away from "hard" CES to "soft" DES generation. The modelling from CSIRO depicts Australia's changing electricity generation mix in the coming decades moving away from coal to prominently renewables, such as solar PV (Figure 16).

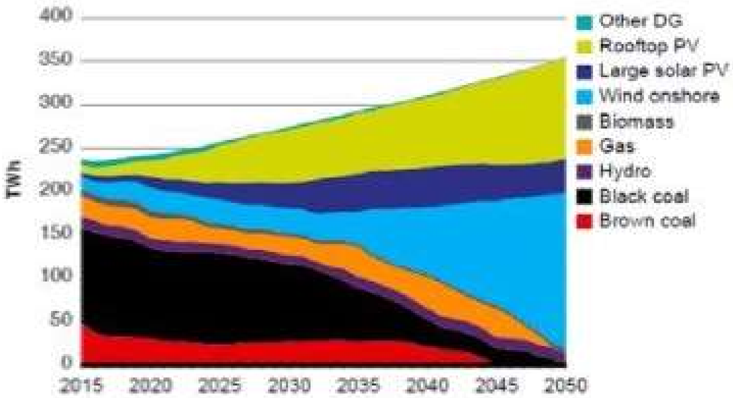
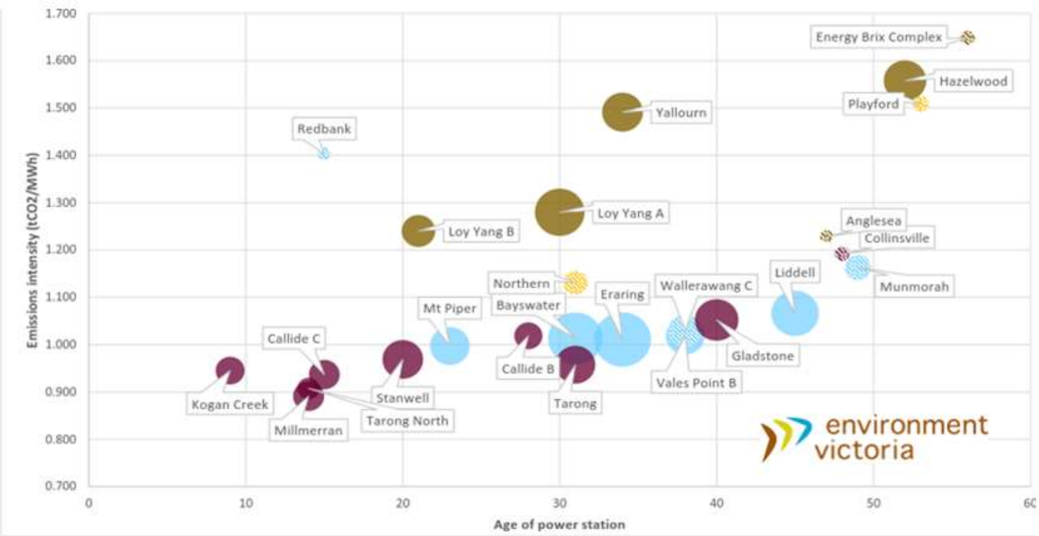


Figure 16. *Projection of Australia's changing electricity mix to 2050* (Parkinson, 2017)

Half of Australia's coal-fired PS within a decade will be over forty years old where they will be too outdated, inefficient and carbon-intensive to be retrofitted with technology to decrease emissions such as CCS (Climate Council, 2014). One additional distinguished feature amongst the recent closures was that they all had a high emissions intensity (Figure 17). Based on this trend of the age coupled with emissions intensity there will be a continuation of large-scale coal fired PS closures in the coming decade.



Coal-burning power stations in the NEM. The size of each circle represents the capacity of each generator. Victorian generators = brown circles; NSW = blue circles; QLD = maroon circles; SA = gold circles. Power stations that have closed in the past two years are represented by the diagonal lines through the circles.

Figure 17. *Australia's Coal-Fired Power Stations Emissions Intensity vs Age of the Power Station* (Commonwealth of Australia, 2017, p. 7)

AEMO (2014) has stated that there is more generation capacity than what is currently needed, and it has been estimated that in the next ten years Australia could remove existing generators, approximately 8000-9000MW, with no short-term risk to energy security. The closure of centralised large-scale coal-fired PS which is the basis of a CES will be a significant enabler for a move towards a DES. Currently, there is no lifetime limit set for closure of coal-fired generators in which Table 1 shows the number of these power stations without any retirement date. There needs to be clarity regarding the set timing of closure to provide certainty to the market in the transition. However, there must be a correlating increase in generation to meet energy demands. There are already a number of emerging low-carbon technologies that can be implemented into a DES which are being utilised in Australia such as solar and wind. Economically, new wind and solar plants are cheaper than new coal plants and even existing coal plants with CCS. According to Bloomberg New Energy Finance (BNEF) (2017), the cost of a new high-efficiency coal-fired PS would range from $134-$203/MWh compared to wind ($61-$118/MWh) and solar ($78-$140/MWh). The cost of coal with CCS is approximate $352/MWh.

Coal Fired Power Stations (Operating)						
State	Power station	Primary fuel type	Year of commissioning	Announced year of decommissioning	Age (years)	Capacity (MW)
NSW	Eraring	Black coal	1982-84		32-34	2,880.0
NSW	Bayswater	Black coal	1982-84	2035	32-34	2,640.0
NSW	Liddell	Black coal	1971-73	2022	43-45	2,000.0
NSW	Mt Piper	Black coal	1993		23	1,400.0
NSW	Vales Point B	Black coal	1978		38	1,320.0
VIC	Loy Yang A	Brown coal	1984-87	2048	29-32	2,210.0
VIC	Hazelwood	Brown coal	1964-71	March 2017	45-52	1,760.0
VIC	Yallourn W	Brown coal	1975, 1982		34-41	1,480.0
VIC	Loy Yang B	Brown coal	1993-96		20-23	1,026.0
QLD	Gladstone	Black coal	1976-82		34-40	1,680.0
QLD	Tarong	Black coal	1984-86		30-32	1,400.0
QLD	Stanwell	Black coal	1993-96		20-23	1,460.0
QLD	Callide C	Black coal	2001		15	810.0
QLD	Millmerran	Black coal	2002		14	851.0
QLD	Kogan Creek	Black coal	2007		9	750.0
QLD	Callide B	Black coal	1989		27	700.0
QLD	Tarong North	Black coal	2002		14	443.0
QLD	Yabulu (Coal)	Black coal	1974		42	37.5
QLD	Gladstone QAL	Black coal	1973		43	25.0
WA	Muja	Black coal	1981, 1986		30-35	1,070.0
WA	Collie	Black coal	1999		17	340.0
WA	Bluewaters 1	Black coal	2009		7	208.0
WA	Bluewaters 2	Black coal	2010		6	208.0
WA	Worsley (Alumina)	Black coal	1982-00		16-34	135.0

Table 1. *Australia's Operating Coal-Fired PS with no set lifetime limit or closure dates except for some generator actors announcing closures (e.g. Hazelwood has been closed by Engie; AGL stated closure of Liddell by 2022).* (Commonwealth of Australia, 2017, p. 5)

There are dynamic changes that are contributing to the dissolvement of the CES "hard" path towards DES "soft" path. The complexity of the transition not only involves the dynamic changes as analysed but also the change from centralised to decentralised socio-technical regime. According to Allen (2014) transitions require multiple changes, involving a "large variety of actor groups" (p. 147). The following chapter shall continue to explore the transition with the actors involved along with the conflicts that arise due to path dependence and the collaboration required to change towards a decentralised socio-technical regime.

Chapter 2: The Conflict and Collaboration of Actors Towards a Decentralised Energy System

The desired outcome for Australia's energy system is for it to be secure, sustainable and affordable. These three outcomes can be observed as "persistent problems" as failures to meet the 'energy trilemma' cannot be corrected by the energy system without the external influence of different networks of actors[15], institutions, technologies and infrastructures (Rotmans, 2001; Gui & MacGill, 2017). With the current CES unable to combat the 'energy trilemma', the actors within the socio-technical system require to work together towards a transition to DES (Fischer & Newig, 2016). However, the nature of an energy system is that it is multifaceted and the transition towards a DES will need to ensure the incorporation of a "coevolutionary element, where the changes which occur in one dimension would need to coincide with all dimensions" (Allen, 2014, p. 149). Therefore, this chapter analyses the extent to which the switch from a CES to a DES may therefore create conflict along with the collaboration that is required in the transition.

2.1. Multi-Level Perspectives Analytical Framework in the Systemic Transition

Drawing on the coevolutionary element, this dissertation employs the Multi-Level Perspectives (MLP) analytical framework which provides a framework for understanding the complexity associated with transition of socio-technical systems, such as energy systems, involving actors (Geels, 2011, 2013; Allen, 2014; Gui & MacGill, 2017). The transition from a CES to a DES in Australia can be viewed through MLP theory as it chooses a holistic approach to identify the different elements involved in the change of pathways through the interplay between processes at different levels (Gui & MacGill, 2017, pp. 4-5). Geels (2010) indicates three different levels that influence the development and transition towards a DES: landscape, socio-technical regime, and niches levels (Figure 18).

[15] This dissertation defines an actor as an "energy system actor" which is any individual or collective players within the energy system whose behaviour impacts on the system (Allen, 2014)

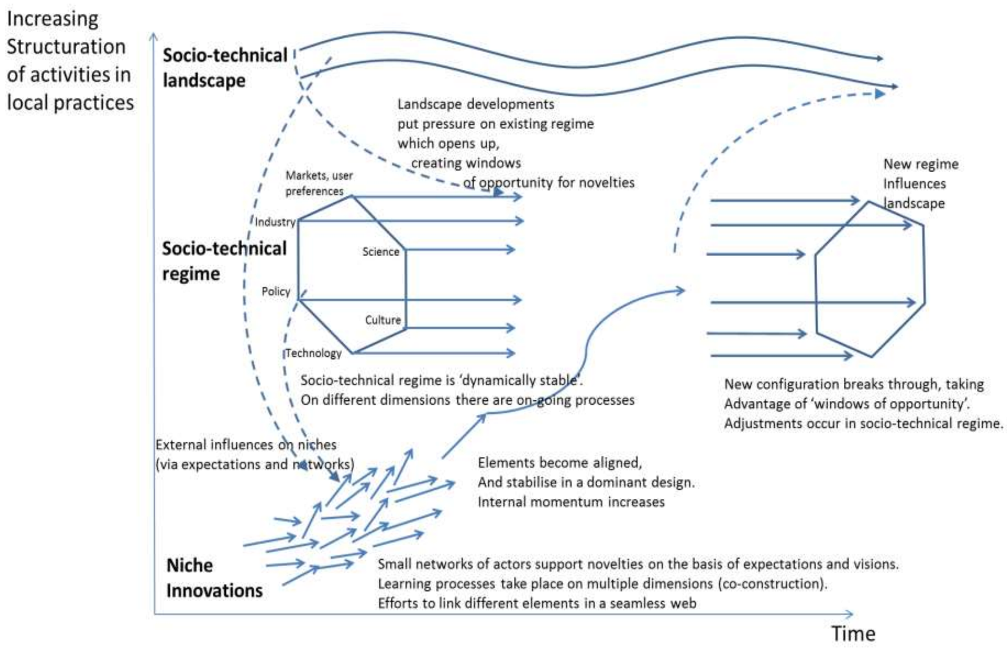


Figure 18. *Multi-Level Perspectives on the transitions will require all levels linked: landscape, socio-technical regime & niche levels.* (Allen, 2014).

Landscape Level

The landscape level is the wider context of the system and provides the environment that consists of exogenous factors, such as the impact of climate change in the context of energy, that influence the interplay between socio-technical regime and niches level (Allen, 2014, p. 149; Quezada & Grozev, 2013, p. 10). Addressing the 'energy trilemma' is considered a landscape factor as set out by the Australian Federal Government which must facilitate regulation and policy along with engaging with actors at the socio-technical regime and niche levels to ensure the transition towards a DES.

Socio-Technical Regime Level

The socio-technical regime for an energy system represents rules and incentives which are supported by stakeholders (Allen, 2014, p. 157). A stakeholder can be considered an actor who possesses the power of action. Within the energy system, this can range from governments and actors across the energy supply chain including prosumers. The stakeholders involved in the Australian energy system are depicted in Figure 19. The rules and incentives are shared beliefs, capabilities, institutional arrangements and regulations which relate in the energy system (Geels, 2004). The socio-technical regime could be considered, according to Allen (2014), as the governance of the energy system in that it consists of the collective decision making of the stakeholders along with the rules and incentives which enable to achieve the desired outcome of the 'energy trilemma' landscape factor (pp. 146-157). The rules and incentives that are moulded by the stakeholders to now address the 'energy trilemma' will play a crucial role in the switch from a centralised to a decentralised socio-technical regime.

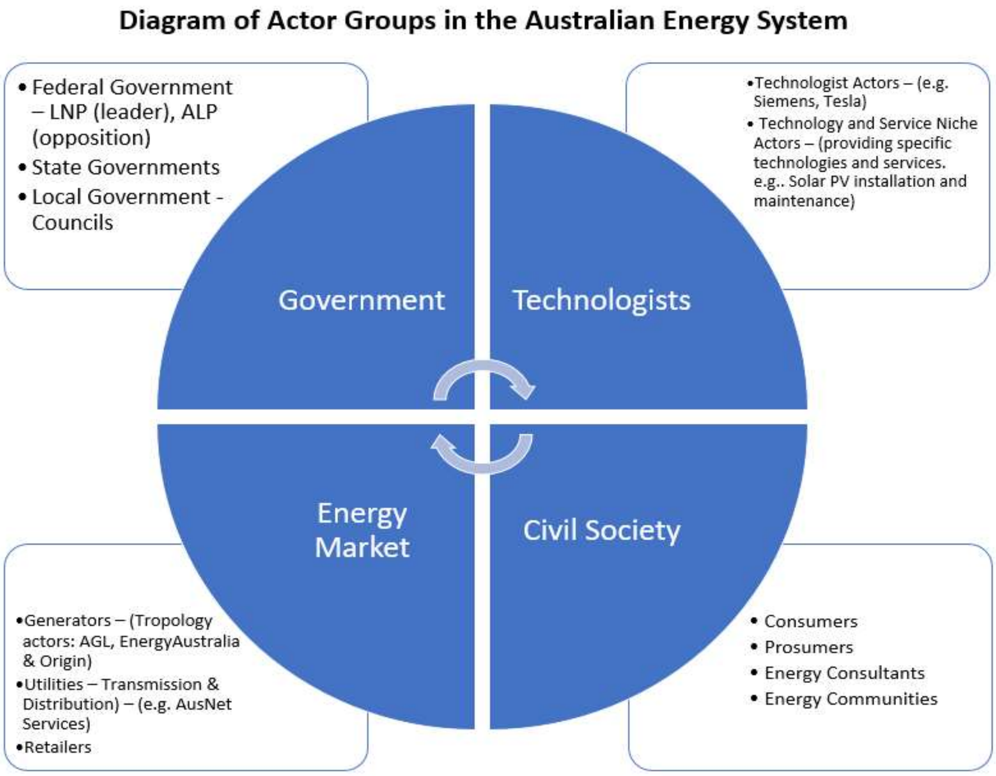


Figure 19. *Diagram of actor groups including type of actor group in the Australian energy system* (elaborated by the author)

Niche Level

The niche level is defined by Geels (2002) as small-scale socio-technical innovations consisting of emerging technologies and supporting a coalition of actors. In the Australian DES context, this niche level consists of innovations in emerging technologies, such as solar PV, wind, storage, EVs, and smart meters that can emerge as a bottom-up approach in providing alternative solutions with the landscape factor of the 'energy trilemma' and exert pressure to break elements of the rules and incentives that enabled the interests of incumbent actors in the lock-in of a CES. The further support of a transition towards a DES can be found with the niche actors working outside the socio-technical regime looking to "break-through and provide a seed for systematic change" (Allen, 2014, p. 151).

