ADAPTIVE GOVERNANCE FOR ENERGY SYSTEM DECENTRALISATION: A CASE STUDY OF THE NATIONAL ELECTRICITY MARKET IN EASTERN AUSTRALIA

Submitted by Helen Poulter, to the University of Exeter as a thesis for the degree of Doctor of Philosophy in Human Geography, May 2020.

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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ABSTRACT

This thesis investigates how the role of an adaptive governance framework, adapted from social-ecological transition (SET) theory, could assist in the challenges associated with electricity system decarbonisation and decentralisation through a case study of the National Electricity Market (NEM) in eastern Australia. The NEM is currently undergoing change at the household, distribution and system level due to the rapid uptake of solar PV and increasingly, domestic battery storage. By using a case study of an area where rapid change is happening, the thesis offers insights in the form of a general framework for adaptive governance that could assist policymakers in meeting decarbonisation targets in Great Britain.

SET theory suggests that adaptive governance is needed within social-ecological systems (SES) to manage the transformation of a system that is locked-in to an undesirable state. Adaptive governance is achieved by the empowerment of local actors to create local policy, thereby increasing the innovation potential of the local areas to meet the local policy strategy. Policy and innovation are then coordinated to meet an overarching national vision.

The NEM is currently experiencing a form of carbon lock-in. While the federal system of government has allowed State initiatives to incentivise the use of DER, a lack of a national vision and coordination of State policy and the innovations stemming from these policies has created challenges in maintaining the functionality of the electricity system. Taking lessons learnt from the NEM case study and SET theory, this thesis suggests an adaptive governance framework that could assist in electricity system decentralisation, through the empowerment of local policy which is coordinated to meet a national vision.

This has lessons for GB, in particular, because GB has set a target for net-zero emissions by 2050. Reaching this target requires increasing the use of distributed energy resources (DER). Enabling decentralisation to work in conjunction with the traditional centralised system requires new rules, new regulations, new markets and new institutions. Taking lessons learnt from an energy system that has already undergone this type of change, an alternative approach for GB policymakers is suggested that may assist with the challenge of enabling decentralisation in the GB energy system.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ACCC Australian Competition and Consumer Commission
ACT Australia Capital Territory
AEMA Australian Energy Market Agreement
AEMC Australian Energy Market Commission
AEMO Australian Energy Market Operator
AER Australian Energy Regulator
AG Adaptive Governance
AM Adaptive Management
ANTS Annual National Transmission Statement
CCC Committee on Climate Change
CCGT combined-cycle gas thermal
COAG Council of Australian Governments
DEIP Distributed Energy Integration Plan
DEM Distributed Energy Market
DER Distributed Energy Resources
DMIS Demand Management Incentive Scheme

DNSP	Distribution Network Service Providers
ECA	Energy Consumers Australia
ESB	Energy Security Board
ETS	Emissions Trading Scheme
FCAS	Frequency Control Ancillary Services
FFR	Fast Frequency Response
FiT	Feed-in-tariff
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISP	Integrated System Plan
LRET	Large-scale Renewable Energy Target
MCE	Ministerial Council on Energy
MLP	Multi-level Perspective
NEC	National Electricity Code
NECA	National Electricity Code Administrator
NECF	National Energy Customer Framework
NEL	National Electricity Laws
NEM	National Electricity Market
NEMMF	NEM Ministers Forum
NERL	National Energy Retail Law
NSW	New South Wales
NTEM	Northern Territory Electricity Market
NTNDP	National Transmission Network Development Plan
NWIS	North Western Interconnected System
PSO	Public Service Obligation
PV	Solar Photovoltaics
QLD	Queensland
RE	Renewable Energy
RET	Renewable energy target
REZ	Renewable Energy Zone
SA	South Australia
SES	Social-ecological systems
SET	Social-ecological transition
SPS	Strategic Policy Statement

SRAS	System restart ancillary services
SRES	Small-scale Renewable Energy Scheme
STT	Socio-technical transition
TAS	Tasmania
TM	Transition Management
TNSP	Transmission Network Service Providers
VEEC	Victorian Energy Efficiency Certificate
VEET	Victorian Energy Efficiency Target
VIC	Victoria
VRET	Victorian Renewable Energy Target
WEM	Western Electricity Market

1. INTRODUCTION

In October 2018, the Intergovernmental Panel on Climate Change (IPCC) released a report on the increasing scale of environmental, social and economic impacts of climate change should global average temperatures rise above the 1.5^{0}C limit. The report stated, that '***rapid and far-reaching transitions*** *in energy, land, urban and infrastructure (including transport and buildings), and industrial systems*' will be required to reach the goal of keeping global average temperature rise to a maximum of 1.5^{0}C (IPCC 2018 p.17). This sentiment was then echoed by the International Energy Agency, which, in a press release of the 2019 World Energy Outlook, stated that if we wish to meet our climate targets then '*the world urgently needs to put a laser-like focus on bringing down global emissions'* and that this '*requires* ***rapid and widespread changes*** *across all parts of the energy system*' (IEA, 2019a).

Globally, data from 2010 shows that electricity and heat production accounted for the highest levels of greenhouse gas emissions by sector (EPA, 2017). Since 1992, when governments signed the Kyoto Protocol, decarbonisation efforts have concentrated predominantly on the electricity sector with renewable electricity in 2018 accounting for 26.2% of global electricity production (REN21, 2019). This production consists of an increase in capacity to over 33% RE in 2018 (15.8% from hydropower, 5.5% from wind, 2.4% from solar PV and 2.6% from other renewable sources (Figure 1-1-1)), up 5% from the previous year. The IPCC report states that if we are to keep to a maximum of 1.5^{0}C of average global warming then renewable generation will need to provide 70-85% of electricity production by 2050. From the figures stated above, this suggests that the installation of RE capacity needs to accelerate considerably over the next 30 years.

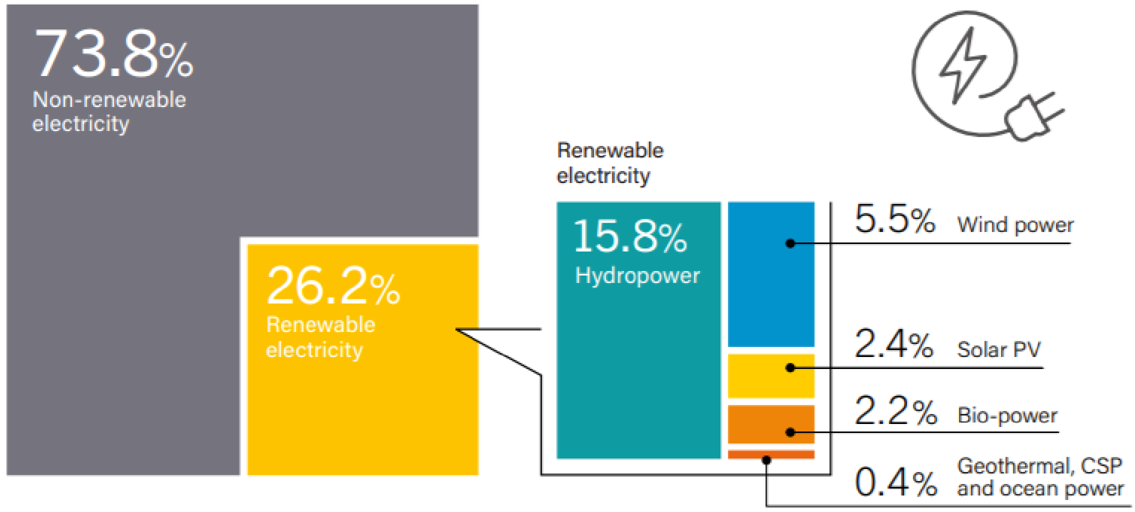

Figure 1-1-1 Global electricity production by fuel type 2019. 26.2% of electricity was produced from RE sources, from an installed RE capacity of 33% of total capacity. (Source: REN21, 2019)

In 2019, the GB Government set a legislated target of net-zero emissions by 2050 (CCC, 2019). The Committee on Climate Change (CCC) has stated that to meet the net-zero target by 2050, renewable and low-carbon generation needs to be increased from a 50% share, as it is today in GB, to 95% in 2050 (ibid.). This growth is also needed to meet the additional expected electricity demand from heat pumps and electric vehicles as the transport and heat sectors decarbonise. It is recommended that the extra demand is met by additional renewable generation and other low-carbon generation capacity and by increased resource and energy efficiency (ibid.). Therefore, decarbonising electricity is essential in reducing the emissions of the other energy sectors and this may increase the use of the electricity distribution system.

To increase the share of renewable generation, the use of domestic solar and small-scale wind and other distributed energy resources (DER) (including other demand-side options, such as demand response and energy efficiency) are now becoming an important part of the solution for emission reduction in the electricity sector (Ofgem, 2017a). The '*rapid and far-reaching transitions*' (IPCC, 2018 p.17) that are needed encompass new technical solutions and challenges, and subsequently, new business models and new economic strategies. Changes to the energy system may also require behavioural changes, such as the future electricity grid enabling, and requiring, the current, passive consumer to become engaged and active (Hoggett, 2016). This new type of customer could assist in meeting the net-zero target by increasing their energy efficiency and reducing their demand for grid generated electricity through local generation and other demand response initiatives (Willis et al., 2019a). The reducing costs of DER allow customers, who were once enforced passive consumers, to now generate, store and trade their energy requirements – becoming a 'prosumer'. Local generation could allow customers to provide other grid services, such as demand response and frequency control, through means such as aggregation into a virtual power plant (VPP) (AEMO, 2019a) or to trade in a local energy market (Bray and Woodman, 2018). Governance of the system needs to ensure that those customers who are not able to become prosumers also benefit from the energy transition and are not unfairly burdened with the costs of a changing system (Willis et al., 2019a). Changes within the electricity system require electricity system governance, that is '*the policies, institutions, market and networks rules and incentives and the process/politics behind them*' (Mitchell et al., 2016), to enable the positive social, economic and environmental changes that DER can bring, and be adaptive to react quickly to unexpected challenges and outcomes that may arise, whether positive or negative.

The exact nature and timing of how system change may happen cannot be predicted since this depends on the governance and other enabling conditions such as new technology, falling technology costs and new business models (Willis et al., 2019b). Decarbonising energy affects energy system interactions across sectors and scales, but again the rate of change and what the resultant effects might be cannot be predicted accurately. Research has suggested that to change the energy system from a predominantly carbon-based centralised system to one that is more decarbonised and can thus integrate centralised assets and networks alongside decentralised assets and networks, the governance surrounding the system needs to be flexible, or adaptive to enable change (Mitchell et al., 2016; Willis et al., 2019a). This is particularly relevant for the distributed area as this is where the majority of change is expected to occur (NIC, 2016).

For this thesis, the 'decentralised' facets of the system are defined as the distribution system and the technologies and processes (including those related to decision-making and customer involvement) that operate within the distributed area. The 'centralised' facet then includes transmission, large-scale generation and the central institutions that have traditionally governed and operated the energy system.

This thesis explores how governance needs to be adaptive to enable an evolving energy system, and for GB in particular, through a case study of the National Electricity Market (NEM) in eastern Australia, which is currently seeing a rapid uptake of domestic decentralised energy generation. The results from the case study are used to suggest an adaptive governance framework for energy and applied to GB to explore how adaptive governance could be used in a GB context. Section 1.1 introduces the case study. Section 1.2 then presents a general overview of why energy systems are now, in the majority, defined as centralised and how enabling DER and decentralisation, therefore, requires changes to system governance. Section 1.3 discusses whether current energy system governance can be considered as fit for purpose. Section 1.4 presents the aims and objectives of the thesis and section 1.5 gives an overview of the thesis chapters.

1.1 Australia's National Electricity Market as a case study

The NEM is the largest of the four energy systems in Australia and covers the eastern states of Australia – Queensland (QLD), New South Wales (NSW), The Australian Capital Territory (ACT), Victoria (VIC), South Australia (SA), and Tasmania (TAS). Unlike other federal countries such as the USA, the rules, regulations and wholesale market of all the NEM States, are operated by centralised institutions (Poulter, 2020). The Australian Energy Market Commission (AEMC) is responsible for the NEM rules; regulation for retail[1], transmission and distribution is undertaken by the Australian Energy Regulator (AER)[2]; and the Australian Energy Market Operator (AEMO) is responsible for the wholesale market and transmission planning. However, the States are run by State governments which can create State policy, including energy policy (the governance structure of the NEM is discussed further in Chapter 5). The NEM is currently experiencing changes to system operation and design caused by a rapid uptake of distributed energy resources (DER) i.e. domestic solar photovoltaics (PV) and battery storage.

By the end of 2019, there were just over 2 million domestic solar photovoltaic (PV) installations in Australia, with the largest proportion of these in the states of South

[1] Except in Victoria where the Essential Services Commission are still responsible for retail regulation as Victoria did not jo in the National Energy Customer Framework (NECF) and Tasmania where the majority of energy assets are still publically owned.
[2] Technical regulation is the responsibility of the State regulators

Australia (SA) and Queensland (QLD), where 32% of households in these States had installed a PV system (APVI, 2019a). An average of the total of *all* of the Australian states in 2015, showed that just over 15% of Australian households had PV installed, rising to 23% by May 2019 (APVI, 2019b). The large amount of PV in Australia has created opportunities for domestic storage companies such as Tesla, Enphase and Sonnen, which are competing for the Australian market (Parkinson, 2015). It could be expected that the demand for traditional generation may be reduced due to the falling costs of domestic storage (Mountain, 2018) and Australia's excellent solar resource (Solargis, 2013), as many householders choose to generate and store some, if not all, of their electricity needs (Mountain, 2016; Simshauser, 2016).

The rapid uptake of PV and storage has caused challenges in the technical, economic and social parameters of the energy system. Part of this challenge is the possibility of a so-called 'utility death spiral' (Stephen Lacey, 2014). A death spiral is a feed-back loop that occurs when, due to rising electricity prices, consumers switch to on-site generation and/or leave suppliers. This then leaves the retailer with either fewer customers, or less kWhs, from which to recoup costs and to pay for the fixed costs of the system i.e. network charges, thus having to raise prices which increases costs to those remaining consumers, and so on, until demand eventually collapses. Within energy, this phenomenon has been recognized as a utility death spiral and is a possibility in Australia due to the high level of DER installation. This is a cause for concern, not only for the electric utilities but also for those customers who are unable to install a DER system, as they are left to bear the rising costs (discussed further in section 7.2.1).

Australia's high level of DER installation was caused by separate and in some cases unforeseen events, (i) an initial, generous State Feed-in-Tariff (FiT) policy for solar PV, (ii) high and rising energy prices, (iii) rapid cost reductions in DER technologies and (iv) unexpected grid blackouts (leading to a government-initiated review of the security and reliability of the NEM, known as the Finkel review (Finkel et al., 2017)). These events led to DER uptake across Australia, and the focus of this case study, the NEM States, happening much quicker than anticipated. Due to the unexpected speed of the uptake, this thesis discusses the limitations of the NEM's centralised governance structure in adapting quickly enough to capture the new social, economic and technical values that DER can bring. Following the rapid uptake of DER, the thesis shows how governance in the NEM has become increasingly reactive, putting pressure on policymakers, the market institutions and regulators to constantly catch up with events rather than to define the desired endpoint and work out how best to get there.

As will be discussed in Section 7.2.1, although some energy professionals in the NEM believe that the NEM is not currently in the grips of a 'death spiral', if NEM governance does not adapt to the evolution of the energy system, then others have suggested that the death spiral is still a possibility or is possibly occurring. The rapid uptake of DER has also caused further challenges which have affected NEM functionality. The NEM is, therefore, an interesting case study because of the rapid change; the drivers behind that change; the impact on the energy system; the impacts on scale – whether people, local or national; the questions this raises and the lessons which can be learnt from this. It is also an interesting case study to understand the ability of governance to be flexible, or adaptive, and what adaptive solutions there might be.

1.2 Centralised energy systems and their governance

The current governance and system structure of energy, both in Great Britain (GB) and in many countries worldwide, was created through reforms designed to maximise the economic efficiency of the large scale generation technologies and associated infrastructure and markets, through the increased centralisation of the system and its governance (Pollitt, 2012). Economic efficiencies in the energy sector in the 20th century led to the deployment of large-scale generation plant, with fossil fuels as the dominant primary energy source (Smil, 2017), and the development of transmission and distribution networks to transport energy from the generator to the consumer (Rutter and Keirstead, 2012). The governance that surrounds the current system has evolved to suit the characteristics of this centralised system of generation and transport (Pollitt, 2012).

Originally, the majority of centralised energy systems worldwide were government-owned (Pollitt, 2012). Following the interest in market-liberalisation ideals, and the 'shock' of the 1970's oil crisis, many governments introduced further reforms to maximise energy security, promote economic efficiency and growth, and encouraging innovation (ibid.). These reforms led many OECD and other governments from leading developing countries to restructure their energy industries from state-owned corporations to private, competitive companies. In many cases, the natural monopoly elements (transmission and distribution) could be vertically separated from the potentially competitive elements (generation and retail). These potentially competitive elements were separated and allowed to operate within markets. Regulation of the monopoly elements was needed to prevent monopoly pricing and encourage efficiency. This led to the establishment of independent regulators for the economic and technical regulation of the monopolistic elements (Pollitt, 2012).

In GB, renewable energy has been incorporated, to the extent that it has, by reducing centralised fossil fuel-based generation e.g. coal, and replacing some of this capacity with large, centralised renewable generation e.g. offshore wind (BEIS, 2017). The energy system has been able to adapt to some change and continues to operate in the traditional centralised manner. To be able to reach the net-zero target for the decarbonisation of electricity generation, heat and transport, the GB energy system needs to increase energy efficiency and embrace both centralised *and* decentralised renewable energy and increase energy efficiency and demand-side participation (Willis et al., 2019b). Enabling decentralisation changes both system operation and design, particularly at the distribution level.

Increasing the use of DER changes the way energy is produced and also how it uses the infrastructure of the system, as DER are connected to the electricity distribution grid. Traditionally, electricity is generated by large centralised generating plant and sent via high voltage transmission lines and then to consumers via low voltage distribution grids. Reports suggest that by 2030, distribution grids need to completely change how they operate to incorporate the rise in DER (NIC, 2016; Ravens and Lawrence, 2017). As the energy system evolves, the grid is expected to be comprised of a combination of both centralised and decentralised generation, with many industrial, commercial and domestic customers generating and storing part of their energy requirements, changing the energy flows from a one-way to a two-way system (Figure 1-1-2). The University of Exeter's IGov project has suggested that supporting such changes requires new institutions, changes to the responsibilities of current institutions, and new markets and new methods of regulation (Mitchell et al., 2016; Willis et al., 2019a). Increasing the use of DER alters system operations, both technically and economically; as mentioned, centralised governance coevolved to suit the efficient running of a an increasingly centralised system, so governance needs to reflect these same efficiencies for an increasingly decentralised system.