2.1.1. Conflicts and Collaboration

Transitions in the energy system are “complex, co-evolutionary processes of fundamental change” (Proka, Hisschemöller & Loorbach, 2018, p. 2). This forces a change of the rules and incentives that shape the behaviour of energy actors (Hisschemöller & Bode, 2011, p. 12). Tensions are created during this process of disruptive change. The MLP analytical framework is not linear as changes can entail tension lines. This can be illustrated with external pressures, such as climate change, occurring at the landscape level. Emission targets, for example those linked to COP21, place pressure on the incumbent centralised socio-technical regime actors to make changes. In addition, this exogenous landscape factor causes further tension for these actors as it enables increasing market competition with emerging technologist niche actors gaining importance (Proka, Hisschemöller & Loorbach, 2018, p. 2). The transition towards a DES requires collaboration that involve multiple and diverse actors from different sectoral backgrounds. The reason behind such collaboration is that mutual goals to aid in the transition towards a DES are developed and achieved through partnerships and developing strategies amongst the various stakeholders (Gui & McGill, 2017, p. 5). However, the diversity between actors in this transition who come into contact during such cooperation also causes conflict. According to Curseu and Schruijer (2017), collaboration and conflict are “interwind” that shape the dynamic of multiple and diverse actors (p. 114). As with all disruptive systems, a shift towards a DES creates winners and losers (Green, 2014). The conflict arises with the incumbent actors who have benefited from the traditional CES as they have a tendency to resist change. Other actors will embrace this change, thus creating increasing pressure for change although they cannot act alone without the effective interaction and collaboration with the incumbent actors. This transition therefore will be a “cumulative and evolving process” for the network of actors in Australia’s energy system and one where collaboration is crucial in creating the opportunity to break the existing CES socio-technical regime and move towards a DES socio-technical regime (Gui & McGill, 2017, p. 6).

2.2. The role of the Key Actors in the Transition Towards a Decentralised Energy System

Individual and collective actors' actions can attempt to prevent or generate change in the transition of an energy system. The Australian energy system comprises of various stakeholders that have an influence on the energy system itself along with the transition towards DES. This is reiterated by Avelino and Wittmayer (2015) pointing out that the transition process consists of a multitude of actors at different levels (p. 632). This dissertation has identified the systemic level using the MLP analytical framework to cluster actors in the transition from a CES to a DES. There is a tendency for centralised socio-technical regime actors to become disruptors in transition and this can result in conflict between members of the incumbent regime and other actors looking to create a decentralised socio-technical regime. (Smith, Stirling & Berhout, 2005). There is also the possibility of these incumbent actors finding opportunities that fit their own interests with a transition to a DES by collaborating with other actors in both the decentralised socio-technical regime and the technology and system niche actors (Fischer & Newig, 2016, p. 6). An example being these actors driven by their interest of having a dominant market-share collaborating with various institutions, technologists, NGOs, and renewable energy niche actors in establishing future requirements of the Australian energy system (Figure 20).

Figure 20. *Collaboration of various actors in establishing future requirements in the energy system* (CSIRO, 2013)

The following three subsections of this chapter examine to what extent conflict and collaboration influence the actors involved in the transition to a DES in Australia, using the MLP analytical framework. Grouping actors into clusters is exemplified by Fischer and Newig (2016) who use the "institutional rectangle" to subdivide the transition of an energy system regime into realms (p. 6). These realms consist of "government", "market" and "civil society". Applying this to the Australian context, this dissertation identifies a cluster of actors for this analysis consisting of: (1) governments; (2) energy market; and (3) energy communities.

2.2.1. Federal and State Government Actors

The 'energy trilemma' is the landscape factor all governments in Australia are required to solve. The national context includes more specifically Australia's participation in international climate change processes, such as the federal government's COP21 emissions target which is an exogenous factor. However, at the state level, there are other factors that have state governments placing different priorities on what is required in the energy system. This results in varying interests of the governments, including relationships with actors that can impact the DES. It can either enhance the move towards a DES, such as the state of Victoria's collaboration with the utility actor, AusNet Services, to mitigate the risk of bushfires with the implementation of microgrids in some rural areas. But these relationships can cause conflict and slow the move towards a DES, as seen with the federal government promoting "clean coal" with technologies like CCS. This was on the back of having some coal lobby groups providing political donations with the interest of keeping coal in the public discourse (Karp & Evershed, 2018). This section analyses the role of the federal government on the move towards a DES through the polity, policy and politics[16]. Furthermore, the possibility of state governments having an impact on this transition is examined which becomes relevant due to a lack of clear directions at the federal level.

[16] This dissertation has based the polity, politics and policy analysis on the chart "Nature of the ideal dimensions of the democratic political process" (Couto & Arantes, 2008) (see Appendix C for the chart)

Polity

Australia is a democracy and a centralised federation, and the federal government under the Australian Constitution is given the responsibility for passing the laws that affect the whole nation (Figure 21). In relation to energy, this means that the federal government drives energy policies, such as the national Renewable Energy Target (RET) and the COP21 emissions target. Moreover, under the Australian Constitution state governments ultimately drive their respective energy needs themselves in relation to the energy generated and distributed. Local government[17] administers in energy the planning schemes and programs, such as energy infrastructure and energy efficiency measures for building (Parliamentary Education Office, 2017)

Figure 21. *Australia's Level of Governments: Federal, State & Local* (Australian Government, 2017)

The liberalisation of the energy market in a number of states in Australia has resulted in state governments' increasing involvement with technologist actors. This is exemplified by the state of SA collaboration with battery storage actor Tesla to address energy security with the exogenous factor being the storm that caused the state-wide blackout. The SA government provided funding and subsidies for the world's biggest lithium-ion Battery Energy Storage (BES) installation. This private-public partnership has enabled the state government to invest in another landmark DES project with the world's largest VPP with Tesla (Ong, 2018). As the state governments are managing their own energy requirements, they depend strongly on industry actors which allows for a more direct involvement with emerging technologists niche actors who provide solutions in the space of DES (Fischer & Newig, 2016, p. 7). This further illustrates the state governments' ability to engage in and create positive outcomes for the transition to a DES.

[17] Local Governments in Australia is referred to as councils

Policy

Throughout the history of Australian federal politics, there have always been differences between the major political parties that have led to what Butler (2017) describes as a defining fault line that separates these parties. Over the past decade, the defining fault line has been energy which is born from divisions on the various parties' attitudes to climate change. This has caused what has been termed the "climate wars" where energy has been the political battleground and has induced further conflict between opposing political actors (Lipson, 2017). Consequently, deep and often toxic divisions have appeared which render the nation unable to make serious progress on energy policies that would enable a move towards low-carbon technologies, to aid the process of moving towards a DES. The recurring changes in energy policies have been linked to, as Cheung and Davies (2016) note the occurrence of "electoral cycles and the change in Prime Ministers in the last decade" (p. 99). The most controversial "climate wars"- occurrence centred around the carbon tax that was introduced in 2011 by the then federal government (ALP) under the leadership of PM Julia Gillard. The leader of the opposition party LNP Tony Abbott led a campaign against the carbon tax (Figure 22) on the premise that Gillard had breached her election promise in 2010 that "there would be no carbon tax under her government" (Butler, 2017, p. 34). Populism[18] was a significant factor in discrediting the carbon tax to the Australian public where Abbott made claims that it would "lead to electricity prices going up by as much as 30 percent" along with "lamb roasts skyrocketing to $100" (Butler, 2017, p. 32). With public support for Gillard diminishing at a rapid rate, the ALP replaced her and called for an early election in 2013. The newly elected PM Abbott appealed to the populist view on the carbon tax and consequently repealed it as one of the first act in office, thereby making Australia the first country to take such a step as repealing the carbon tax (Baird, 2014). The "climate wars" have been a significant factor in inhibiting the rules and incentives that are required for decentralised socio-technical regime stakeholders to have certainty and be able to make long-term investments needed for the implementation of emerging technologies that will move Australia towards a DES.

[18] There are many views on populism with this dissertation considering populism to be a "superficial political tactic that involves crude solutions or policies that appeal to the politically naïve rather than respond to intricacies of an issue" (Howitt, 2013)

Figure 22. *Tony Abbott's campaign against the carbon tax was a populist movement that led to becoming PM and repealing the carbon tax*. (Haines, 2012).

The reliance on energy policy solely from the national level for a transition towards a DES is not a prerequisite as the state governments have the constitutional responsibility for the energy system in their own states respectively. The reliance at a national level on the implementation of energy policies to support a DES is somewhat volatile considering the history of fractions and divisions due to the "climate wars". Therefore, when the RET was reduced to 20% in 2014, the state governments announced their own specific RET. Currently, the federal government has a RET of 23.5% (33TWh) by 2020 which is far below those of some of the state governments' targets as depicted in Figure 23. State governments acknowledge the need for economic growth through infrastructure projects where, according to the Victorian energy minister, one key driver for increasing its RET to 40% (52TWh) by 2025 was to "restore the confidence needed to invest" (McConnell, 2016, p. 1).

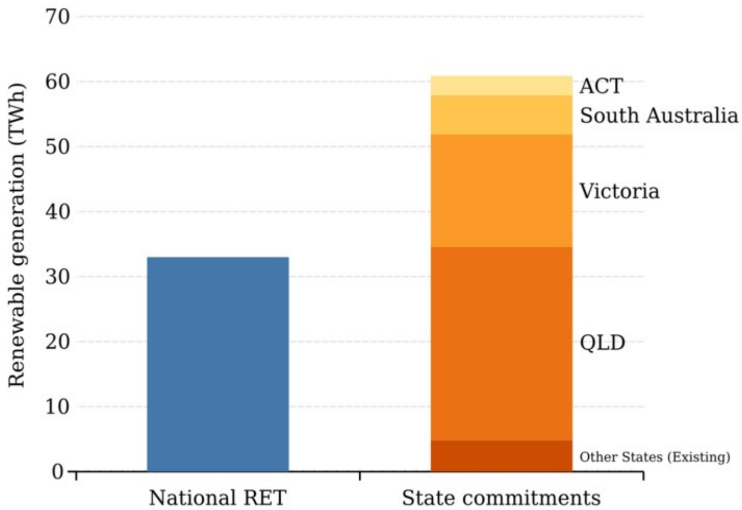


Figure 23. *Comparison of the national RET & states' RET depicting the state governments' have in most cases a higher RET for renewable generation than the federal government.* (McConnell, 2016).

State governments have their individual sustainability plans with, for example, the state government of SA having committed to net zero emissions by 2050 which is a major catalyst for setting its RET to 50% by 2025 (Aliento, 2015). This has caused conflict with the federal government due to its interest in coal as energy resource in the centralised socio-technical regime. After the event of the SA state-wide blackout, PM Turnbull had criticised the state government for placing a heavy reliance on intermittent renewables that places pressures on the grid rather than relying on traditional baseload power (Grattan, 2016). In response, the state government of SA has not avoided the conflict by continuing to put in place policies to support the transition to a DES by stating that they will be introducing the nation's first energy storage target (Slezak, 2018).

State governments have the constitutional scope to act both independently on energy and as a collective group, such as with the development and implementation of the National Electricity Market (NEM) which was achieved through the COAG with the harmonised legislation of each state (Bruce, Mills, & MacGill, 2016). However, conflict looms with different political parties in office at state levels compared to the federal level. This was further illustrated with the federal government blaming Labor state governments for being "unrealistic" and "ideological" with their RETs (ibid.). One way that state governments are influencing the federal government is by having a common position which is typically politically motivated, with key Labor states (Victoria, SA and NSW) setting a Clean Energy Target (CET) (Murray, 2017). The outcome of this collaboration of states is potentially another driver for a DES in Australia as this has put pressure on the federal government to add this to the national agenda. Whatever energy policy emerges at the national level through the federal government, the state governments are well adapted to the changes needed to both energy market and policy developments to enable the transition towards a DES.

Politics

Politics, as defined by Heywood (2013), is "the making, preserving and amending of general social rules" resulting in political actors being "inextricably linked to the phenomena of conflict and cooperation" (p. 17). The federal and state relationships that involve energy policy in Australia have resulted more in conflict than cooperation despite the acknowledgment that energy is a shared responsibility (Cheung & Davies, 2016). This is a reflection on the role of ideas, interests and institutions that is shaping energy policy (Warren, Christoff & Green, 2016, p. 9). The federal and state governments respectively have ideological differences as they are run by various political parties, the nation and states have their own individual agendas which feature different interests and there are cooperative agreements between these governments and industry actors. From a technical perspective, the transformation towards a DES in Australia is viable; however, the politics in this energy system transformation is littered with conflict where cooperation is required to enable stability in the signals to the market for actors to develop and invest in the move towards a DES. The proposed CET of the Finkle review illustrates the conflict between the ideologies of the two major parties in Australia. If adopted, this target would require retailers to purchase a certain percentage from low-emissions generators (Murphy, 2017b). However, this was not implemented in the proposed energy policy, NEG, put forward by the federal government who has stated that this policy should be "technology agnostic" to involve all options of generation including "clean coal", thus providing further positive feedback to CES (McDonough, 2017). The federal opposition has stated that they will not support the NEG without this target as this is a mechanism that the Labor party believe is required to boost investment in renewables which support their view of a RET for the nation to be 50% by 2030 (Butler, 2017, pp. 89-90). This conflict further exemplifies uncertainty concerning policy direction that has an impact on the rules and incentives enabling decentralised socio-technical regime actors to move towards a DES.