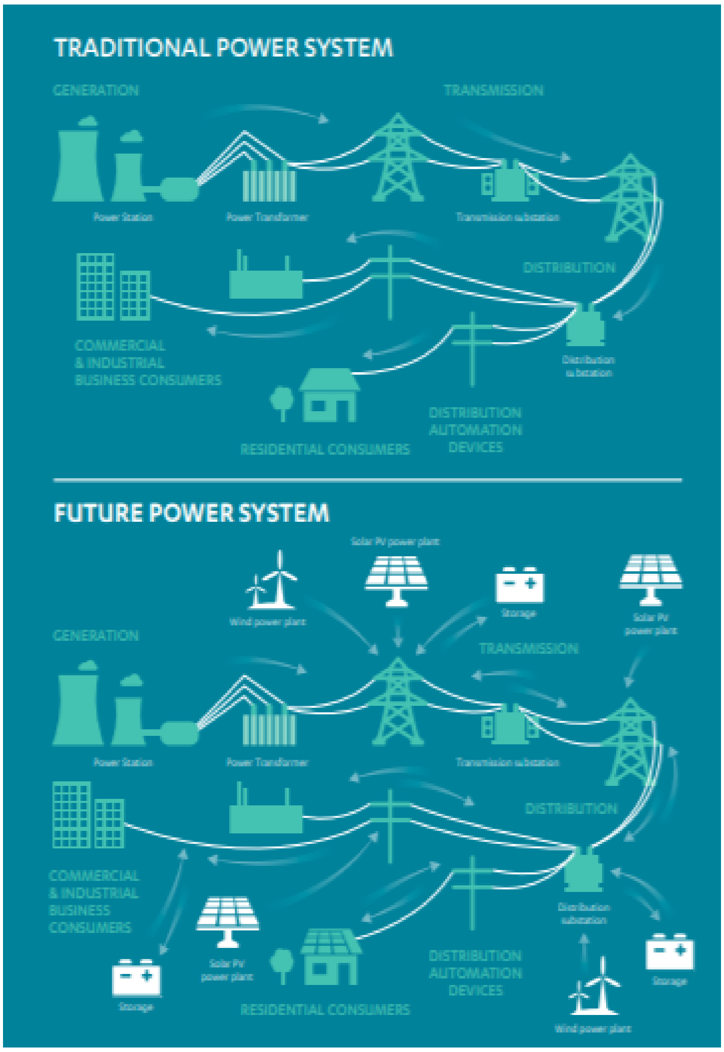

Figure 1-1-2 Changing electricity flows on the future power system (NIC, 2016)

As the energy system evolves to one which includes more decentralised resources, as in happening currently in many electricity systems worldwide (e.g. Krog and Sperling, 2019; Beermann and Tews, 2017; Sheldrick and Tsukimori, 2017), this changes the characteristics within the energy system (summarised in Table 1-1). Enabling decentralisation needs the governance of the system to be able to adapt to these changing characteristics, so avoiding the challenges currently being experienced in the NEM. For the centralised and decentralised facets to work together, there needs to be coordination between the wholesale and new distribution markets to ensure system reliability (see section 7.3.3) and operational coordination between the centralised and decentralised physical system as decentralised generation changes the demand for grid-supplied electricity, causing challenges to the security and system strength of the whole system (meaning the combined decentralised and centralised facets and is discussed further in section 7.1).

Table 1-1 Comparison of the changing characteristics of the energy system as it moves to include decentralisation (source: Pownall, 2019)

Characteristics	Traditional Energy System Characteristics	Emerging Energy System Characteristics
Structure	Centralised	More decentralised
Fuel-type	Fossil and nuclear-based	Decarbonised, multiple scales
Energy flow	Supply based, load following	Supply and demand
Generation design	Firm power	Smart and flexible
System operation design	Linear, top-down system operation	Two-way, dynamic, digitalised system operation
Consumers	Passive consumers	Passive and more active consumer behaviours
Interactions	Clear lines between power, heat and mobility sectors, supply chain activities and business models	Breaking down of demarcation lines and coalescing at the distribution level, and particularly domestic level
Location of generation	Distant from use	Distant and increasingly local
System stakeholders	Energy focused stakeholders	Multiple stakeholders – data/IT, car manufacturers etc.

The core argument of this thesis is that governance will need to become adaptive to (i) enable the power system suggested in Figure 1-2, (ii) to absorb the changing characteristics, without negatively affecting system security, reliability and affordability and (iii) to react to unforeseen outcomes and events in a positive and timely manner.

1.3 Fit for purpose governance

The growing use of energy since the industrial revolution to provide power, heat and transport services enables modern society to function and, as will be described in more detail in Chapter 2, allows energy to be defined as essential to modern living (Cook, 1971; Smil, 2017). This co-evolution of energy systems and society has created energy systems that are dependent on ‘dirty’ energy and involving social, technical, economic, political and environmental aspects. The multiple interactions between each of these parameters allow energy systems to be defined as complex systems (Bale et al. 2015).

Due to this interdependence, and modern society needing energy to function, the energy system can be viewed as a complex, essential system. As a complex system, energy governance needs to recognise that as the current system decarbonises any changes made in one aspect can cause expected, or unexpected, interactions within other parts of the system (Oughton et al., 2018). Reaching decarbonisation targets involves heat, transport and electricity and subsequently creates changes in the social, technical, economic, political and environmental parameters of the system. As an essential system, governance will need to ensure that, as these new interactions occur, the energy system continues to function securely, reliably and affordably.

The increasing use of DER, both now and in the future, is a positive new development for the energy system. As well as helping to reduce carbon emissions, it is happening because of changing energy economics and it is increasingly connecting more people to the way they use energy and the way the energy system works. As is discussed further in section 7.2.2, an engaged and active prosumer will be essential in enabling DER to benefit all customers. However, the changing role of the consumer to a prosumer has also led to concerns about the public service obligation (PSO), one aspect of economic regulation. The PSO is an important part of the supplier’s licence which ensures that vulnerable customers still have access to energy. Ensuring that energy remains affordable for all energy users may require changes to the method in which customers are charged for their energy use.

The use of variable domestic DER is becoming a challenge to the incumbent utility business model and the traditional centralised governance structure. For example, as new actors become involved in the energy system, so this changes the value streams within the system, away from the traditional system actors and industries, reducing the revenue available for traditional generation and supply assets, leaving the incumbent utilities attempting to protect their assets by slowing change to guarantee revenue (Lockwood et al., 2017).

As the results from NEM case study in Chapter 7 show, enabling decentralisation to make a positive contribution to decarbonisation, overcome incumbency and to benefit all energy customers, requires new methods of designing energy policy, new rules and regulations, new distribution level markets and new methods of paying for energy, essentially new governance. This thesis suggests that ongoing decentralisation both requires and stimulates a requirement for, new forms of governance (i.e. to fill the 'distribution governance gap') and that this new governance will be essential to overcome the incumbency within current governance. The newly evolved system (i.e. combining centralised and decentralised assets) requires new coordination between centralised and decentralised systems of assets and systems of governance. Moving from the current centralised energy system to the new coordinated, and evolved energy system is discussed in Chapters 8 and 9.

Governance needs to ensure that, as an essential system, the electricity system continues to function by protecting the centralised assets that are needed, but also to allow the positive social, economic and environmental contribution that decentralisation can bring. In particular, as energy systems evolve, governance needs to protect the functionality i.e. the security, reliability and affordability, of the system.

Understanding that energy systems are essential and complex suggests that, as systems begin to evolve, governance needs to be able to adapt to system changes. In particular, system governance needs to enable the system to function even as unforeseen outcomes or occurrences happen. Governance also needs to ensure that all customers have equitable access to energy and recognise that changes to system interactions will be temporal and occur over different sectors and scales. The adaptive structure will need to work efficiently, both economically and technically to ensure affordability, reliability and security, for traditional centralised systems *as well as* incoming decentralised assets. This allows governance to initiate, absorb and capture the benefits of energy system change wherever change is happening.

In this case, it is important to understand whether the current governance structure is:

- fit-for-purpose for an energy system that combines centralised and decentralised assets?
- adaptive enough to absorb and capture the system-level benefits that new technologies and business models can bring for (i) all customers (including those that cannot become part of the new, smart distributed system), (ii) grid operation, (iii) markets and (iv) decarbonisation targets?
- adaptive enough to deal with unforeseen events and occurrences, and
- if not, what needs to be changed?

In Chapter 2, this thesis reviews two transition and transformation theories, that of socio-technical transitions (STT) and social-ecological transitions (SET). Both theories recognise the challenges associated with transitions of complex systems. However, Chapter 2 concludes that the theory of SET is more suitable for the changes that are currently being seen in energy, due to the similarities in the parameters of social-ecological systems and energy systems and the recognition that changes may be needed to the governance of the system to allow for a transformative change. This thesis will answer the broad questions above by applying the theory of adaptive governance from social-ecological transition theory to a case study of the NEM, which is undergoing rapid change at the distribution level.

1.4 AIMS AND OBJECTIVES

This PhD was designed to contribute to the IGov2 project (Willis et al., 2019b). IGov2 is a research project that questions the nature and dynamics of change within energy systems, concerning energy system governance and innovation. The results from IGov2 suggested institutional, market and hierarchal changes needed within energy system governance in GB. It is not the aim of the thesis to identify adaptive governance at all levels of the NEM as it would be beyond the capabilities of the study to produce a framework for governance for the entire energy industry in Australia, as has been done in GB by the IGov project (Mitchell et al., 2016; Willis et al., 2019a). It is, therefore, the aim of this work to study the adaptiveness of governance i.e. '*the policies, institutions, market and networks rules and incentives and the process/politics behind them*' (Mitchell et al., 2016) of the NEM, to create an adaptive governance framework which could enable decentralisation and can coordinate with the traditional system and the new centralised institutions as suggested by the results of the IGov2 project. The framework suggested has been created through research of both the theoretical framework taken from social-ecological literature and its practical application in water and food systems, and, by applying this to a case study of the NEM in Australia creating a possible governance framework for decentralising energy systems. Australia was chosen as a case study area due to the rapid uptake of DER at a household level and the lessons that could be learnt from the effect of this uptake on system governance for GB.

As a member of the IGov2 research group, I attended meetings, workshops and conferences between 2016 and 2019, focussing on future markets, regulation, direction setting, coordination, and the importance of local authorities in the future energy system. The focus of the IGov project was to understand how changes to governance could enable the decarbonisation of the GB energy system. The project employed analyses of energy system change in countries/areas beyond GB, namely California, New York, Germany and Australia, to take lessons learnt for best practice for the governance of decarbonising energy systems. The insights from the case studies helped to inform the final project results (Mitchell et al., 2019).

Results from the initial IGov project (Mitchell et al., 2016) suggested that current GB governance was not fit-for-purpose and that, for the changes needed to meet decarbonisation targets, new institutions, markets and practices would be required. A report was produced for IGov2 suggesting new roles for existing institutions and the new institutions that were needed to enable energy system change. The need for changes to governance has also been recognised among industry actors, where the Open Networks project is researching the future role of the distribution networks, a distribution market and the integration of new business models (ENA, 2017a).

The thesis assesses the practicalities of adaptive governance within an energy system, employing a case study of Australia's National Electricity Market (NEM). This thesis develops the principles of adaptive governance for energy system change through the means of the NEM case study by employing the research questions:

- What factors are driving the uptake of DER in Australia?
- What has been the NEM governance response to the uptake of DER?
- Following Unruh's (2000) ideas of carbon lock-in, how does the history of the Australian path-dependent coevolution of energy systems and technology make it more or less inclined to be adaptive?
- To what extent do the principles for adaptive governance from SET theory feature in the Australia case study and if present, how have they enabled a positive contribution to the changes being seen?
- What are the regulatory and governance lessons to be learnt for GB?

The results of the research questions are discussed to create a framework for adaptive governance for practical application and to assist policymakers for GB energy system decentralisation.

1.5 Overview

This thesis is structured over 10 Chapters**, Chapter 2** provides the context and looks at the theory of transitions; how we should define an energy system for transition purposes; and the arguments for the transition theory which provides a better understanding of transition versus transformation and what is needed to create a successful transformation. This chapter will also identify gaps within the literature for the use of adaptive governance for energy system change and introduce the research questions to answer these gaps.

Chapter 3 establishes the methodological processes for answering the research questions. It provides the rationale for using mixed methods and the use of a single case study to provide a narrative and the value of this within social science research. The Chapter sets out the approach to the research and justifies the identification of the interviewees within the case study area.

Chapters 4 through to 7, provide the results of the NEM case study. **Chapter 4** introduces the case study area and tracks the drivers for the rapid uptake of DER in Australia between 2010 and 2018. The Chapter investigates the technical, political, environmental, economic and social drivers. The chapter discusses that it was an unexpected combination of all these drivers that led to the rapid uptake of DER in the NEM. The Chapter concludes that, although this can be seen as a success, the unexpected speed of uptake led to further challenges in the electricity system, due to the issues investigated and discussed in Chapters 5-7.

Chapter 5 traces the history of the NEM and its governance to provide insight into the current governance structure, including any changes to governance following the Finkel review. It introduces the reforms that have led to the current centralised governance structure of the NEM, and the vested interests of some State governments. The chapter then discusses why this centralised structure and the vested interests of some of the States have led to difficulties introducing new reforms, as recommended by the Finkel review, that would enable decentralisation to create whole-system benefits. **Chapter 6** provides an insight into the influence of the coal industry on Australia's energy system and its governance, and the difficulties for decarbonisation due to lock-in and the vested interests of the government. It discusses how the national government's support of the coal industry has helped to create 'carbon lock-in' of the NEM. The chapter then discusses how the federal system of government has allowed some States that have a positive decarbonisation agenda, to counter the national government's position. **Chapter 7** looks at the challenges and governance responses due to the expansion of DER, until September 2019. The chapter discusses that, although the NEM has been successful in the adoption rates of DER, this success has created challenges throughout all the parameters of the system, due to the inflexibility of current governance, and that this inflexibility can be partly blamed on the influence of the coal industry on NEM policy.

Chapter 8 considers the principles of adaptive governance in relation to the NEM case study and its application for energy system decentralisation. It discusses how some principles of adaptive governance were present in the NEM and the benefits that have been realised from these. It also discusses how challenges arose due to the lack of adaptive principles in other areas of governance. By taking lessons learnt from both the positive and negative aspects of NEM governance, the chapter suggests principles for adaptive governance by that may be applied for energy system change elsewhere.

Chapter 9 applies the principles from Chapter 8 to Great Britain as a guide to policymakers. The chapter suggests a framework for adaptive governance that could be used to assist in reaching the 2050 net-zero target. **Chapter 10** concludes the thesis by summarising the key messages and suggests avenues for further research.

2. TRANSITION THEORIES FOR CHANGE WITHIN SYSTEMS

Chapter One introduced the ideas that DER will be necessary for energy system decarbonisation efforts and that governance is needed to complement this relative shift towards decentralisation. The chapter introduced the energy system as essential and complex, and that changes within the energy system can cause multiple reactions due to this complexity. In this Chapter, Section 2.1 briefly describes the history of energy systems and society and discusses further how this coevolution has created a system that is essential to modern societies. It then summarises why energy can be defined as a complex system and identifies the system parameters and the interactions between them. Section 2.2 reviews transition theories and introduces the relevance of using social-ecological transition theory for managing the evolution of the energy system.

Complex system theory suggests that changes in one part of the system may have consequences, seen or unforeseen, in another part of the system due to the complex dynamics within it (Meadows, 2009; Oughton et al., 2018). Due to these system complexities, changing the energy system, in the time available as set out by the IPCC, from its current top-down, fossil fuel-based, centralised structure (see Table 1-1) to one which also incorporates decentralisation, will not be a simple task. Enabling the rapid change needed in the energy system requires a governance framework that can adapt to the consequences of rapid change.

The complexity of energy transitions is recognised within academia, not least within the literature on socio-technical transitions (STTs) (Berkhout et al., 2003; Foxon et al., 2010; Geels, 2011, 2002). In 2002, Geels (Geels, 2002) introduced the Multi-Level Perspective (MLP) as an analytical tool for studying technological transitions, which is discussed further in section 2.2.1. Alternative literature for complex systems transition and its management, this time concerning the sustainability of ecosystems, is social-ecological transitions (SET) theory. SET theory concentrates on the mitigation of environmental sustainability issues such as climate change (Engle, 2011; Folke et al., 2005; Foxon et al., 2009; Gupta et al., 2010; Pahl-Wostl, 2009; Walker et al., 2004). Within SET, adaptive capacity i.e. the ability of a system and it's actors to adapt to change is recognised, as is the need for adaptive governance should a system become locked-in to an undesirable state (Westley *et al.*, 2011; Foxon, 2011; Smith and Stirling, 2010; Foxon *et al.*, 2009).

This chapter discusses why the principles for adaptive governance (AG) from SET may be more relevant for energy system change than the transition management approach from socio-technical transitions and introduces the research questions which will help create an AG framework for practical application.

2.1 DEFINING ENERGY SYSTEMS

'Modern industrial society is totally dependent on high rates of consumption of natural gas, petroleum and coal'

(Cook, 1971)

Before a strategy to further decarbonise the energy system can be decided, the type of energy system, the elements within that system and how they interact – the parameters of the system - need to be understood and defined. This will help to create a framework for changes to the energy system that acknowledges, and works with, the system parameters to enable energy system decarbonisation. This section will briefly describe why energy can be defined as essential and complex and identify the system parameters.

2.1.1 Why energy can be defined as an essential system

'*The history of human culture can be viewed as the progressive development of new energy sources and their associated conversion technologies*' (Hall et al., 2003 pp. 318). Smil (2017) noted that energy transitions have always been a part of human life. From the first use of biomass for cooking, from the original windmills and watermills to the steam engine, electricity and the internal combustion engine, energy has vastly improved economic productivity as well as the living and working conditions of modern societies (Smil, 2017).

The first industrial revolution changed population geographies, as economic, political and social changes occurred resulting in rising urbanisation. The larger population densities in the towns and cities created areas of high energy needs. Providing goods and services for these growing population centres required an increase in the use of transport and power (Smil, 2017). Gradually the internal combustion engine, and the use of liquid fuels for transport, overtook coal-fired steam engines, barges and traditional horsepower. Gas use increased for heating and cooking as pipelines enabled gas to be transported over longer distances (Smil, 2017).

As the health and wealth of the newly industrialised nations grew, so did their use of energy (Cook, 1971). By 1971, 30% of the world's population was consuming 80% of the world's energy (ibid.). An increase and reliance on hydrocarbon energy (Hall et al., 2003) allowed for progress in medicine, food production, industrial processes, transportation, living standards, and communication, among other things (Smil, 2017) but also created path dependency between a 'successful' society and energy intensive industries (Fouquet, 2016). In developing societies the positive health benefits of reducing the use of solid fuels 'in situ' for cooking and moving to a modern energy system has also been noted (e.g. Smith et al., 2013). Increasingly, it is the services that rely on energy that provide some of Maslow's (1943) foundations for society's physiological (e.g. food, water, shelter), and safety and security (e.g. health, employment, property) needs.