The topic of energy security has brought out conflict between the federal and some of the state governments. This is illustrated by the SA government revising its energy plan to include more renewable generation and storage to provide stability of the state's energy system and to be more self-sufficient from the NEM. The security of energy supply is a landscape factor for decentralised socio-technical regime actors to develop technologies that will enable DES. Generator actor AGL has stated that this energy plan provides reliability to invest in renewables which led to the collaboration with decentralised socio-technical regime actors to develop VPP utilising solar and BES. (CWS, 2017). The federal government, in response to SA's revised energy plan, claimed that the SA state government "can't keep the lights on" due to the amount of renewables in the state's energy system as it is not reliable such as "dispatchable generation" such as coal and gas-fired PS (Kallies, 2017). This is further positive feedback for CES as historically, for instance, the coal industry has always enjoyed a close and beneficial relationship with the federal government, even reaching the level where senior coal lobbyists were allowed to write energy policies (Four Corners, 2006).

To sum up, the move towards a DES in Australia will not be solely dictated by the movement of the federal government with its energy initiatives which have been affected by the "climate wars" of recent years. The state governments can have an influence on policy that can promote DES as demonstrated. They have played a key role in federal energy policy, such as with the initial ETS proposal in 2007 that formed the basis of the federal government initial implementation of the ETS (McConnell, 2016, p. 3). The continuation of trial projects of DES will continue to enable the transition. According to the Federal Minister of Energy, MP Combet, "state governments will be predominantly driving these trial projects before any involvement from the federal government" (G. Combet[19], personal communication, May 16, 2012). There is still a need for a both stable and bipartisan approach from federal and state governments to address the landscape factor being the 'energy trilemma'. Such action, along with rules and incentives, will allow for stakeholders to move from a centralised to a decentralised socio-technical regime.

[19] Interview with the Hon. MP Greg Combet, Minster for Climate Change and Energy Efficiency; Minster for Industry and Innovation, Australia Labor Party

2.2.2. Energy Market Actors

The Australian electricity market comprises of the NEM that consists of segments of actors in the energy supply chain (Figure 24). The electricity is produced by generators, such as coal-fired PS, and this electricity is then transported over the transmission networks and distributed to consumers. The T&D of electricity is the responsibility of the utilities. Electricity retailers purchase electricity in wholesale markets before it is sold to the consumers. The total electricity price includes the costs incurred by the entire energy supply chain (Department of Industry, Innovation and Science, 2015, p. 38).

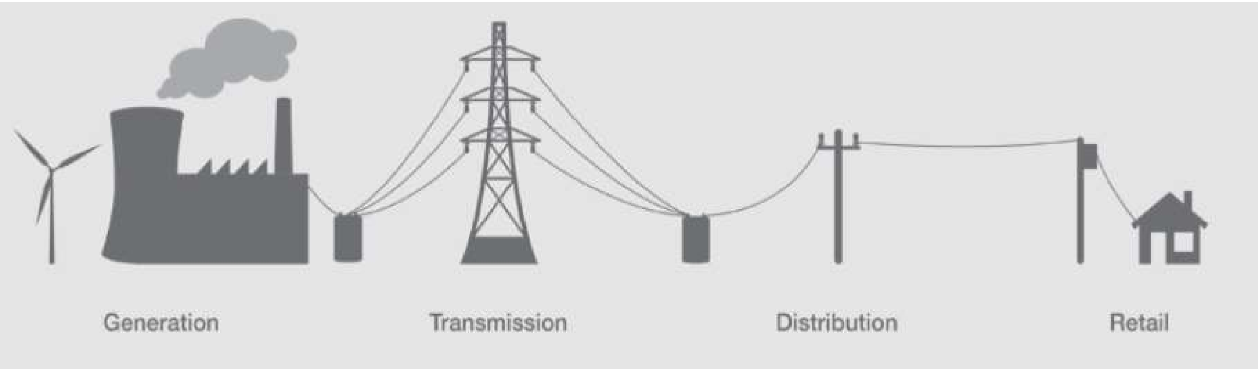


Figure 24. *Energy Market Actors in the unidirectional CES. Australia's energy supply chain includes Generators, Transmission & Distribution Utilities & Retailers* (Zema, 2017)

The Australian energy market was previously state-owned before the liberalisation process in the 1990s encouraged the interconnection of the grid to other regions, competition and free trade in electricity (Figure 25) (IEA, 2015, p. 194). This meant the unbundling of one actor, who was the whole energy supply chain, into generators, T&D utilities and retailers. As a result, the government now sees its influence on a landscape factor such as energy security limited due to the multitude of actors on the liberalised energy market (Allen, 2014, p. 291). The energy market actors are privatised and thus the move towards a DES will be influenced by whether these actors will change their business models to adapt to the future energy market. Conflict from this centralised socio-technical regime actors will occur due to the current models in place. The move towards a decentralised socio-technical regime will require collaboration along with other technologist actors and technology and service niche actors in conjunction with rules and incentives. The following parts of this section examine the role of different energy market actors, namely generators and retailers as well as the utilities, in the transition towards a DES.

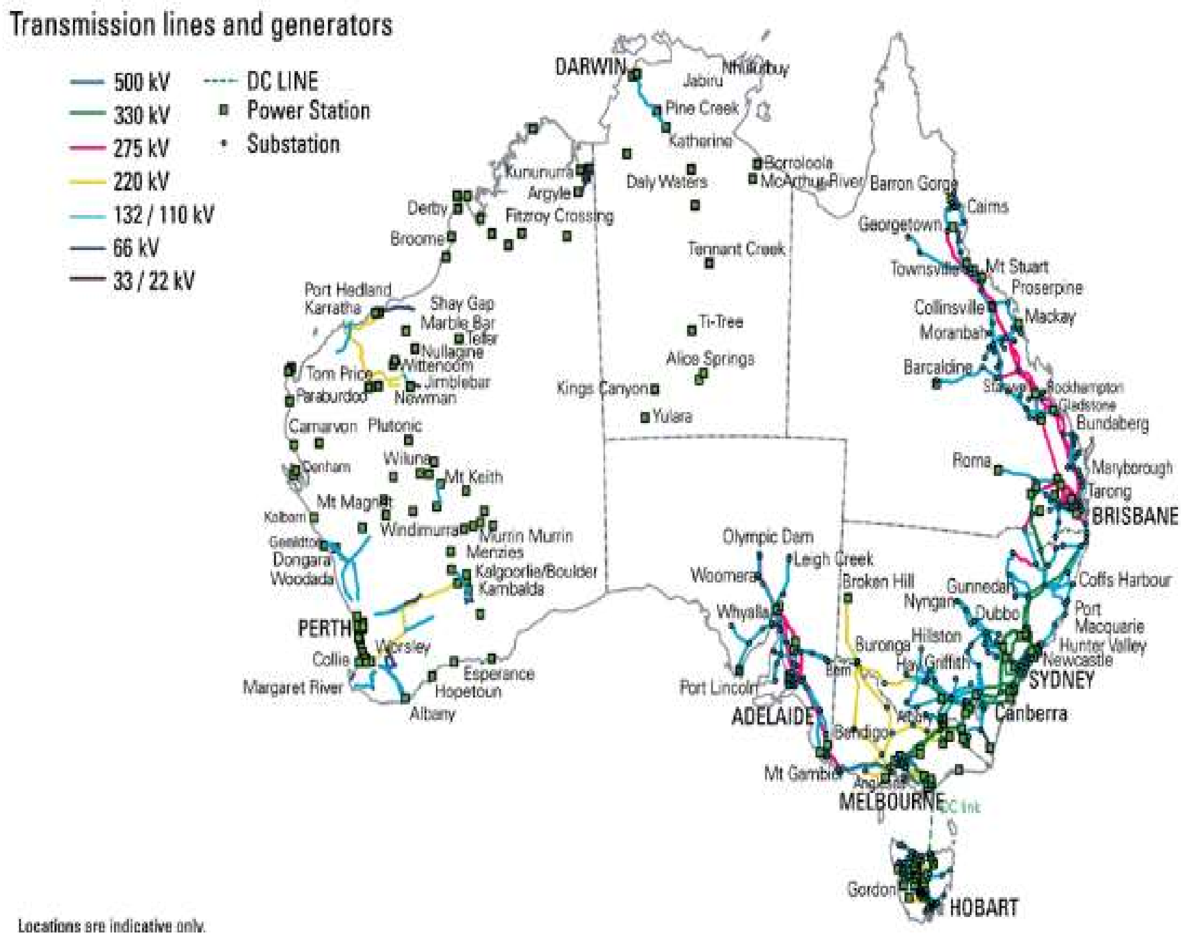


Figure 25. *Australia Map consisting of Generators and Transmission Lines as part of the Energy Sector in Australia* (Commonwealth of Australia, 2017).

Generator and Retailer Actors

The situation of the generator and retailer segment of the energy market can be best described by using the term 'natural monopoly' which refers to a market in which one actor serving the whole market is less costly than multiple actors. The supply and selling of energy are often cited as examples of natural monopolies (Tschirhart, 1995). In Australia, there is a current "triopoly" (AGL, EnergyAustralia and Origin) of three electricity "gentailers" (integrated generators and retailers) which hold approximately 75% of the market-share (Figure 26) (Green, 2014, p. 2). Most of their generation assets[20] are coal-fired PS which form part of the CES. (Environmental Justice Australia, 2015).

[20] The percentage of coal-fired power station generation for the "big three" gentailers in Australia: AGL – 81%, EnergyAustralia – 86%, Origin – 66% (Environmental Justice Australia, 2015)

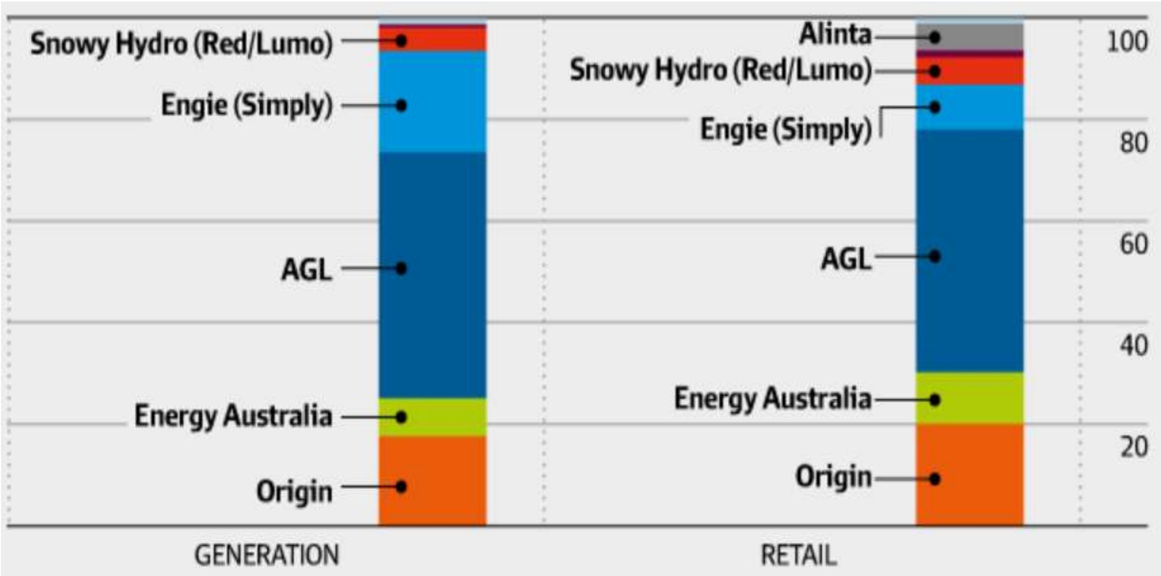


Figure 26. *Australia's Energy Generation and Retail Market-Share is Dominated by the Triopoly Actors: AGL, EnergyAustralia & Origin (*MacDonald-Smith, 2017)

The path dependence of CES explains why these actors are so dominant in the Australian energy market. The electricity market reform was introduced to liberalise the energy market in aiming to improve the competitiveness and to increase the efficiency of the operation of the energy system as well as decrease prices (IEA, 2005, p. 195). However, the scale of investment and risk in the Australian energy market is so high that it accommodates only a few actors with high capital capacity. This is due for instance to the wholesale electricity market capable of a swing from the usual price of around $50/MWh to over $5,000/ MWh during peak demand events (Figure 27) (Green, 2014, p. 2). This creates an enormous exposure of risks for generators and retailers with supply contracts. The triopoly actors can offset their risks as vertical integration[21] gives them the ability to utilise and if required acquire more generation assets when required to withstand the occasional exposure to extremely high peak demand that creates a high price period (ibid.).

[21] Vertical integration in this dissertation is defined as generators who also participate in the retail market as one company in the energy sector. (Frontier Economics, 2017)

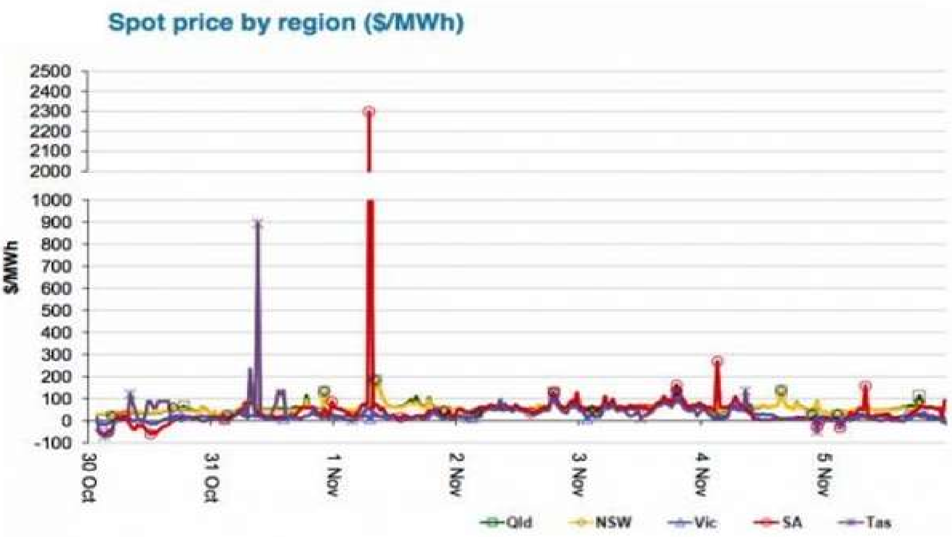


Figure 27. *Generation spot market pricing in the various states of Australia. This depicts the peak demand generation costs far exceeding the average generation costs.* (Parkinson, 2016a).