These advances have contributed to the exponential growth of the population on the planet, from one billion people at the start of the industrial revolution to two billion by the 1920s and nearly 8 billion today. Providing the services that support such a huge population, relies on energy. Therefore, this reliance on energy to provide our basic needs, which in turn, contributes to the economic growth of a nation, allows energy to be defined as essential to modern living.

2.1.2 Energy as a complex system

The coevolution of energy systems and society have created a system that comprises multiple interactions between actors and technologies. Energy systems are also influenced by politics and economics, as global policy to reduce the environmental effects of climate change, changes the value streams within energy markets (Karl, 2004). Changes to these value streams need to account for the influence of incumbent actors over changes to energy policy, as these actor's business models have been designed around the traditional fossil-fuel-based, centralised system (Lockwood et al., 2017; Unruh, 2000). It is these multiple parameters and the interactions between them and their sub-systems, and the influence of the actors in them, that give rise to uncertain system-level outcomes so that energy can be understood as an example of a complex system (Goldthau and Sovacool, 2012).

How energy is generated and supplied is influenced by societal preferences and needs. The energy system has evolved to provide heat, power and transport and the means to transport that energy through infrastructure. This co-evolution, as described in Section 2.1.1, illuminates the social and technical linkages of the energy system.

There are other interlinking elements to the energy system as well as the social and technical. As mentioned, innovations in the use of energy enabled industrialisation which in turn increased the wealth of the industrialised nations. Energy is traded globally, so fluctuations in the market price for energy can affect world economies, and the societies they support, in positive or negative ways (Karl, 2004). The supporting global and national infrastructure for the generation and supply of energy has grown to complement the fossil-fuel-based system. Changes within this supporting infrastructure change the value streams within the energy system. For example, renewable energy has been shown to reduce the wholesale price of energy – the merit-order effect (McConnell et al., 2013; Ray et al., 2010) - changing the dynamics of the wholesale market and the investment conditions for new electricity generation (Alba et al., 2017). Changes to the energy system, and its markets, alters the value streams and costs of different energy services and resources, locally, nationally and globally, and so the economic element of energy also needs to be considered as energy systems change.

Current energy policy is influenced by the global need to reduce greenhouse gases, alongside sustainable development goals such as energy justice and security concerns. Energy policy is also influenced by the institutions, companies and organisations that have grown alongside the fossil-fuel-based energy system (Lockwood et al., 2017). The influence of these incumbent groups over any changes to the energy system has been recognised as one of the elements of carbon lock-in (Unruh, 2000). Changes to the energy system will need to recognise and reduce, the existing influence of some energy system stakeholders. It is not possible to think about changing energy system dynamics without also including the effects of politics on change because of the distributional effects, both negative and positive.

Energy also has an environmental effect. The burning of fossil fuels causes climate change, which has environmental, social and economic impacts (IPCC, 2018). Extraction and processing of the resources needed for energy systems can have detrimental effects on the local ecology and environment, increasing water and air pollution (Karl, 2004). The technology drivers needed to help stabilise carbon emissions may also have other environmental impacts and so these impacts also need to be considered when addressing system change e.g. the use of lithium for battery storage.

Energy systems can be defined by their social, technical, economic, political and environmental parameters. The functionality of a complex system is dependent on the multitude of interactions between the parameters of the *whole* system, including sub-systems (Bale et al., 2015). A complex system can learn, evolve, or be locked into a path-dependent cycle, using the linkages which are spread within and through the parameters of the entire system (Goldthau and Sovacool, 2012; Meadows, 2009; Unruh, 2000). There are numerous linkages and interactions within energy systems. For example,

- Society's energy demand has shaped the infrastructure needed to supply that demand (Rutter and Keirstead, 2012; Smil, 2017).
- The resource used to generate energy can have positive or negative environmental and economic consequences (Karl, 2004).
- Policy and society dictate the necessity, speed and direction of system change, which in turn influences the demand for energy, and the infrastructure and resource used (IPCC, 2018; Smil, 2017).
- Incumbent's economic interests in resisting change can slow the speed of change (Lockwood et al., 2017).

Bale et al (2015 pp. 152) suggest that energy systems can be described as complex adaptive systems as they have '*interrelated, heterogeneous elements (agents and objects)*' which have no autonomous control and may be self-organising, non-linear, emergent and may have co-evolved. This allows any introduction of a new element to cause repercussions with further objects or agents within the system (ibid.).

Due to the combination of these characteristics, as a complex adaptive system, energy systems can be difficult to predict, steer and manage towards sustainable futures. Indeed, as energy systems begin decentralise this increases the complexity through the introduction of further objects and agents and increasingly shifts them from a traditional 'hierarchal system' to one which is becoming polycentric (Wolsink, 2020). Therefore the inherent unpredictability, such as emergence and disruption (Winskel et al., 2019), of an increasingly polycentric energy system can frustrate current energy system governance (Goldthau and Sovacool, 2012) as the evolution of the system, and the system itself, may enter into unexpected, or unintended, states (Oughton et al., 2018). This unpredictability of complex system change suggests that governance will need to be flexible (Mitchell et al., 2016), or adaptive (Geels et al., 2019), to react to these emergent and disruptive pressures.

2.2 Transition theory for change within complex systems

Among the many theories that offer perspectives into processes of change in complex systems, two are that of socio-technical transition (STT) theory and social-ecological transition (SET) theory. STT theory has been applied to energy transitions but there have been criticisms in the use of STT and the multi-level perspective (MLP), and this will be discussed further in Section 2.2.1. Section 2.2.2 suggests an alternative avenue for energy transitions, by taking lessons from SET which, although recommended as an interesting avenue for research (Goldthau, 2014), has gained little traction in energy transitions until recently (e.g. Akamani, 2016; Geels et al., 2019; Brisbois, 2020).

2.2.1 Socio-technical transitions

Building on Rip and Kemp's (1998) model on socio-technical transitions, *Geels* (2002) developed the multi-level perspective (MLP). He suggested that the transition would occur as changes in distinct 'levels' of systems:

1. landscape – macro-pressures which are beyond the influence of the regime and niche actors
2. the current socio-technical regime – a combination of current technologies, policy, knowledge, culture, infrastructure and markets (meso)
3. advancement of technology in the niche level – for new/radical technologies at the beginning of their development (micro).

The MLP (illustrated in Figure 2-1) suggests that landscape pressures would destabilise the current regime and open a 'window of opportunity' for niche technologies to become established. As a new niche technology is adopted over time to become the 'norm', the socio-technical regime then stabilises, causing a transition shift, with the new technology and regime influencing the landscape level. The MLP describes a progression as new technologies that are better able to answer a consumer need change, over time, the regime and landscape.

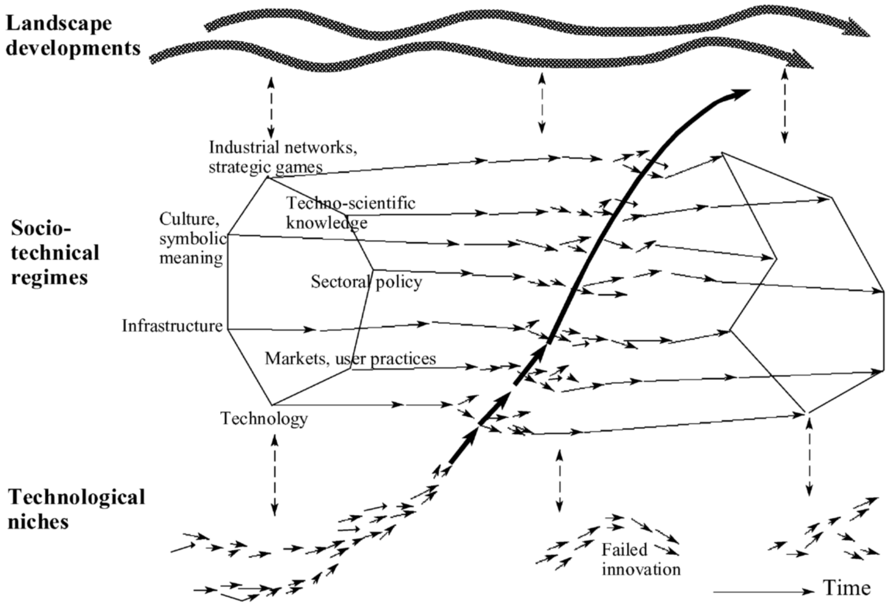

Figure 2-1 The multi-level perspective (Geels, 2002)

In the current energy transition, these system levels as described by the MLP could be characterised by global priorities (Foxon et al., 2010; Geels, 2011; Verbong and Geels, 2010). For example, the landscape-level - climate and global policy to mitigate the effects of climate change; the regime – the incumbent energy companies and infrastructure, individual countries' energy policy, energy markets and consumer choice; the niche – new renewable energy technologies; and it would be possible to manage elements of these boundaries to ensure a smooth transition to a new energy future (Kemp et al., 2007; Loorbach, 2010; Rotmans et al., 2001; Smith et al., 2005).

This landscape pressure – the acknowledgement of the speed of anthropological climate change - drives global energy policy. Previous transitions, due to technical innovations, had no set time limit. These previous transitions were due to a change in resource - from biomass (wood) to coal, then oil and then gas - rather than a societal need to reduce carbon emissions, and took place over at least three generations (Smil, 2017). The need to reduce global carbon emissions to avoid the consequences of climate change means that there *is* a time limit on the current transition and therefore the concept of 'over time' needs to change (Sovacool, 2016).

At the regime level, social movements have demanded a change from dirty energy but existing incumbent technologies and infrastructure have resisted this change (Lockwood et al., 2017). These incumbents are also able to influence future political objectives through the use of lobbying (Kuzemko et al., 2016). Within the technological niche, an individual country's energy policy has provided 'windows of opportunity' for new technologies, ahead of what would be a normal transition process (ibid.). Unlike previous energy system transitions, the current transition is landscape, regime and niche led, rather than just led by technical innovation at the niche level. Pressures are occurring at all levels, as defined by the MLP, rather than just pressure from the landscape level, suggesting that the MLP may not be the best approach to understanding how the current energy transition may proceed.

The STT approach has been used as the basis for proposals of how to govern energy transitions more effectively. Proponents of STT theory believe that the use of transition management (TM) could be used on elements of the transition to push towards a cleaner energy system (e.g. Kemp *et al.*, 2007; Loorbach, 2010; Rotmans *et al.*, 2001). They recommend that by managing all levels of governance, and by the use of experimentation and learning, that niche technologies could be encouraged that would fit into the long-term strategy.

TM has been used in the Netherlands (Kern and Smith, 2008). However, problems occurred due to the focus on the technological aspects, without recognising the influence of society and politics on transitions (ibid.). Due to the influence of the fossil fuel industry on the national transition taskforce advisory board, the outcome of the intended transition to renewable energy was focussed more on economic efficiency rather than institutional changes and structural innovation, which were needed to achieve an increase in RE generation (ibid.). This agrees with one of the criticisms of the MLP, in that it did not recognize the effect of politics and power on transitions and was too focused on technological communities (Genus and Coles, 2008; Smith et al., 2005).

Stirling (2014b pp.1) cautions against the use of TM in that historically it is '*unruly, bottom-up 'transformations' rather than top-down structured 'transitions' that typically achieve the most profound (sometimes rapid) radically progressive social changes*'. It is these transformations which lead to an effective change as social movements need to challenge the resistance of incumbent companies. Stirling (2014b) recognized that in energy systems, rather than a system transition, there is a need for institutional transformation and that this type of transformation would counter the inertia of the incumbents, whose influence can challenge change, as seen in the Netherlands example (Kern and Smith, 2008).

Unruh (2000) recognizes this incumbency and suggests that it is the influence of these actors within energy system governance that create the carbon lock-in of the institutions and technologies in the original energy system. He suggests that this carbon lock-in will slow any transition of new technologies and actors as incumbents protect their position within the energy system – which points at the need for institutional transformation, as suggested by Stirling (2014b). The complexities of energy transitions are discussed by Berkhout *et al* (2003), who suggest that it is social movements who put pressure on the regime from the macro-level that have forced a window of opportunity for the niche innovations to come through. It is discussed that these socio-political actors see that their efforts are best used in destabilizing the incumbent regime, allowing an avenue for the successor, thus forcing a top-down transformation. Geels (2014), by bringing the idea of politics and power into the MLP, agrees that the resistance of the incumbent regime and their ability to influence policy is slowing down the shift to a decarbonised future and the adoption of green technologies from the niches. Geels (2014) also states that to progress with the inclusion of new, green technologies the regime would need to be de-stabilised. This discussion – that incumbency within socio-technical systems needs to be addressed and that any transition requires the previous social-technical system to be removed – suggests that the system will need to be transformed but there is little understanding of how a managed transformation may be achieved.

Other criticisms to the MLP framework recognize the bias that transitions would begin from the bottom up, with niche innovations leading the way (Genus and Coles, 2008; Smith et al., 2005). For a traditional technical transition, such as from the horse and cart to the motor car, this is true. However, for renewable energy, others suggest that it was social movements that initiated a change within the *regime* level which then allowed entry for the niche innovations. For example, the start of the German Energiewende was initiated by social movement groups taking control of local electricity networks (Morris and Jungjohann, 2016). In Denmark 'Folk High Schools' designed the first wind turbines in response to the 1973 oil crisis and a desire to find alternative energy sources to nuclear power (Toke, 2011). It has been suggested that the transition to a sustainable energy future would come from these types of social movements rather than technological innovation (Stirling, 2014b).

For current energy system change, pressures are coming from every level as defined by the MLP - landscape pressures of time-limiting climate change and subsequent climate policy; regime pressures from social movements and niche pressures from innovative technologies and ideas. This is contrary to the idea of niche innovations and a 'window of opportunity' leading to a steady transition, as suggested by the MLP.

The MLP is a useful descriptor for explaining how levels interact within energy systems and how transitions take place, but it is limited in its recognition of the complexities within the modern energy system. Although recognizing the resistance of the incumbent regime (Geels, 2014), the MLP does not suggest how to manage against a political climate which does not favour change, or how to transform to a completely new system. The MLP is also basing its theories on historical energy transitions, initiated by fuel economics and technical innovations, rather than a move to a sustainable system. It could be suggested that the MLP does not fit with the current energy system change of a forced transition to meet decarbonisation targets within a prescribed timeframe, and which may require political, societal, environmental and economic changes, as well as technical change. The incumbency within the energy system will also make a transition difficult (Unruh, 2000). For example, this incumbency may allow the uptake of DER to create a possible death spiral for incumbent utilities unless there is the transformational change to the way the energy system operates, as suggested by Stirling (2014b). Regulators, companies etc. will have to have a timely recognition that change is necessary but is also likely to affect their business model in the future.

Energy system change may require the governance of the system to be adaptive – have an 'adaptive capacity' to respond to these known multiple pressures and future unknowns (Berkhout *et al.*, 2003; Smith *et al.*, 2005). Berkhout *et al* (2003) and Smith *et al* (2005) refer to the adaptive capability functions of a technological regime and use this as a basis for assessing it's adaptive capacity. However, due to the complexity of the energy system, all system parameters will be affected and so these need equal consideration. Due to the complex nature of the energy system, system governance needs to be adaptive to these future unknowns, thereby allowing and managing change, whether transitional or transformational, while still protecting the functionality of an essential system.

In recognition of these criticisms, and the need to protect system functionality, this thesis suggests that a social-ecological transitions (SET) framework may be more applicable to the type of change that is needed within energy. I argue that SET is able to offer more insights into how change within energy as an essential and complex system may take place and that the theory provided within SET literature offers an alternative approach to understanding whether transition or transformation is needed. SET achieves this by assessing the adaptive capacity of a system and suggesting principles for adaptive governance that can manage a transformation, should a transformation be needed or is happening.

2.2.2 Relevance of social-ecological transitions for energy

Similar to socio-technical systems, social-ecological systems (SES) are complex systems made from diverse multiple layers, involving the ecosystem landscape as well as the social actors, institutions, culture, politics and the technology needed within the ecological systems to provide sustainability for water and land use (Engle, 2011; Westley et al., 2011). Unlike the MLP, social-ecological transition theory recognizes the effect of politics on transitions and includes technology, not as the cause of the transition but as one part of, or a solution for, a disturbance (Walker et al., 2004; Westley et al., 2011). So, like energy systems, the parameters of social-ecological systems involve social, technical, environmental, economic and political levels.

In the same vein as STT theory, SET theory recognizes resilience and adaptability within a transition, but unlike the MLP and more in agreement with Stirling (2014c), SET recognizes that to move to a new desired system then the old system may need to be transformed (Folke et al., 2005; Walker et al., 2004; Westley et al., 2011). Within the SET literature, authors identify the nature of adaptability within a system, its governance and its social actors (Folke et al., 2005; Gupta et al., 2010; Pahl-Wostl, 2009; Schultz et al., 2015; Walker et al., 2004). The authors suggest that adaptability within the system needs to be assessed, to understand if this adaptability allows the system to transition to a preferred system through learning and flexibility, or whether a transformation of the entire system is needed.

As discussed previously, within the MLP there is limited consideration of the time limits associated with climate change (Sovacool, 2016). Time limits *are* an important consideration within SETs, as ecological systems are being disturbed by the speed of climate change. Climate change has led to intermittent rainfall, increased flooding and droughts putting increased pressure on water and land use (Engle and Lemos, 2010; Westley et al., 2011). Within SET, and similar to transition management used within STT, management has been needed to ensure that social-ecological systems (SES) are able to adapt, safeguarding food and water security in a sustainable environment. Folke et al (Folke et al., 2005) term this adaptive management (AM). AM seeks a flexible, sustainable system that can be resilient, adaptable and transformable to absorb shocks and disturbances (Engle, 2011; Foxon et al., 2009). Foxon *et al* (Foxon et al., 2009) suggest that insights from both TM and AM would create governance that is both resilient whilst also being robust – able to adapt to shocks whilst also retaining system functionality. They also stress that diversity within AM has proven invaluable and that the use of multiple stakeholders at all levels and representative of all agencies, is something that is missing within TM. Also missing within STT theory, SET proposes that the adaptability of governance is needed to manage transformational change (Folke et al., 2010; Walker et al., 2004; Westley et al., 2011).

Previous literature that discussed the use of SET for energy systems warned against its use, suggesting that unlike the discreet geographical areas that are preferred by ecological systems, energy systems have no physical place (Smith and Stirling, 2010). However including DER, and indeed any RE generation, has changed the view of energy as a finite 'owned' resource to that which perhaps can be defined as a 'common pool resource' (Roelich and Knoeri, 2015; Wolsink, 2020). Brisbois (2020) suggests that, due to the increasing decentralisation of energy, comparisons can be made across water and energy governance. Water governance, due the nature of water systems are already polycentric and therefore lessons may be learnt for the increasingly polycentric nature of energy as it begins to include both centralised and decentralised assets. Therefore, it could be suggested that the decentralised elements of energy systems have similarities with the decentralised elements of water systems, as both make use of a common pool resource which can be regionally, or locally, specific.

Like an ecosystem, enabling decentralisation uses a diverse range of resources to create a local energy system that is preferable for a particular geographical type. For example, in rural areas the majority of households have access to roof space for solar and could choose to self-generate electricity, whereas in urban districts, where a greater number of people live in apartments, individual access to solar may be difficult and so a community solar project may be more applicable.