The triopoly actors regard a move towards a DES as a threat due to their number of coal-fired PS assets and profit margins from selling electricity. This is because the process of decarbonisation, which entails a move from coal towards renewable energy-based generation, will have an effect on reducing the reliance of coal-fired generation and a further reduction of electricity spot market pricing (Castaneda et al., 2017, p. 105). For now, these incumbent actors are looking at maximising their assets. This has resulted in actors with generation assets delaying the closure of coal-fired PS which can be attributed to the current favourable electricity market conditions where even some of the power stations that are not operating on a continuous basis can be brought back online if necessary and some others operate seasonally.

Although these triopoly actors are currently the majority in terms of the CES domestic market, they are not going to maintain the same proportional level of ownership of generation assets in a DES. This can already be observed with a substantial increase in market competition with renewable energy generation, such as with the various number of actors in solar farms as depicted in Table 2 (Green, 2014, p. 2). The increase in renewable energy generation will come from the requirement to reduce not only emissions but also the price. Currently, generating power from existing coal-fired PS is around $40/MWh (Baldwin, McConnel & Wood, 2017). However, the renewable energy generation price is closing the gap on coal where, according to the forecast from Australian National University, pricing will fall to $50/MWh by 2020 (Latimer, 2018). The shift from centralised to decentralised socio-technical regime actors will evolve around renewable energy generation. Compared to coal-fired PS which are placed next to coal for the fuel source, the economics show that the operating costs of renewable energy projects are typically significantly lower than those for the same capacity of coal-fired PS with the primary reason being no direct fuel costs associated with most renewable energy technologies (Green, 2017, p. 3). There is another important way, rather than the CES model, the DES market has the potential to bring out the intended liberalised market. The principle of a CES is the unidirectional power flow from a small number of large-scale generators to consumers, whereas the DES relies on a bidirectional power flow, there by seeing more actors involved in the energy system (Green, 2014). The rise of prosumers has seen the DG, the increase of solar PV which will reduce the demand for energy from large-scale generators.

Organisation	Project	Town	State	MW
Origin Energy Limited	Darling Downs Solar Farm	Dalby	QLD	106.8
Gannawarra Solar Farm Pty Ltd	Gannawarra Solar Farm	Kerang	VIC	52.8
Syncline Energy Pty Ltd	Bannerton Solar Park	Bannerton	VIC	51.2
FRV Services Australia Pty Ltd	Baralaba Solar Farm	Baralaba	QLD	50.0
Genex Power Limited	Kidston Solar Project	Kidston	QLD	50.0
KCSF Consortium	North Queensland Solar Farm	Proserpine	QLD	50.0
Neoen Australian Pty Ltd	Parkes Solar Farm	Parkes	NSW	46.0
Infigen Energy	Manildra Solar Farm	Manildra	NSW	42.4
RATCH Australian Corporation Limited	Collinsville Solar Power Station	Collinsville	QLD	42.0
Infigen Energy	Capital Solar Farm	Bungendore	NSW	39.0
SF Suntech Australia Pty Ltd	Griffith Solar Farm	Griffith	NSW	33.9
Neoen Australian Pty Ltd	Griffith Solar Farm	Griffith	NSW	26.4
Canadian Solar (Australia) Pty Ltd	Oakey Solar Farm	Oakey	QLD	25.0
Neoen Australian Pty Ltd	Dubbo Solar Hub	Dubbo	NSW	22.4
APA Group	Emu Downs Solar Farm	Cervantes	WA	20.1
Goldwind Australia Pty Ltd	White Rock Solar Farm	Glen Innes	NSW	20.0
Kennedy Energy Park Pty Ltd	Kennedy Energy Park	Hughenden	QLD	19.2
Lyon Infrastructure Investments Pty Ltd	Roxby Downs Solar Farm	Roxby Downs	SA	17.0
Canadian Solar (Australia) Pty Ltd	Longreach Solar Farm	Longreach	QLD	15.0
Overland Sun Farming Company Pty Ltd	Hughenden Sun Farm	Hughenden	QLD	14.2
EPHO Pty Ltd	Gidginbung Solar Farm	Temora	NSW	12.2
juwi Renewable Energy Pty Ltd	Ebenezer Solar Project	Ipswich	QLD	10.0

Table 2. *Solar farm projects are increasing the competition between generator actors* (Parkinson, 2016b)

External support for coal-fired generation has been diminishing on the part of banking institutions already with the chief economist at NAB Markets, Rob Henderson, stating that in Australia "the big four banks have ruled out funding any significant new developments in the coal or the coal-generation areas" (Yates, 2018). On the back of the World Bank announcement at the One Planet summit stating it will no longer finance fossil fuels and vowing to increase its portfolio dedicated to climate action (Caughill, 2017), Australian banking institutions have already identified the DES with disruptive technologies as a necessary transition that will impact on the existing CES as this will experience declining generator revenues in the long-term (Tayal, 2016, p. 14). The impact of the National Australia Bank announcement to drop coal from its investment portfolio coincided with Origin, one of the triopoly actors, announcing the closure of Australia's largest coal-fired PS, Eraring, by 2030 due to the plan to decarbonise its assets with a target of halving emissions by 2032 (Latimer, 2017).

There is a shift with the triopoly actors to move from their coal-fired generation assets towards DES technologies (Table 3). This has seen AGL committing to shutting down its existing coal-fired PS by 2050 as part of a plan to decarbonise its generation portfolio. This incumbent actor has implement a new policy to commit to improving emissions efficiency of its operations, investing in new renewable energy technologies and providing its customers with DES solutions (Vorrath & Parkinson, 2015).

Triopoly Actors	Closure of All Coal Generation Assets	Renewable Energy Investments	Decentralised Energy System: Business Focus
AGL	• 2050	• Largest Wind Farm in Australia at 420MW • Building Solar Farms in the states of Victoria & New South Wales	• Virtual Power Plants • Demand Response • Distributed Generation
EnergyAustralia	• 2042	• Estimated capacity for supply 280,000 households powered by Wind Farms	• Distributed Generation • Demand Response
Origin	• 2032	• Constructing a 530MW Wind Farm in Victoria • Continuing to invest in Solar Farms with already 7 in its portfolio	• Distributed Generation • Blockchain

Table 3. *Triopoly actors change in business model from coal generation to a DES focus including investments in renewables and distributed generation* (elaborated by the author).

A further aspect of the current changes affecting the generator actors is the adjustment of their business models. This includes Engie, with its director for European Affairs, Emmanuel Tuchscherer, citing the need for the company to evolve towards to a DES to "capture the opportunities in areas including storage such as hydrogen power-to-gas technology to support the intimacy of renewables". Engie and other actors could only do this with the confidence of energy policy makers and the economy to handle this transition towards a DES (E. Tuchscherer[22], personal communication, March 22, 2018). With the rules and incentives being the COP21 commitment and subsidies for clean energy technologies, the incumbent actors are reducing their coal-fired generation assets and focusing on DG.

[22] Interview with Emmanuel Tuchscherer, Director for European Affairs, Engie

The transition towards DES provides new opportunities for generator actors. With AGL expecting one-third of its customers to go off the grid by 2030, these actors have focused on the prosumer market. This has enabled actors to engage in social innovation by offering households and businesses the option to be prosumers which will provide a more reliable and sustainable energy supply whilst feeding power back into the grid will provide further financial gains. One such example was the VPP project in the City of Adelaide conducted by AGL. This was achieved through collaboration with technologist actor Tesla and further funding from the SA government (Parkinson, 2018a). Here, AGL would not only diversify its energy generation source and provide for additional customers through its retail business, but it also improved the reliability of energy supply for consumers during periods of instability.

The risk of conflict, between incumbent actors and generator and retailer niche actors in the decentralised socio-technical regime, will occur due to the potential monopoly of the market. Already the triopoly actors are investing in DES initiatives, such as DG where subsidies from the government enables these actors to acquire the technology and offer leases and power purchase agreements for its retailer consumers. This creates the opportunity to retain ownership of DG technologies of the consumers, thereby allowing them to lock their customers in long-term (Parkinson, 2015).

With actors having assets such as coal-fired PS along with the monopoly of the market in the case of the triopoly actors, it would seem these incumbents would continue path dependence with positive feedback of CES. However, with the rules and incentives towards a DES, these generator and retailer actors are restructuring to ensure that they remain competitive in future markets. A DES will also introduce more competition which would allow for more actors to break the carbon lock-in of the CES.

Utility Actors

The current business model of utilities has a path dependence towards a CES which is underpinned by large capital costs in transporting electricity from coal-fired PS to consumers. The utility actors' interests of maximising the production and sale of electricity through their expanding grid is creating conflict with the interests of consumers (Roberts, 2015). The latter have been exposed to continual electricity price rises which has led to Australia's residential electricity prices being amongst the highest in the world (Mountain, 2017). As illustrated in the introduction, almost half of the electricity price is based on the utilities T&D network costs. The significant increase in electricity pricing in Australia throughout the past decade can be attributed to the energy peak demand causing some major blackouts and putting pressure on the network. This resulted in political actors reacting to the landscape factor of energy security by increasing the reliability of the network.

Energy security standards were developed by the energy regulator actors where the rules and incentives for the utility actors were to increase the reliability of the grid. The outcome was this centralised socio-technical regime which incentivised the various monopolised and privatised utility actors into "gold-plating[23]" (Butler, 2017, p. 65). This regime further provided increasing returns for the CES but at the consequence of increasing electricity pricing. This correlated with the uptake of consumers using DES technologies, engaging with solar niche actors to implement rooftop solar PV which has increased significantly in Australia. The inherent conflicts are now rising due to the utilities still being responsible for maintaining the grid and supplying electricity on demand to the consumers. Utility actors have concerns about the impact of a DES on their revenues, existing infrastructure along with costs already invested in the network and the further upgrades to the network required to support the large uptake of DG (Cohn, 2017). Although there is the potential for conflict from the incumbent actors wishing to keep their business model on the existing CES, the scope for these actors to expand their market opportunities enables a shift towards decentralised socio-technical regime.

[23] Gold-plating refers to an excessive amount of capital spending to upgrade the utilities transmission and distribution electricity grid (Butler, 2017, p. 65).

The changing dynamic towards a DES introduces a convergence of factors including change in technology, economics and policy. Utility business models are coming under growing pressure as there is a move from centralised to decentralised socio-technical regimes through technology innovation with more and more niche actors providing DES technologies whose costs are falling along with the government policy on reducing emissions (Tayal & Rauland, 2017, p. 60). Utility actor AusNet Services explains that traditionally the business model had only two main focusses: asset management and grid operations. Strategist for AusNet Services, David Marrick, elaborates that this worked for the CES but now is an opportunity to be "much more than poles and wires" and move to be "innovative in the changing the energy system by utilising the technology solutions that are available now and, in the future," (Figure 28) (D. Marrick[24], personal communication, March 3, 2018). Utilities can utilise their existing know-how of the energy system by being key actors in the decentralised socio-technical regime. There is now a focus on digitalisation which is a trend that is currently being seen amongst utility actors globally. Although change can be conducive to causing tension, the utility actors in Australia are starting to also have a focus on the emerging DES and the business model. Instead of conflict, Marrick from AusNet Services argues that digitalisation brings "opportunity for growth" along with the ability to be involved in new market areas such as "operation of cloud base services for Electric Vehicles charging infrastructure" (ibid.).

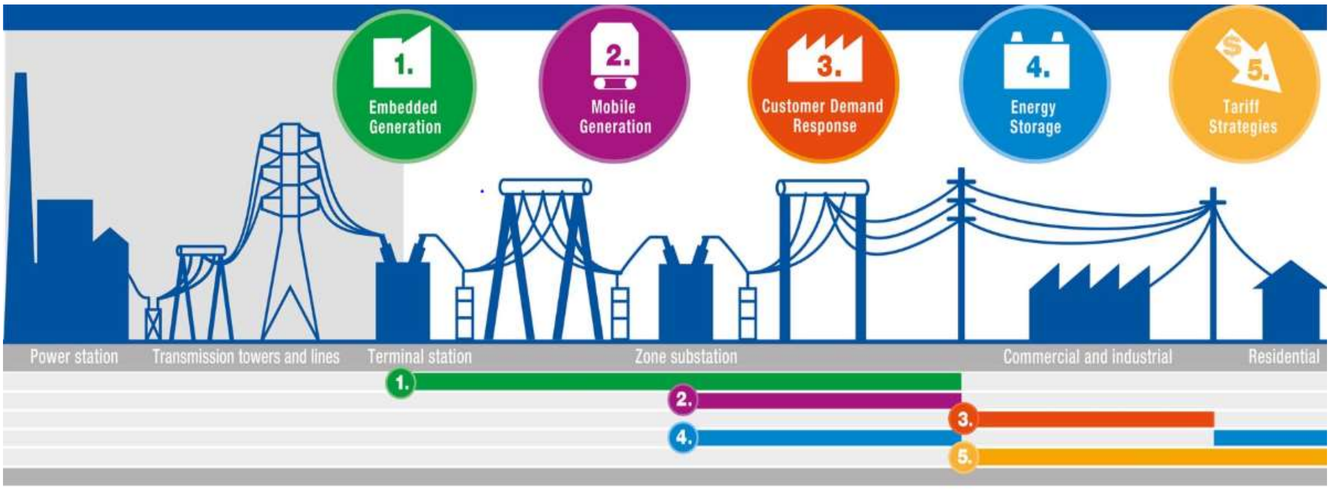


Figure 28. *Utility actor AusNet Services integrating a DES approach by using demand management options to reduce peak demand on the network.* (AusNet Services, 2018).

[24] Interview with David Marrick, Strategists for AusNet Services Emerging Energy Markets, AusNet Services

Various technological innovations along with regulatory standards for the networks could accumulate to form a change in the current centralised socio-technical regime towards a decentralised socio-technical regime. The importance of collaboration of utility actors with other actors in the decentralised socio-technical regime is paramount in the move towards DES. Conflict arises for utility actors as the change in energy system introduces new competition from niche actors offering DES technology and energy services (Nieponice, 2017). AusNet Services believes utilities cannot "go it alone" and require changing their mindset to become collaborative with the move towards a DES. The failings of utilities undertaking projects that are outside the CES is demonstrated by AusNet Services with the "smart meter project that initially failed due to AusNet not having the full capabilities of delivery" and that only succeeded upon collaboration with multiple smart meter niche actors (D. Marrick, personal communication, March 3, 2018). Therefore, collaboration will assist in the building of the utility actors' competencies and capabilities.

Utilities tend to be heavily regulated monopolies with guaranteed returns based on the CES which is a model that encourages "nimble innovation" (Roberts, 2017). This can inhibit consideration and adoption of innovative ideas that is required in a DES (Lee & Gloguen, 2015). Utilities having their own innovation hub internally and partnerships with technologist actors can potentially leverage new ideas and capabilities towards a DES, thus mitigating potential internal conflicts that stem from path dependence of CES within the utility organisation (Tayal, 2016, p. 14). The risk for the utility actors' changing business model to include innovation departments along with collaboration with other actors shifts the balance within the organisation which can lead to a loss of jobs on the CES side of the business and the requirement for new skilled workers. However, this is a small risk in the move towards digitalisation, as the risk of utilities is much higher in not being a player in the move towards a DES by ending up like Kodak who failed to join the digital transition in the photography industry (Bachmann, 2018). Utility actors therefore must increase their products and services when there is a move towards a DES. As the nature of DES involves many technological inputs, utilities do not have, according Fabrice Nicolas from Siemens Microgrid division, "the internal capabilities to know what technology is required for a decentralised system as that has not been their domain". Instead, they have focused on CES and to now adopt DES, the utilities will have to work with technologist actors so that they can optimise the solution required such as "managing the distributed generation of the network using preconfigured controllers" (F. Nicolas[25], personal communication, March 15, 2018). AusNet Services has been looking at reduce peak demands as part of reducing network costs that would result in lower electricity pricing for consumers. This social innovation involved collaboration with niche actor MPower who provided the monitoring and control by digitalisation process on household and industries (MPower, 2015). The MLP with all three levels linked for the move from centralised to decentralised socio-technical regime was at play, the landscape factor being reduction in electricity pricing as well as the collaboration from the actors with the incentives of government subsidies for DES technologies used for this solution.

A DES will act as a competitor to centralised socio-technical regime actors with coal-fired generators, change the financial dynamics for retailers by influencing wholesale cost prices, along with adding another layer for regulators to consider (Simpson, 2017). Utilities may well be the most influential incumbent actors in the adoption of a DES. This is due to utilities transporting electricity from any generation source including from DG and prosumers along with meeting consumer energy requirements that can include initiatives such as demand response to reduce electricity pricing. There will still be the lingering effects of path dependence in the timing of the transition which is illustrated by Siemens head of technology and innovation strategy Dr. Rolf Apel outlining how utilities had the "first shock" when renewable energy systems were starting to be implemented throughout last decade. This took utilities by surprise and they required some time before building a strategy in integrating that technology into their network. The "second shock" with digitalisation will not be as significant as utilities have been conditioned to this previously with "smart grids"; however, it is worth mentioning that even though utility actors are active in the DES space that there will still be a timing factor to the move towards a DES (R. Apel, personal communication, March 16, 2018). Utility actors in Australia will continue to future proof their businesses and have strategic development in moving towards a DES as they see this as a growth area rather than "an existential threat" (Tayal, 2016, p. 13).

[25] Interview with Fabrice Nicolas, Head of Sales – Microgrids Energy Management Division, Siemens AG

2.2.3. Energy Community Actors

Incorporating a DES into the current energy system requires collaboration and coherent efforts by all actors including governments, generators and utilities along with niche actors such as consumers. DES changes the balance of power with the dominance of the CES regime being challenged by energy users at the local level. There is a growing consensus amongst scholars about the role of the local level for the development of clean energy initiatives through citizen engagement in sustainable living (Mey, Diesendorf & MacGill, 2016, p. 33). The social acceptance of clean energy in DES is the extent to which community members will support or oppose DES projects. Community-based clean energy projects generally achieve a higher level of social acceptance due to the inclusive nature of their development than large-scale clean energy projects that are facilitated by renewable energy actors (Simpson, 2017, p. 3). The emergence of energy communities reflects the wish of consumers to produce energy locally and to be engaged in addressing social, environmental and economic opportunities (Rathanyaka et al., 2015, pp. 48-49). Although there are many definition of the term "energy communities", this dissertation concept of energy communities as structures formed to achieve specific goals of their members primarily in the clean energy production, consumption, supply, and distribution (Gui & MacGill, 2017, p. 2). These energy communities engage with various stakeholders as depicted in Figure 29.

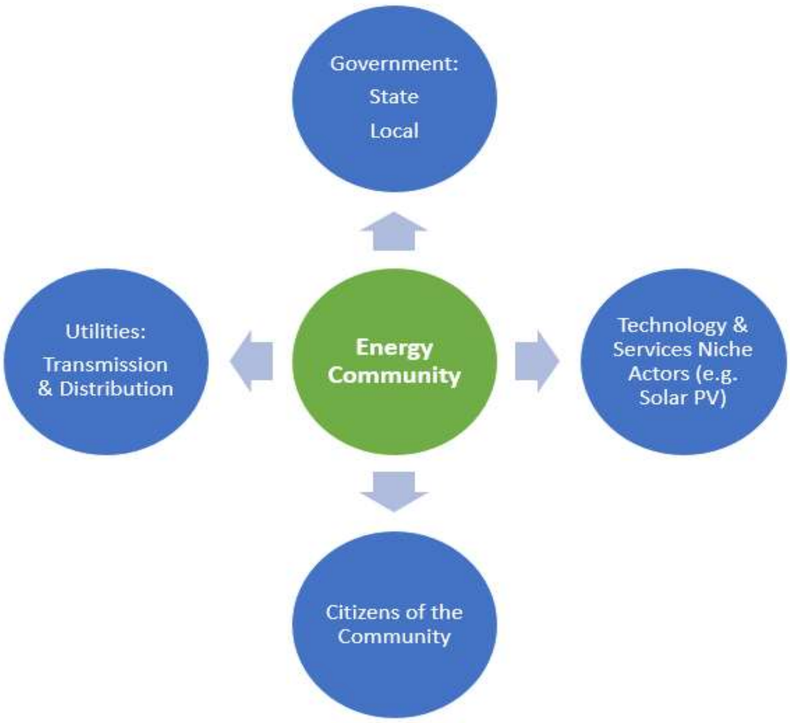


Figure 29. *Energy Community stakeholder map* (elaborated by the author).

Energy communities in Australia are multifaceted which results in various implementations of DES initiatives depending on the requirements of community members (Table 4). However, there are specific common interests amongst these energy communities' which include, as illustrated by Gui and MacGill (2017), the incorporation of sustainable energy, self-sufficiency, and participating in the energy system by means of own energy production (p. 3).

Types of Energy Communities	Definition	Key Motivations
Centralised Energy Communities	Community initiated and investing in energy-related projects	Commitment to sustainability, clean energy supply and concerns for climate change
Individual Members of Energy Communities	Prosumer who will act on an individual basis and allow for an entity to aggregate generation	More grid stability by using Virtual Power Plant to behave like a single large power generator
Decentralised Energy Communities	Community being self-sufficient with its local energy system	Energy self-sufficiency, more sustainable electricity, more reliability, retained economic benefits in the community

Table 4. *Types of Energy Communities* (elaborated by the author).

Centralised energy communities are characterised by a high level of cohesion in collectively owning or participating in energy-related projects. Hepburn Wind, Australia's first community-owned wind farm, uses a cooperative structure. This energy community collaborated with renewable energy niche actor Future Energy to provide industry experience in the development of the project (Wise, 2014). Social acceptance is a potential conflict as parts of the community previously rejected the idea of a former renewable energy developer actor for a wind farm to provide local power to the community of Hepburn. Community engagement was undertaken by the energy community, including holding public forums to provide updates on the project (Wise, 2014). Conflict occurred with the centralised socio-technical regime utility actor subject to path dependence causing this project to overrun. This was due to grid access and connection delays by the utility actor not effectively collaborating with new market niche actor such as Hepburn energy community (Gui & MacGill, 2017). However, conflict can turn into effective collaboration between energy communities and utility actors when they are a stakeholder in the project. This is depicted in the case of individual community members who are prosumers and are not wanting to participate in a cooperative. The utility is the entity that links a number of these members in an energy project such as with VPP pooling the various prosumers generation where these members will be incentivised.

Decentralised energy communities are regarded as a key contributor towards a DES due to being disconnected from the existing CES (Tongsopit & Haddad, 2007). This particular type of energy community generates and consumes energy locally to be self-sufficient without reliance on the electricity grid. They can own DES resources individually or collectively in a group. This kind of energy community, according to Gui and MacGill (2017), relies on a “shared vision of the participating community” (p. 8). Here, an example is the community of Tyalgum developing its own microgrid to meet the community’s goal of zero carbon emissions. This energy community microgrid project will benefit the Tyalgum community “financially and socially” whilst the landscape factor is the ‘energy trilemma’ (Szatow, 2015). The collaboration with the decentralised socio-technical regime and technology and services niche actors is required for a project of such complexity. Tyalgum sharing the same vision with the local government with its high level of sustainability measures including long-term goal to become zero carbon neutral has accrued the benefit of this political actor providing funding. Tyalgum energy community has leveraged the cohesion of its community to engage in crowd funding (ibid.).

Local governments have found niche responsibilities in the form of energy issues for communities. The role of this political actor with energy communities is seen to be critical for coordinating and influencing effective measures around the move towards a DES with addressing issues such as sustainability along with supporting the creation of a business model (Fudge, Peters & Woodman, 2016, p. 1). Local governments can provide new political opportunities for energy communities. Under the centralised socio-technical regime, local governments were not involved in coal-fired generation, but this has changed over the past few years with the diversification of generation through renewable energy. Energy communities can leverage off the local government strategies to further enable the transition towards a DES. The Moreland Council demonstrated such measures with developing the Zero Carbon Evolution Strategy which involves an action plan to become a net zero emissions community by 2020. To this end, the strategy of this energy community with the framework for reducing emissions involves the Moreland Council to engage with actors to create initiatives to meet their target (Gui & MacGill, 2017, p. 7). One such energy community actor was Moreland Energy Foundation which is a corporative that develops solar generation for the local community of Moreland. There is collaboration with solar niche actors for the technology and in addition to the cooperative funding from local members of the community, this energy community receives funding from the Moreland Council (Moreland Energy Foundation, 2015). Adding to both actors' interests in reducing emissions, there is also a focus on delivering assistance to low-income households where the local government is solving an issue on the community impacted by energy whilst the energy community can expand on delivering electricity and engaging in various parts of community concerns.

The social innovations that energy communities present for households, such as improving efficient energy solutions to reduce the impact of the existing high electricity pricing in Australia, will allow for further growth of these energy communities. Moreover, local generation enables increased stability, for example by avoiding blackouts. There are currently already over forty energy community initiatives around the nation, with a further seventy that are currently in the planning phase (REN21, 2016). Energy communities will play an important role in the transition towards a DES. This is due to this system being able to provide a solution for the energy communities' needs such as BES options to reduce the dependence on external suppliers within a CES. The bottom-up approach of niche actors and technologies disrupting the existing socio-technical regime will continue to only increase as communities become more empowered. The reason for this is the collective cohesive measures to provide local energy and for the local government in developing their own initiatives thus not relying on national and state governments to provide legislation (A. Gray[26], personal communication, February 28, 2018).

[26] Interview with Amy Gray, Senior Sustainable Development Officer, Aberdeen City Council

Chapter 3. The Challenges and Opportunities for a Decentralised Energy System in Australia

There is a transformation of the energy system in Australia as observed by AEMO with the sector rapidly evolving with emerging technologies, the rise of prosumers requiring more innovative solutions from energy market actors and the government aiming to reduce emissions (Zema, 2017). Consequently, in the energy sector is becoming less centralised and the diversification in generation has seen the growth of renewables creating a move towards a DES. This presents a challenge across the network including how the energy market will respond to the generation mix of DG and what impact this will have on energy security (Grant Thornton, 2016, p. 2). But the DES also provides an opportunity in readily being able to respond to shortages of energy supply due its diverse DG along with reducing emissions and decreasing electricity pricing as it does not require an expansive grid. Australia already has the highest ratio of rooftop solar PV per capita globally and the trend towards decentralised energy, according to BNEF, has Australia moving exponentially in the coming decades as indicated in Figure 30.