This thesis is not suggesting that the energy system *is* a social-ecological system but rather that lessons from SET could be learnt, and applied, particularly for decentralisation, due to the similarities between the complex interactions between these system's parameters and the recognition of the importance of the local resource. Sustainability transitions in both energy and ecological systems need to consider the social, environmental, political, technical and economic elements of the system, and to recognise the individual needs of a particular locality.

Section 2.3 introduces the concepts of resilience, adaptability and transformability as defined within SET literature, and the definitions from SET theory that are to be used throughout this thesis. Section 2.4 will introduce the principles of adaptive governance from social-ecological literature, Section 2.5 discusses the difference between a transition and a transformation and section 2.6 applies SET theory to energy systems.

2.3 Resilience, adaptability and transformability

The idea of resilience, adaptability and transformability was applied in ecological literature, primarily within ecosystem sustainability (Holling, 1973) and then defined for social-ecological transitions (SET), where:

1. Resilience - 'the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks' (Walker et al., 2004) and its capacity for renewal, re-organisation and development (Folke, 2006; Nelson et al., 2007)

2. adaptability – 'the capacity of the actors within the system to influence its resilience' (Nelson et al., 2007; Walker et al., 2004)
3. transformability - 'The capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable' (Folke et al., 2010; Walker et al., 2004).

When deciding whether a system needs to be resilient or transformative, it is important to understand resilience and adaptive capacity in relation to the aspirations of the system that is required, that is, it's desirability. System desirability can be a subjective term. For example, if an ecosystem is left to its own devices (what the ecosystem desires), the outcome that the system achieves may not be one that is useful for the social actors within the system, such as pastureland returning to scrub. Therefore for social-ecological systems, and used within this thesis, desirability is defined as the social goals that the system actors wish the system to achieve (Nelson et al., 2007).

A resilient system has a high adaptive capacity enabling it to adapt to changes in its environment. A system with a high adaptive capacity is able to absorb changes through renewal, re-organisation and development (Folke, 2006; Nelson et al., 2007). Such changes help to maintain alignment with current system function, structure, identity and retain the same feedbacks. In this case, a resilient system, which includes the actors within the system, will exhibit a high adaptive capacity i.e. be able to absorb changes within, or to, the system, while perpetuating a system's existing structures and functions (Folke, 2006; Nelson et al., 2007). System pathways may then be said to be 'locked-in' (Smith and Stirling, 2010; Westley et al., 2011). Should a system become 'locked-in' to a state, that is on the whole, undesirable and is therefore not able to achieve the required outcome, it would be necessary to bring about a system transformation to achieve the new, desired state.

In SET, system transformability has been defined as '*the capacity to create untried beginnings from which to evolve a new way of living when existing ecological, economic, or social structures become untenable*' (Walker et al., 2004). In this case, it is not adaptive capacity within the system that is required but *adaptive governance* to achieve the new requirement whilst still maintaining the functionality of the essential system.

Within energy systems, such as GB, the desired function is to ensure that the energy system provides customers with a reliable, secure and affordable source of power (Energy Systems Catapault, 2018). For those countries which have a decarbonisation agenda, meeting these targets now also requires the energy system to become decarbonised, so including decarbonisation as a desired function (ibid.). As discussed here and in Chapter 1, achieving this desired function requires changes to the way that energy is generated and supplied, changing its identity from carbonised to decarbonised, and its structure from centralised to incorporate increasing levels of decentralised assets, which can affect system interactions (as discussed in section 2.1.2). In this case, it is necessary to identify resilience within the system. If the system has the adaptive capacity to absorb the desired changes needed to decarbonise without detriment to the desired function, then a transition can occur. However, if the system resilience is not allowing a required change to occur, and is protecting the original system, or if a change *is* occurring and this change is creating challenges to the desired system function, this suggests that a transformation will be needed, requiring adaptive governance.

2.4 ADAPTIVE GOVERNANCE

Adaptive capacity has been defined as '*the ability to recover or adjust to change through learning and flexibility so as to maintain or improve into a desirable state*' (Engle, 2011). If a system is to be transformed into a new desirable state, then the institutions that govern it need to have the adaptive capacity to achieve this – adaptive governance. Adaptive governance '*is a process of creating adaptability and transformability*' in SESs (Walker et al., 2004).

Within the SET literature, authors suggest that for governance to be adaptive it needs to develop systems in such a way that they have the capacity to absorb any changes, both seen and unforeseen, without a collapse in basic functioning (Engle, 2011; Folke, 2006; Folke et al., 2005; Gupta et al., 2010; Nelson et al., 2007; Smith and Stirling, 2010). There is consensus from the authors mentioned that the principles of adaptive governance include:

- an increase in the use of informal networks across multiple levels, away from the rules and regulations of agencies;

- that increasing participation increases diversity within system governance, easing the flow of information and expertise, which in turn, creates an environment that encourages innovation and alternative policies, thereby increasing social capital;
- that AG would see policy as a hypothesis and policy would become an iterative process to increase institutional learning;
- that transformative leadership from individuals and empowerment of social actors is needed, giving the capacity to respond to changes at any level and speed, either through current policy or by encouraging creative responses.

Dietz *et al* (2003) and Nelson *et al* (2007) also suggest that the use of informal networks would reduce conflict by including all interested parties in the planning process and recognize the importance of creating an institutional infrastructure for the coordination of research, social capital and multilevel rules across all levels of governance. Following these principles, as suggested by the authors above, would then reduce the resilience of locked-in systems.

Social capital has been defined as '*networks together with shared norms, values and understandings that facilitate co-operation within or among groups*' (OECD, 2001). Within SET theory, social capital is met by an increase of participation and representation where multiple social networks combine local knowledge with scientific knowledge and encompass both local and national organisations and institutions (Folke et al., 2005; Schultz et al., 2015). Having governance that connects across multiple organisational levels and multiple social boundaries allows for transparent policymaking that can be considered more legitimate and has the potential to increase trust between individuals, institutions and government (Dietz et al., 2003; Nelson et al., 2007; Schultz et al., 2015; Westley et al., 2011).

Increasing participation in this way then increases diversity within system governance. An increase in diversity, with coordination between each of the diverse areas/groups, can reduce the negative effects for unforeseen events, or shocks, due to the increased knowledge base from a range of local perspectives (Granovetter, 1973). Authors suggest that to be effective (in some way) these social networks should be politically independent, away from the formal processes around regulation and implementation (Folke et al., 2005; Nelson et al., 2008; Schultz et al., 2015).

These social networks require transformative leadership that can recognise and identify opportunities and constraints (Folke et al., 2005). Where there are practical examples of increasing social capital for social-ecological systems, the results suggested that this increase enabled the adaptive capacity of the system, which in turn improved the responses to disturbances through increased knowledge (Engle and Lemos, 2010; Nelson et al., 2008; Schultz et al., 2015).

Change within complex systems creates outcomes that may or may not be predictable (Allen et al., 2010; Ostrom, 2007). Therefore, it is important to create a governance process which will be able to react to these changing events through innovation in policy, technology, economics and social processes (Westley et al., 2011). *Westley et al* (2011) note that within innovation studies for business, technology and organisational behaviour, should large firms wish to innovate then this is best achieved, not through a 'control and direct' approach, but by providing the resources and opportunities needed to promote innovative practices from the lower levels. These innovative practices are then coordinated by middle management to meet a firm's strategic priority.

Rather than being employed as a one-off action, several authors highlight the value of treating policy as a hypothesis to be tested (Folke et al., 2005; Nelson et al., 2008; Pahl-Wostl et al., 2007). Thus, designing and implementing policy becomes a continuous process of assessment which, by acknowledging the inevitability of policy failure, becomes an opportunity for learning to be generated and shared (Mazzucato, 2013). Nelson *et al* (2008) suggest that this policy experimentation is generally more achievable when implemented locally, where financial and political risks are reduced, rather than at a national level. Allowing a policy process to evolve at local levels has the potential to empower social actors within the local regions who have an interest in the local system while creating smaller areas of policy trials which can be constantly modified through learning and communication (Nelson et al., 2008) (see Figure 2-2). While Figure 2-2 considers policy experimentation, in the context of energy any policy experiment will cause interactions between the various elements of the system. These interactions cause challenges not only within the physical system but also the social and economic parameters. These challenges and possible solutions to these challenges are discussed further in Chapter 7.

Following the lessons from SET literature, this suggests that local policy becomes the hypothesis, the actions taken from the local policy direction as the experiment (Folke et al., 2005), and the results of the experiment the learning from the local policy areas able to be used through diffusion or scaling up (Westley et al., 2011). Local policy then needs mid-level coordination of the experimentation process, which would include the coordination of research and social capital across all levels of governance, to achieve a strategic national or global priority (Westley et al., 2011).

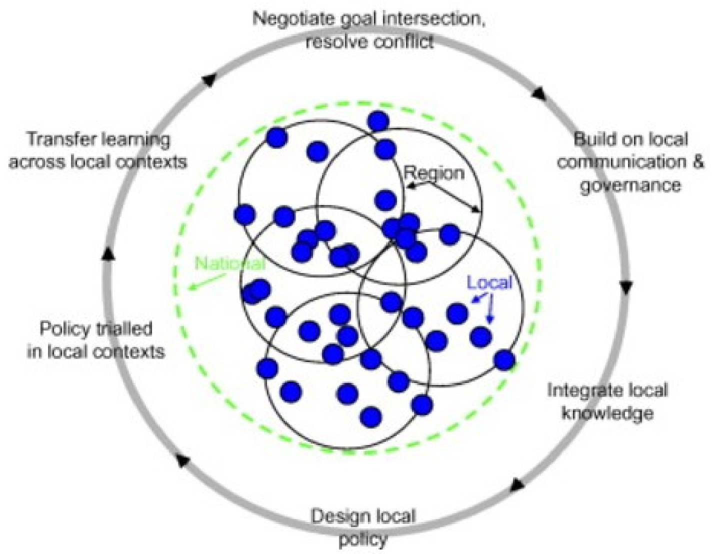

Figure 2-2 The process of adaptive governance. Local policy trials are coordinated regionally within the boundaries of the national policy objective and is a continuous process of experimentation and learning (Nelson et al., 2008).