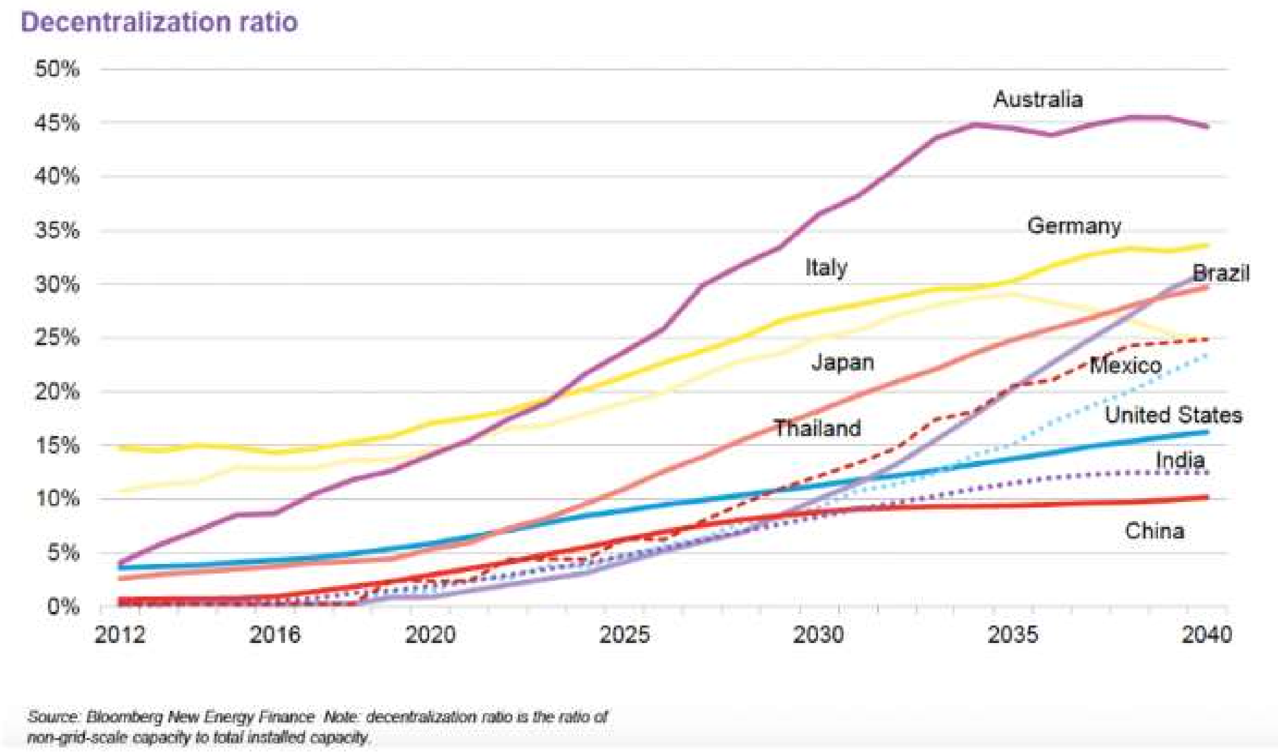


Figure 30. *Decentralised Energy Ratio of Non-Grid-Scale Capacity to Total Installed Capacity* (Watts, 2016)

3.1. The Influencing Factors in the Systemic Transition

The status quo of Australia's energy system is that it is heavily influenced by the centralised socio-technical regime. Consequently, there are challenges in the transition towards a DES as conflicts between incumbent actors are made more divisive in the instances of weak policy and issues with social acceptance. The following subsection will examine the current challenges for the DES and analyse if there are opportunities to overcome barriers to prevail in the transition.

3.1.1. Energy Policy: Federal vs State

The objectives for the energy sector are clear in addressing the 'energy trilemma'. In response to this, the federal government announced its new energy policy, National Energy Guarantee[27] (NEG), which is currently under discussion requiring bipartisan support from the federal opposition and state governments. The NEG contains two new obligations on electricity retailers: to reduce the energy sector's GHG emissions and to ensure that there is enough electricity generation available to meet consumer needs (Blowers, 2017). COAG forecasts that the electricity pricing will reduce under the NEG by an average of approximately $115 per year (Hopkin, 2018).

The challenge of bipartisan support for this energy policy is with the state governments who have their own RETs. The influence of the state governments on shaping the NEG has already been demonstrated by stating that they would not agree on this policy if their RETs would be altered in any way. The federal government thus assured them that the NEG will not prevent state governments pursuing their own RETs as long as, as outlined by MP Frydenberg, the states can "meet their reliability obligations under the NEG" (Hopkin, 2018). Moreover, another challenge is the path dependence of the CES that can be observed in the PM promoting the fact that as Australia is "the world's largest coal exporter, there is vested interest in showing that emissions can be lowered with reliable baseload power though state-of-the-art clean coal-fired technology" (Energy Matters, 2017). With the economic costs favouring renewables over clean coal generation, the market would be favouring a DES approach. In addition, intermittent renewables can be transformed into dispatchable generation with the combination of storage.

[27] See Appendix D for an overview of the NEG

The NEG policy provides an opportunity for the transition towards a DES with the requirement in reducing emissions being achieved by increasing the low-emissions generation and concurrently pushing out high-emissions intensity generation such as the ageing coal-fired PS (Blowers, 2017). Australian business is calling for certainty in a national energy policy to have the confidence in making long-term investments that foster the development of emerging technologies which will assist in the move towards a DES (Pears, 2017).

3.1.2. The Economic Battle: Centralised vs Decentralised

The rapidly falling cost of DG demonstrates that this will increasingly become the cheapest option in replacing ageing CES generators. In its comparison using 'Levelised Cost of Electricity' (LCOE), BNEF suggests that, for example, building new wind farms is already cheaper than building new coal-fired PS (Figure 31) (Butler, 2017, p. 91).

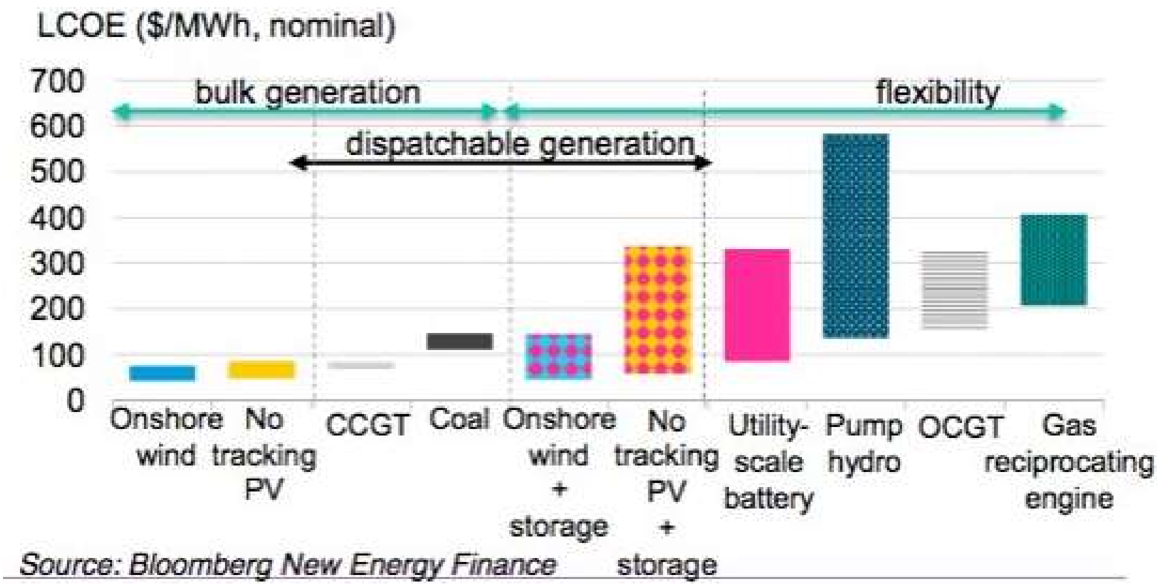


Figure 31. *LCOE of the technologies grouped in Australia* (Parkinson, 2018b)

The challenge for a DES is the economic investment of $85 billion in the expansion of T&D capacity over the past decade to increase Australia's energy security. Utility actors will be looking to capitalise on their investment by utilising this grid and a transition towards a DES would be a disruptor to these actors. However, recent experiences such as the state-wide blackout in SA suggest that the investment has not purchased energy security but has in fact increased electricity pricing (Garnaut, 2016, p. 8). Rational network design would see an opportunity for a DES to reduce T&D upgrades along with playing a large role in balancing energy from different sources (Coote, 2011)

The opportunities for a DES is the nation's substantial cost advantage of renewables due to better wind and solar resources compared to countries such as China and the United States. As there is a transition towards a DES with more renewables being used globally, over time this cost advantage of Australia will result in substantial economic benefits (Butler, 2017, p. 92).

3.1.3. Energy Sector: Loss of Jobs in Coal vs the Growing Decentralised Energy

Australia now faces with the challenge of reducing its long-time reliance on access to cheap fossil-fuels such as coal to move towards a DES. The transition will affect the existing communities in Australia whose economy was largely built on the existence of coal-fired PS (Butler, 2017, p. 160). This has led to these communities along with the workers supported by unions opposing the closure of these power stations. The government has set a 'just transition' plan for the energy sector that addresses elements linked to the impact of workers and communities of the coal-fired PS. The transition to a DES will require substantial adjustment support for the workers and communities that currently sit in the centre of the existing CES.

Already there is a change in the job market in the Australian energy sector where an investigative report found 13,300 people employed in solar PV business which is far larger than the total employed in Australia's coal-fired PS at 9,487 (Vorrath, 2016). There is an opportunity with the roll out of the transition towards a DES which will be over a period of many years for the increase of job opportunities. To reduce conflict with the coal workers and communities, this will require a staged closure of power stations to limit the impact which currently is challenge due to the governments not setting lifetime limits. However, the discussion in federal politics has commenced with the Greens Party stating that Australia should have a plan for "the orderly retirement of coal-fired powers stations and their replacement with renewable energy" (Asher, 2016). This is an important component in breaking the carbon lock-in of the CES. The opportunity, as expressed by Butler (2017), is there for these communities to play a leading role in the transition towards a DES with their existing expertise and skills in energy to transfer this to renewables (p. 163).

3.2. South Australia: Leaders in the Transition Towards a Decentralised Energy System

The state of SA reflects the way of how a DES can go forward at state level despite hesitations at federal level. One in four homes in the state have solar PV panels. That level of rooftop solar PV penetration is a record for any major grid in the world (Parkinson, 2017). Australia must only look in its own backyard for an example of a region that is successfully transitioning towards a DES. SA has shown that it is not only a national but also international leader in the transition, according to, the Clean Energy Council (2018). The state announced both RET and energy storage targets that has resulted in increasing confidence in industry. This is illustrated by the state government collaborating with technology actors such as Tesla to build the world's largest VPP (Figure 32).

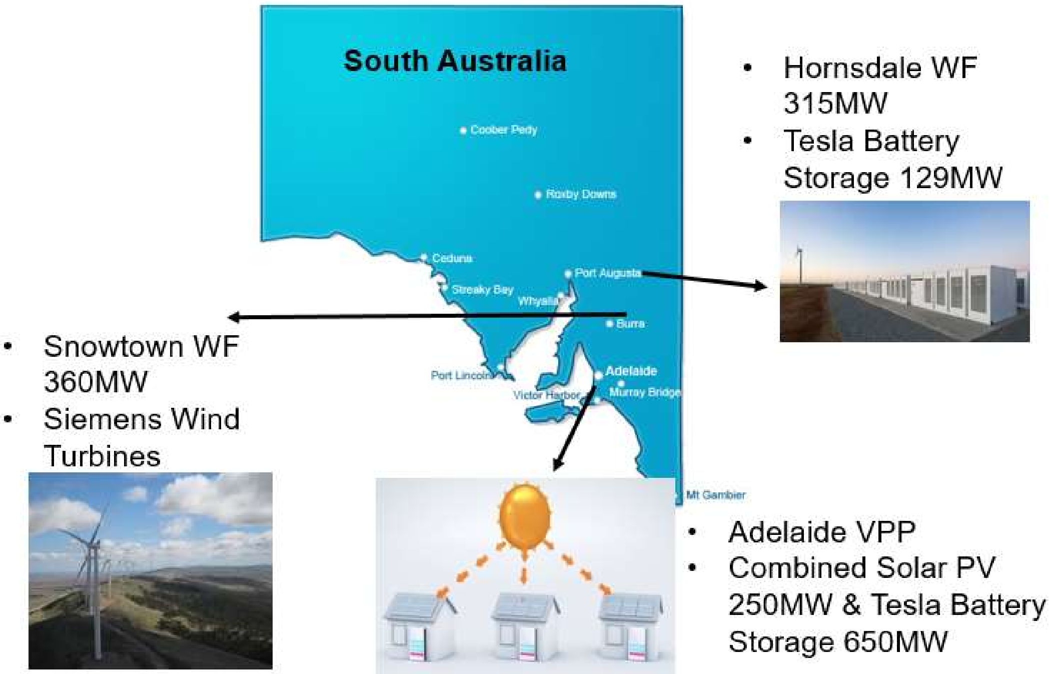


Figure 32. *South Australian clean energy projects are leading all states in the transition towards a DES* (elaborated by the author).

The plan by SA to adopt a target of zero net emissions by 2050 and has produced a roadmap on how the state can reduce emissions in a way to support job growth with the increase of emerging clean technologies (Better Energy, 2017). This has not only involved industry actors but also allowed for the city of Adelaide to build on these state initiatives by investing in a strategy to decarbonise the city and set the goal of becoming the first carbon neutral city in the world. Already, there is a goal in attracting $10 billion in low-carbon investments in SA through setting energy targets and policies which is critical for the transition towards a DES (Milman, 2015).

3.3. The Influence of Endogenous and Exogenous Factors on the Centralised and Decentralised Energy Systems

The current carbon lock-in with the CES is a significant barrier for the transition towards the DES. This section identifies the costs and benefits of both CES and DES by using a 'PESTLE' analysis, which is a structured framework for categorising "macro-elements" of a system (Table 5) (Prpich, Darabkhani, Oakey & Pollard, 2014, p. 6). This analysis allows to determine the energy system that is best adaptable for the requirements of Australia.

For an energy system to flourish, it requires certainty from the market and that is through the confidence gained politically in the commitments, policies and investments employed. The driving forces politically to solve the 'energy trilemma' have put in place mechanisms such as emission targets and energy policies that support the transition towards a DES. Although currently there are significant funding and subsidies for a DES compared to a CES, it is expected that with the fall in pricing for emerging technologies the market will not need to rely on these heavy concessions and will be able to compete with, for example, coal-fired generation (Butler, 2017). Already in Germany there are offshore wind farms that have been built without any government subsidies due to the market competition, and it is expected that within a liberalised market like Australia that this, too, would be the case (Jones, 2017). The economic trend towards a DES can be observed through the LCOE.

There is a high social acceptance for DES technologies such as renewables. There are health concerns with the current coal-fired generation not only from citizens who reside close to the power stations but also for those who live in the cities due the spread of pollutants. Furthermore, the issue of increasing electricity bills from the CES has an impact on households. With the ability of a DES to use various methods to reduce pricing, citizens getting involved in energy communities along with the expanding the job market, the social aspect will be a significant driver in transitioning towards a DES.

The challenges in meeting energy demands from the CES have resulted in high emissions and pricing. The technologies in a DES will not only reduce those results but also be adaptable due to being modular and it will be able to meet future changes in energy profile and demography. The regulation and standards to support a DES are in place and will assist in reducing the vulnerability to extreme climatic conditions that Australia is prone to, such as mitigating bushfires through rural towns going off-grid (e.g. microgrid).

The 'PESTLE' analysis presented below points to a DES as the optimal energy system for Australia. Although there is path dependence of the CES, moving forward this system is unable to provide the required outcome. There are dynamic changes along with the influence from actors in the energy sector that are impacting the transition towards a DES. Although there will be challenges with increasing returns and incumbent actors of the CES, the opportunities for a DES outweigh the risks and will ultimately be able to provide a stable, safe and sustainable long-term solution for the Australian energy system.

PESTLE Categories	Items	Centralised Energy System (CES)	Decentralised Energy System (DES)
Political	**International Commitments** COP21 Paris Agreement (reduction of GHG emissions 26-28% below 2005 levels by 2030)	• Reduction of Coal-fired PS emissions will require closure of generators that are not able to be retrofitted • Large-scale fossil fuel (i.e. coal-fired PS) generators with more output power will have high emissions • International climate community is critical of Australia's reliance on coal for energy generation	• DG generation is low emissions with renewable energy sources such as wind & solar • Small-scaled DG generators will have low output but will have low emissions • Generation is close to the source reducing transmission losses which results in reducing emissions • Moving towards DES will show initiative from the Australian federal government and provide international credibility to reduce emissions
	Energy Policy The National Energy Guarantee (NEG). Increase reliability, reduce emissions and decrease electricity pricing.	• Centralised baseload power stations such as coal-fired PS are dispatchable • Meeting emissions guarantee will reduce reliance on high emissions coal-fired PS • Reliability risk with Transmission Line faults resulting in large-scale blackouts	• Increase reliability with multiple generation (i.e. low emission renewable energy) • Smart Grid enables fast response time of providing energy to where the demand is required along with self-healing restoration of faults through the network • Peak Load management initiatives through demand response will provide consumers reduce energy consumption and financial incentives

			• State governments have RETs and will be continuing to increase their energy mix with renewables along with energy storage (i.e. to have renewables move from intermittent to dispatchable generation)
	Funding and Subsidies	• Fossil-fuel generators such as coal-fired PS does not receive any funding from governments • Subsides for coal-fired PS is $0.40 per MWh (Minerals Council of Australia, 2017)	• Emerging technologies that is used in DES such as renewable energy generation, smart meter programs etc. can be funded by the Emerging Renewables Program. • Subsides for renewables include $74 per MWh for solar; $74 per MWh for wind; $33 per MWh for all other renewables (Minerals Council of Australia, 2017) • Small-scale Renewable Energy Scheme (SRES) assists household and small businesses with installation of eligible renewable energy systems
Economic	**Infrastructure and Generation Costs**	• High variable cost; High maintenance cost (Momoh, Meliopoulos & Saint, 2012) • Coal-Fired PS cost range $134-$203 per MWh (BNEF, 2017) • Coal-Fired PS with CCS cost ~ $352 per MWh (BNEF, 2017)	• Low variable cost; Low maintenance cost (Momoh, Meliopoulos & Saint, 2012) • Wind cost range $61-$118 per MWh (BNEF, 2017) • Solar cost range $78-$140 per MWh (BNEF, 2017)
	Electricity Household Pricing	• $0.29 per kWh (Mountain, 2017)	• Energy consumption using solar PV ~$0.08 – $0.15 per kWh (Solar Choice, 2018)
	Public Perception Acceptance of different energy generation	• 59% of Australians (National Climate of the Nation survey) want the phaseout of coal-fired generation (Hunt, 2017) • 38% support fossil-fuel generation (Hunt, 2017)	• 96% of Australians (National Climate of the Nation survey) want the nation's primary energy source to be renewable (Hunt, 2017) • 58% support the use of storage technologies (Hunt, 2017)
	Demography 80% of the Australia population live in	• Transmission and Distribution lines from centralised coal-fired PS are long and consequently costly	• Generation is close to the consumer allowing to be more efficient with less line losses along with reduce

Social	urban areas (i.e. cities) (Huffadine, 2015)	• Potential fault in the line can cause wide spread blackouts of parts of the city	transportation of electricity costs • Microgrid is able to support rural areas with limited or intermittent access by the current CES grid. The ability to be self-sufficient allows for increased reliability of energy
	Health Risks	• Health concerns with coal-fired PS with the main pollutants (sulphur dioxide and nitrogen oxides) collectively can cause inflammation in the lungs. Pollution and its health hazards are greatest near power plants and also can affect other areas as sulphur dioxide can travel 100km or more. (Shearman, 2016)	• Generation of electricity in DES is from low emission technologies such as renewable energies that will reduce health risks to society compared to fossil-fuel generation in CES
Social	**Energy Poverty** Increasing electricity bills for households	• Current CES has increased household energy prices by 73% between 2003 and 2013. The increase in electricity pricing has affected low-income households spending disproportionately high percentages (10% or more of disposable income) of their income on energy and are vulnerable to price increases (Crowley & Jayawardena, 2017). • Climate change from the high emissions from CES is affecting low income and disadvantaged Australians with impact on food and water increase in prices	• Renewable energy such as solar PV coupled with energy storage in a household can decrease electricity bills • The establishment of community energy production such as renewable energy such as wind or Virtual Power Plants (VPP) for example can contribute to increase energy needs for more of the community reducing reliance on CES that is contributing to higher electricity prices • DES digitalised technology such as smart meters can enable consumers to understand where costs were escalating and enabling them to manage this • Emerging technologies such as battery energy storage and energy efficiency measures with DES can alleviate electricity consumption along with being able to use energy from storage when electricity is at a higher price due to for example peaks (Maher, 2017)
	Job Opportunities	• Existing coal-fired PS has led to a supply chain from contractors, OEM suppliers of equipment, workers in	• Jobs are created in the construction, operation and maintenance of generation sources such as renewables

		the power station and coal mines • CES job opportunity market only extends to a certain number of actors in generation and the installation and maintenance of Transmission and Distribution lines. No future growth areas in innovation apart from retrofitting technology to reduce emissions on generators.	energy installations (e.g. rooftop solar PV) • DES will provide a diverse array of opportunities for actors such as utilities to provide innovative services like VPP and technology and service niche actors who can provide for example solar technologies and installation of energy management systems to enhance energy efficiency in buildings • Job losses in coal-fired PS are more than compensated for by increased employment in the renewable energy sector with Climate Council (2016) modelling showing that over 28,000 new jobs will be created by 2030 which is nearly 50% more employment than aa business as usual scenario (p. 2)
Technical	**Meeting Energy Demand**	• Coal-fired PS requires continuous generation output to meet demand even if the demand is not there. Large-scale baseload generators are not able to be shut off as it can take 2-3 days to start the generation of electricity. • Low electric efficiency due to thermal losses of fossil-fuel generation such as coal-fired PS (~30% efficiency for large-scale coal-fired PS in Australia) along with high losses in the transmission lines • The infrastructure is built to accommodate high peak periods that occur infrequently which increases both emissions and electricity pricing	• DG generation along with energy storage integrated into a smart grid allows for demand to be met either on continuous basis or if there is a drop-in demand then the energy can be either shifted to another part of the grid or stored • High electric efficiency due to generation close to consumption • DES manages high peak load with initiatives with load shedding, flexible transfer of electricity from various energy sources and storage
	Adaption of Technology to Meet Changing Energy Requirements	• Existing generation is aging and as a result there are coal-fired PS that are unable to be upgraded to either meet reduction in emissions along with increase energy output if required	• Modular digitalised energy system that is adaptable with the ability to add generation sources and build on the existing network

		• Level of R&D is diminishing which will see the shift from large-scale to small-scale generation in the future	• Consumers can become prosumers and be part of the energy supply chain • Communities can be self-sufficient with for example microgrid applications • The ratio of Decentralised Energy technologies is expected to grow from US$20 billion in 2016 to US$93 billion in 2025 (Gui & MacGill, 2017)
Legal	**Regulations and Standards**	• There are no regulations in place to limit emissions intensity for coal-fired PS • National Energy Market standards requires generators such as coal-fired PS to bid into the wholesale market and for the network to be able to support additional 10% of generation for interconnection to various states	• Australia Energy Regulator administrates the Renewable Energy Target (RET) that ensures 20% of generation in Australia will be renewables • Small-scale Renewable Energy Scheme encourages DG generation such as solar PV by providing an incentive for investment • Residential and commercial consumers are able to generate their own power from DG with no restrictions • Consumers can go off-grid with no legal or standard requirements to be connected to the grid. • Local government approval for installation of certain technologies (i.e. rooftop solar PV facing the street) is required
Environmental	**Extreme Unforeseen Climatic Events**	• CES is vulnerable to extreme climatic conditions that can damage the transmission line that is transporting electricity to the consumers • Small group of large-scale generation does not allow for suitable alternative solutions if there are failures due to damage to generation infrastructure	• DES reduces the vulnerability of extreme climatic conditions as there a large number of small-scale generation and this is close to the source (i.e. cities). The infrastructure being diverse is able to mitigate potential of blackouts • Micrograds can allow rural areas to be off-grid to reduce the risk of bushfires being started by electrical faults from the transmission lines

Table 5. *Comparison of CES and DES in Australia to deduce the costs and benefits using 'PESTLE' analysis* (elaborated by the author).

Conclusion and Recommendations

While its current energy system is characterised by a carbon lock-in effect due to its centralised structure, Australia is facing increasing pressures linked to the ‘energy trilemma’. The failure of the CES in providing energy security against exogenous shocks along with the inability to curb rising emissions from its coal generation and increasing electricity pricing due to the expansive T&D network challenges this lock-in. Therefore, there is an opportunity for a systemic transition towards a DES that can meet the requirement of solving the ‘energy trilemma’.

This dissertation has examined whether Australia can transition towards a DES, given the legacy of the CES underpinned by the path dependence of coal used as the nation’s primary energy fuel. The increasing returns for the CES are now not as significant as in the past and the advent of challenging DES technologies is now diminishing the advantages of a CES (Unruh, 2000, p. 828). Critical junctions, such as the storm that resulted in the state-wide blackout in SA, are a catalyst for breaking the path dependence of the CES. There are dynamic changes occurring as the coal-fired PS are ageing while the country is seeing the increase of DG. This allows for substituting the loss generation along with creating further opportunities for actors such as the energy market, prosumers and energy communities to develop DES initiatives including for instance microgrids and VPPs.

Systemic transition scholars define the energy system as a socio-technical system that not only consists of the technology infrastructure but is also deeply influenced by social structures and coevolves with energy actors and institutions (Geels, 2002, 2012; Allen, 2014). The examination of the conflicts and collaboration of the actors involved in the transition has unpacked the variety and complexity of the pathways towards a DES. There is no linear approach with actors since the dynamics are variable, as academics Geels and Schot (2007) demonstrate, as they are prone to “changing perceptions”, “lobby for favourable regulations” and “compete in markets” (pp. 402-403). There is a high conflict potential among the incumbent actors benefitting from the path dependence of the CES. The transition relies on these actors engaging and collaborating towards a DES.

Despite the energy market actors' well-established position within the centralised socio-technical regime, this dissertation has found that, rather than turning into prominent roadblocks, a change in their business model can be detected, such as in the cases of generators retiring their coal-fired generation assets and utilities focusing on digitalisation. At times there is inherent conflict as they are incumbent actors that have a monopoly on the energy market and are challenged by the competition a DES brings with the rise of technology and service niche actors along with energy communities. However, these incumbents have shown a long-term vision towards the economic opportunities a DES can provide. The speed of the transition will depend on the extent to which the energy sector allows for innovation and how quickly these niche actors can to become the incumbents of tomorrow. This speed will be determined by the political actors. This transition requires the federal government to set the rules and incentives, but currently, although there is a push with the NEG energy policy, the conflict between parties at various levels is inhibiting confidence in the market and thereby hinders the investments necessary for transitioning towards a DES. Nevertheless, state and local governments have illustrated that unlike the federal government, who are more attuned to a short-term vision as exemplified with the national RET only lasting until 2020, they are setting their own rules and regulations that is allowing for the collaboration of energy actors in developing DES solutions.

The South Australian state government has set renewable and storage energy targets that have enabled investments from energy actors in the development of a DES. They are a national example showing that long-term stable energy policies and collaboration with energy actors are required for the way forward for a DES. The drive for transition at state level can be compared to Germany which has a similar multi-level political system. In their case, the transition towards a DES is strongly driven from the bottom-up by states. Australian states can observe the potential afforded by a DES through looking at their German state counterparts which in the development of a DES has offered opportunities for emerging markets, jobs, revenues along with the increase of social acceptance with the rise of energy community cooperatives (Ohlhorst, 2015).

Recommendations

Although there are changes that are enabling the transition towards a DES, there are several recommendations to be drawn from the analysis in this dissertation that can support this process (Table 6). One example is utilities having, such as in the case of Western Power, previously produced recommendations for increasing technologies required for a DES; however, these reports did not receive a formal response from the state government. This is just one case in which unclear priorities and a lack of objectives from government to utility actors may have restricted resourcing potential options to increase DES technologies such as DG. This is a theory supported by Simpson (2017) who suggests that “blocking mechanisms” for systemic transitions include uncertainty and a lack of political support (p. 430). Therefore, the recommended action required is for an established process managed by an external party to ensure these interactions are dutifully processed and actioned accordingly. Nethertheless, this is by far not the only instance where action is required as illustrated in the table below.

#	Items	Recommendations
1.	Closure of coal-fired power stations	Federal government has to set lifetime limits on the closure of these power stations. Applying this nation wide will provide certainty for investors in the investment of other generation, such as renewables.
2.	Collaboration of political, industry & energy market actors	Require energy policy makers to actively cooperate with industries and energy market to achieve delivery of optimal mix of energy-related programs and outcomes. Independent agency should be established in order to have set discussions on energy related topics between all levels of government and energy market actors .
3.	Establish Decentralised Energy coordination agency	Within the energy department at federal government level there should be reviews carried out in regards to responding to energy market developments.
4.	Decentralised Energy Fund	While the Australian Renewable Energy Agency (ARENA) is currently providing funding for clean energy projects, this has been largely focused on large scale renewable projects. A separate fund for Decentralised Energy Systems it is important to insure that there is not a scale gap in the current incentives specifically that funding is available for medium to small scale Distributed Generation projects.
5.	Training & Skills Development	As part of the federal governments Clean Energy Future Package, there should be training and skill development policy in providing funding and educational facilities to support the transition. This will in particular assist the workers that will be affected by closure of coal-fired power stations.
6.	Energy Community Projects	Supportive regulatory and institutional structures are required in order to prioritise community funded Decentralised Energy System projects.
7.	National Energy Efficiency Trading Scheme	Implementing this scheme will entice demand response bidding into the electricity market.

Table 6. *Recommendations to support the transition towards a Decentralised Energy System* (elaborated by the author)

Scenarios for the Future Australian Energy System

Key trends in technology and consumer choices, such as renewable DG and cost-reflectivity in pricing, will change Australia's energy landscape in the decades to come. The four scenarios that will change the Australian energy system by 2050 will not only suitable but be an enabler in the transition towards a DES (Figure 33).

1. **Peak Demand Management:** curtailing high electricity pricing will be a driver towards demand response initiatives and on-site storage to manage the load.
2. **Prosumers:** with almost half of generation in 2050 supplied by DG along with the adoption of EVs, prosumers will become an active energy actor in not only consumption but also in trading of electricity (CSIRO, 2013, pp. 4-5).
3. **Leaving the Grid:** by the late 2030s with reduced battery storage costs, disconnection from the grid will become a "mainstream" option for consumers with poor access to energy supply along with those situated in rural areas with the increase of energy communities employing microgrids for self-sufficiency (ibid.).
4. **Growth of Renewables:** with the declining costs of renewable technologies, government energy policies with increasing RETs, along with the closure of ageing coal-fired PS, will result in renewables accounting for 86% of both centralised and on-site generation by 2050 (ibid.)

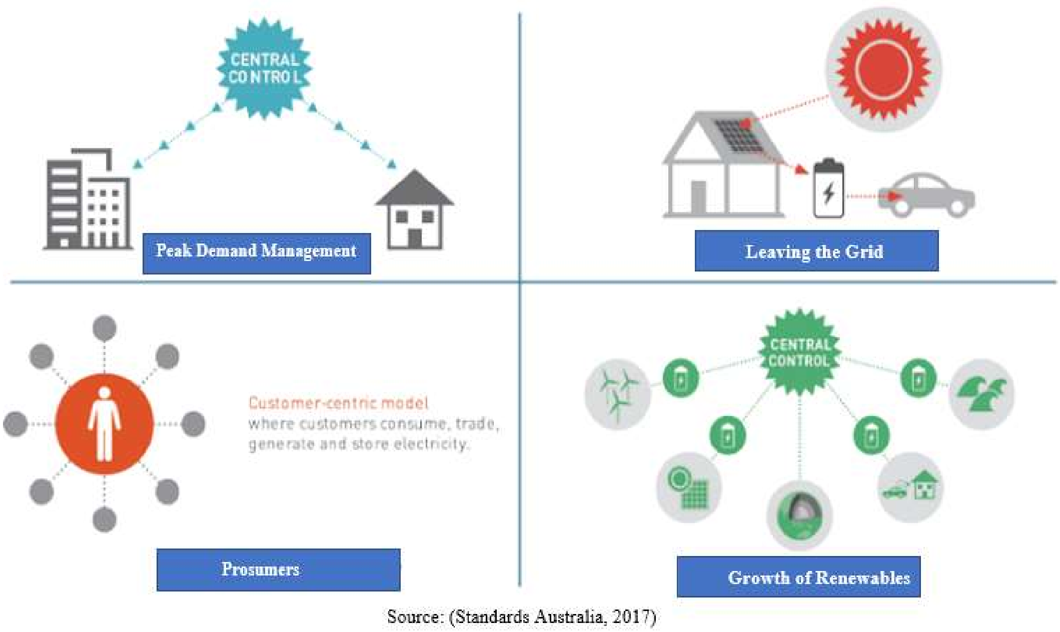


Figure 33. *The four scenarios of the future of the Australian Energy System by 2050 that will foster the transition a Decentralised Energy System* (Standards Australia, 2017).

While the overall outlook in Australia for a move towards a DES seems positive, it must be noted that this dissertation deals with the transition at a systemic level. Therefore, many of the areas considered in the analysis require a more detailed examination and provide an excellent opportunity for future research, one example being Australia's manufacturing industry which is facing a loss of productivity due to increased electricity pricing. In addition, the strong focus on South Australia and its best practices could be complemented by looking into less well-developed case studies of other states and regions and outlining their potential as well as possible challenges in transitioning towards a DES. Although from the analysis in this dissertation between the two energy systems determined that a DES is most optimal for Australia's requirements, there is no 'silver bullet' in terms of meeting all the various scenarios when it comes to energy. The analysis of the co-optimisation of a CES/DES that leads to a future grid should be further explored to maximise the potential of Australia's energy system.

In conclusion, this dissertation has shown that despite many systemic differences, difficulties and conflicts, a transition from a CES to a DES in Australia is possible. Here, the real benefits include a cleaner energy system that will mitigate climate change and reduce local air pollution. Electrification through a DES with clean energy allows in contributing to reducing emissions else elsewhere in the economy including the transportation sector with the switch towards EVs. Moreover, the increase in DES projects will see the increase of jobs and investments along with the opening of opportunities for innovation in Australia's energy sector. By utilising Australia's abundance of renewable energy resources, the country will experience a competitive advantage in energy costs over parts of Asia, Europe and North America (Butler, 2017, p. 165). In addition, consumers will have a greater control over the way they generate and consume electricity. However, it is important to note that this transition can only happen as a result of a collaborative effort of all actors involved, guided by a common vision. This process will not be linear due to the high conflict potential linked to many of the core issues that need to be worked on. But while everyone needs to be involved as not one actor can turn the DES into a reality by themselves, there is also not one actor who can hinder the development to a sufficient extent for the transition to stop. Therefore, Australia is on its way to collectively jump into a bright energy future with its own Decentralised Energy System.

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Appendix A

The Council of Australian Governments (COAG) is a regulator of the national framework to operate the National Electricity market (NEM) in the long-term interests of consumers in Australia.

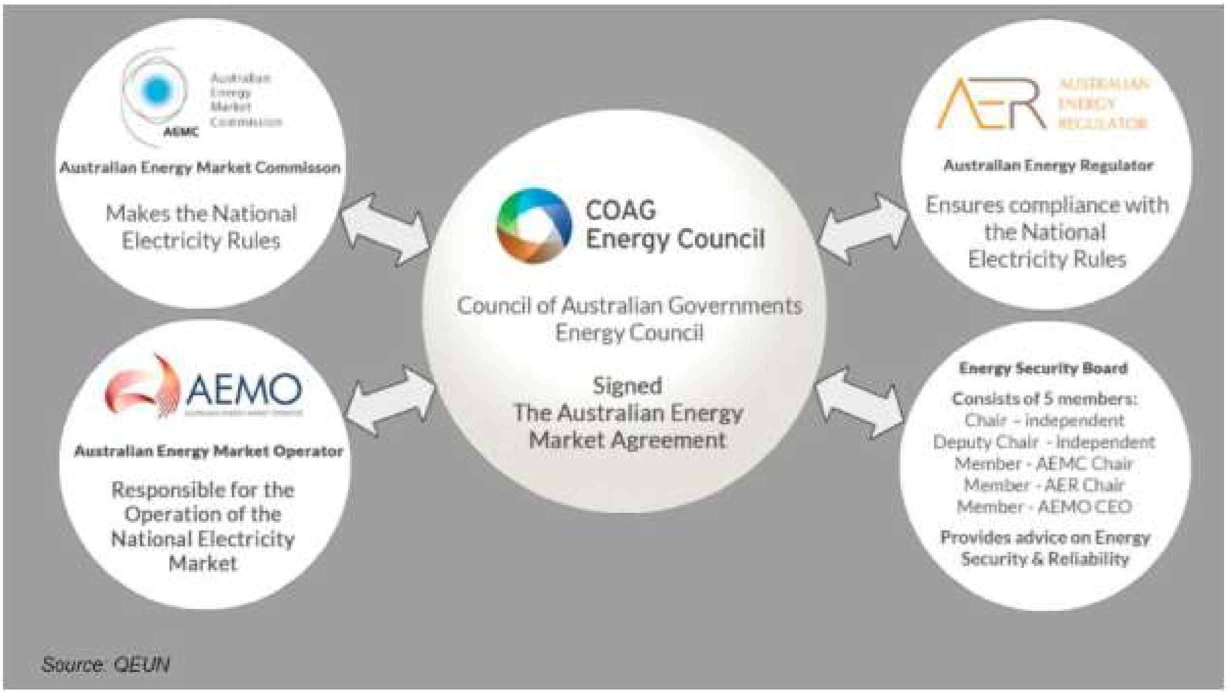


Figure 34. *COAG Energy Council (QEUN, 2016)*

Appendix B

Technical information and diagram of Decentralised Energy System

Figure 35. *DES Technical Details & layout of this system* (Arup & Siemens, 2016)

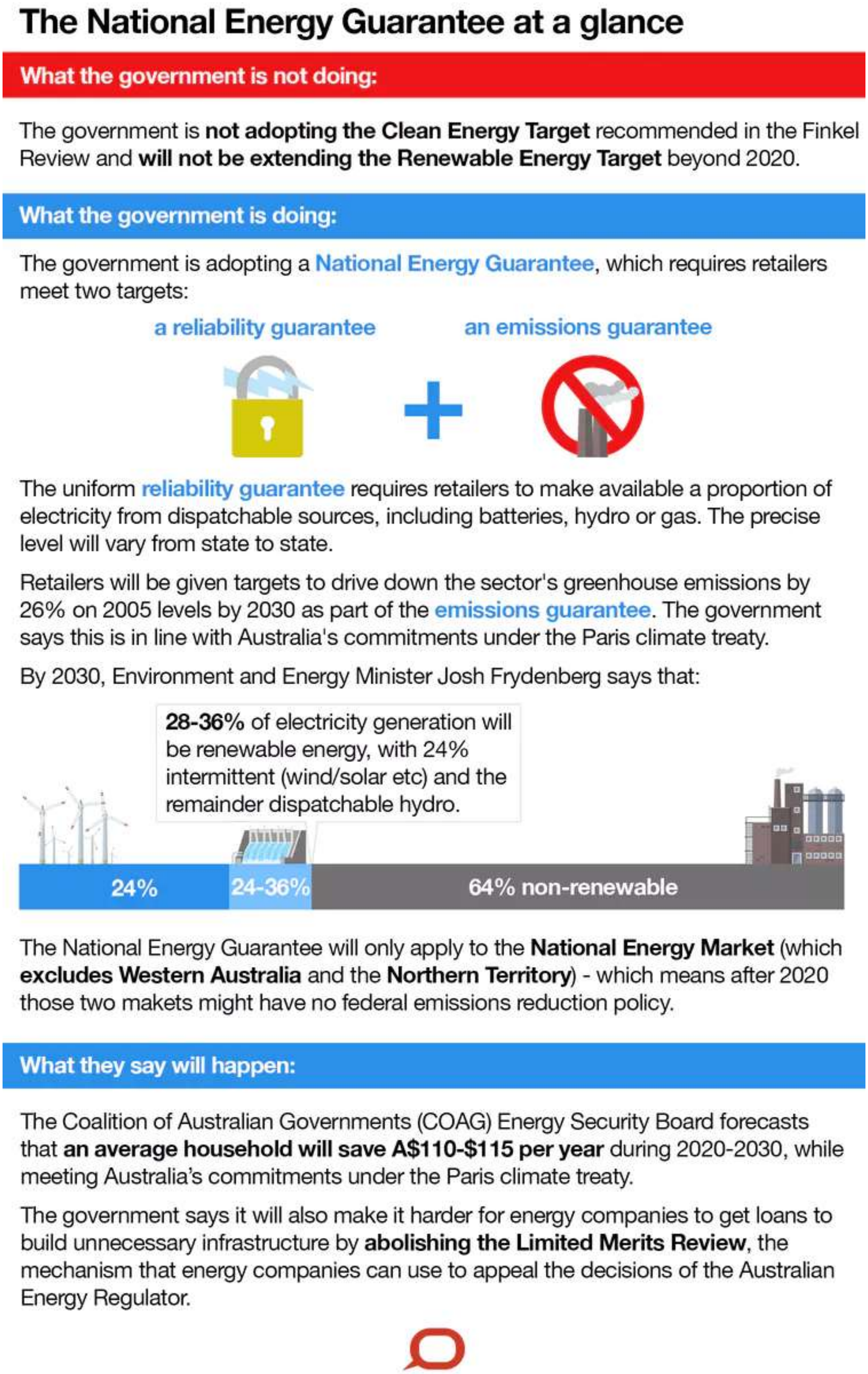
Appendix C

Nature of the ideal dimensions of the democratic political process

DIMENSION	NATURE	DENOMINATION	SUBSTANTIVE CHARACTERISTIC	FORMAL CHARACTERISTIC
Constitutional Lawmaking	General Parameters of the Political Game (Structure)	Polity	Minimum consensus agreed upon by the diverse political actors	Generality, relative neutrality
Clashes and Political Coalitions	Political Game	Politics	Dynamic relationship between political actors	Conflict and/or Cooperation
Government Lawmaking	Outcomes of Political game (Conjuncture)	Policy	Victory/Loss of different political actors	Specificity, controversy

Figure 36. This chart was a basis for the analysis of Chapter 2 with the polity, policy and politics (Couto & Arantes, 2008).

Appendix D



The National Energy Guarantee at a glance

What the government is not doing:

The government is **not adopting the Clean Energy Target** recommended in the Finkel Review and **will not be extending the Renewable Energy Target** beyond 2020.

What the government is doing:

The government is adopting a National Energy Guarantee, which requires retailers meet two targets:

a reliability guarantee + an emissions guarantee

The uniform reliability guarantee requires retailers to make available a proportion of electricity from dispatchable sources, including batteries, hydro or gas. The precise level will vary from state to state.

Retailers will be given targets to drive down the sector's greenhouse emissions by 26% on 2005 levels by 2030 as part of the emissions guarantee. The government says this is in line with Australia's commitments under the Paris climate treaty.

By 2030, Environment and Energy Minister Josh Frydenberg says that:

28-36% of electricity generation will be renewable energy, with 24% intermittent (wind/solar etc) and the remainder dispatchable hydro.

24% | 24-36% | 64% non-renewable

The National Energy Guarantee will only apply to the **National Energy Market** (which **excludes Western Australia** and the **Northern Territory**) - which means after 2020 those two makets might have no federal emissions reduction policy.

What they say will happen:

The Coalition of Australian Governments (COAG) Energy Security Board forecasts that **an average household will save A$110-$115 per year** during 2020-2030, while meeting Australia's commitments under the Paris climate treaty.

The government says it will also make it harder for energy companies to get loans to build unnecessary infrastructure by **abolishing the Limited Merits Review**, the mechanism that energy companies can use to appeal the decisions of the Australian Energy Regulator.

Figure 37. *Overview of NEG* (Degabrie, 2017)