Creating policy in this way increases participation and representation in the policymaking process, and therefore the transparency and legitimacy of local policy (Westley et al., 2011). This, in turn, creates the trust needed between those involved in the transformation process to increase the acceptability of the process itself and the other actors involved (ibid.).

2.5 TRANSITION OR TRANSFORMATION?

Energy systems need to become more flexible to incorporate both large and small-scale generation, new technologies and changing social preferences (Mitchell, 2016). In energy system change it is necessary to understand the system we need to take us to a sustainable, clean energy future - whether the current system is desirable, i.e. does the system have the required adaptive capacity to achieve this new desired outcome and so able to undergo a transition to the new desired state?;

or is the system 'locked-in' to a path trajectory that will make this transition difficult?; suggesting that a transformation may occur or is needed.

SET theory suggests that transformation needs to be, in some way, managed. This management then defines the desired function of the system which is achieved through adaptive governance processes (Nelson et al., 2007). For energy, in those countries with a positive decarbonisation agenda, the desired function is to provide a decarbonised energy system that is secure, reliable and affordable. An unmanaged (but perhaps desired) transformation e.g. the unexpected uptake of DER seen in Australia, may negatively affect other features of this desired function. It is, therefore, necessary to be able to create the environment that allows transformation to occur, but then also to have some control, so that the positive elements can be absorbed and solutions found to any negative elements or unexpected events. Westley *et al* (2011) and Nelson *et al* (2008) suggest that this management can be achieved by opening up the innovation capability of the system at a local level and coordinating this innovation to meet an overarching system vision.

In GB, the energy system has begun to decarbonise and has successfully incorporated large-scale RE generation into the grid (BEIS, 2017). Following the definitions from SET, the GB system could be described as having undergone a transition as the adaptive capacity of the system was able to absorb some changes, and these changes did not negatively affect the desired function of the system. It has been able to perpetuate its structure as a centralised system and the adaptations needed to protect the system function have been accommodated within the centralised governance structure. However, as discussed in Chapter 1, meeting GB's decarbonisation targets require further changes, including increased use of DER and increasing system decentralisation. This decentralisation requires new governance and could be considered as a transformational change as it requires '*evolving to a new way of living'*, as defined by Walker (2004). Enabling decentralisation may need operational and institutional coordination as the traditional system evolves (and this is discussed further in Chapters 8 and 9). Therefore, it is necessary to understand how transformational changes, such as decentralisation through the uptake of DER, can be managed so that the desired function of the energy system is protected, and this may require adaptive governance.

2.6 Principles for Adaptive Governance in Energy System Transformation

Within energy, using lessons from SET, adaptive governance would need to involve informal networks of social actors. Social movements, such as those that initiated system change in Denmark and Germany (Morris and Jungjohann, 2016; Toke, 2011), should be encouraged. Informal networks could include industry, NGOs, academia, consumer groups and social movement representatives, represented at all levels of energy system governance to ensure expertise from independent sources (e.g. Nelson et al., 2008). The inclusion of independent representation in energy system governance can disperse the influence of incumbent actors and industries. These informal networks and social movement groups could create spaces for innovation. The learning and knowledge gained from experimentation within these networks and groups, then coordinated and passed throughout the hierarchy. The coordination of knowledge gained may allow for dispersion and scaling up of innovative solutions to the challenges that may occur.

There is a need to view policy as iterative learning. Although it may not be possible to get things right initially, 'learning by doing' and sharing these lessons amongst these informal networks, both locally, nationally and globally, may help to enable transformational change. While it may be difficult at a national level to experiment with policy, the risks may be reduced at a local level, as should these smaller policy trials not be successful, the negative political and economic impact is limited. However, it should be noted that physical trials stemming from local policy may be 'risky' when considering the effect on the physical energy system as a whole, so local trials should still ensure that the desired system function is protected. Empowering local actors to create local policy would allow for local solutions, with these learnings able to be shared between similar regions (Nelson et al., 2008). Having multiple local policy areas may also increase the capacity for transformative leadership and social inclusion.

Adapting the principles from SET for energy systems, this suggests a need for increased customer representation and participation in the policymaking and regulation processes; that local policy should be empowered so increasing innovation potential, with access for all participants to the knowledge gained; that innovation and local policy should be coordinated to meet a national vision of the desired outcome of the energy system; and that the physical and operational elements should be coordinated to protect the desired system functionality (illustrated in Table 2-1).

Table 2-1 Suggested principles for adaptive governance in energy systems, adapted from the principles for adaptive governance in SET (Source: author).

Adaptive governance principles from SET theory	Adaptive Governance Principles for energy systems
An increase in social capital	Customers at the centre of the policymaking and regulation process (through increased customer representation and participation)
Policy as hypothesis	Empowered local policy Knowledge sharing National vision and target for decarbonisation
Coordination of social capital	Coordination of innovation; Coordination of local policy; Coordination between the physical and operational elements (distribution, transmission, markets)

To achieve a functional transformation, AG suggests that the rules and regulations would need a high adaptive capacity. The speed of rule changes needs to match the speed of technological innovation. Within energy, this suggests that changes to regulation may be needed to allow for novel approaches to 'keeping the lights on', and networks should assess the value of these to the industry. In Australia, and theoretically, at some point elsewhere, consumers now have the power to cause a 'death spiral' for the business models of established electricity monopolies. Consumers can, less shockingly, provide resources to energy systems at certain times as they are being resource providers in a minor form of the conventional utilities. Consumers ought to be able to access this value, as well as their value for their contribution to reducing carbon emissions. This would suggest a changing role for *all* actors including networks and retailers, and therefore a change in regulation, so that the new roles provide the value for this input. For example, by changing the role of institutions, such as the passive distribution system operator (DSO) to an active distribution service provider (DSP) by creating a platform which acts as a market facilitator, or to move from traditional 'cost plus' regulation[3] to performance-based regulation[4] (Mitchell et al., 2016), this would then create an institution with the adaptive capacity to allow for these changing roles.

In essence, in order for the global energy community to decarbonise, energy system actors must assess if the current energy system is able to transition or whether a transformation is needed or is happening. They will need to adopt policy to allow for increased adaptive capacity of a current desired system or for adaptive governance to enable a managed transformation to occur.

2.7 Significance

Several authors have argued that adaptive governance can enable a current transformation within SESs, and there are practical examples for its use in water systems (e.g. Dietz *et al.*, 2003; Engle and Lemos, 2010; Westley *et al.*, 2011). Although the literature for SET is based on ecological systems, there are many similarities between how these ecological systems need to operate to be sustainable and that of the new, sustainable, decarbonised and increasingly decentralising energy system. Although recommended as a 'promising starting point' (Goldthau, 2014; Goldthau and Sovacool, 2012), the use of adaptive governance within energy is only recently beginning to gain traction (Akamani, 2016; Brisbois, 2020; Geels et al., 2019)

Therefore, this thesis will add to this new approach to energy governance through a case study of an energy system that is undergoing an unexpected change, due to the rapid uptake of DER. By empirically examining the relevance of SET for energy transitions, with the aim of contributing to theory development, this thesis aims to increase the understanding of the concept of transformation and adaptive

[3] Companies are able to earn extra revenue through increasing efficiency and therefore reducing the amount of revenue needed for system costs compared to the requested revenue. The saved costs can then be kept by the company and/or shared with customers.
[4] Extra revenue as a reward can be earned through meeting or outperforming performance based targets/outcomes.

governance within energy and the extent to which adaptive governance could be usefully applied. It will use the case study to discuss the benefits of local empowerment, coordination and vision that AG may allow and which acknowledges the complex interactions that take place within an energy system. The thesis takes the key principles from AG in SET theory, discussed in section 2.6, and applies these to the NEM (illustrated in Table 8-2, page 167) to understand whether AG may be assisting, or could have enabled, the current system change that is happening at the distributed level of the electricity system. Results from the research questions (introduced in Section 2.8) will help guide the debate on an approach to adaptive governance within energy system change for the electricity industry on a practical level, and how these could be applied in GB (summarised in Table 9-2, page 191).

2.8 Research questions

***Research question 1**:*

What is driving the take up of solar PV/storage in eastern Australia?

Research question 2:

What has the governance response been to the uptake of DER in eastern Australia?

Research question 3:

Following Unruh's (Unruh, 2000) ideas of carbon lock–in, how does the history of the eastern Australian path-dependent coevolution of energy systems and technology make it more or less inclined to be adaptive?

Research question 4:

To what extent do the principles for adaptive governance from SET theory feature in the Australia case study and if present, have they enabled a positive contribution to the changes being seen? If so, how?

Research question 5:

What are the regulatory and governance lessons to be learnt for GB?

Research questions 1, 2 and 3 provide the background and context of past and current governance in the NEM while research question 4 provides an insight into whether elements of adaptive governance were/are present in Australia's electricity system, and if so, their role in the current changes that are occurring. Question 5 takes the lessons learnt from the NEM governance approach and uses these to suggest an adaptive governance framework for GB electricity decentralisation.

2.9 Conclusion

This chapter has discussed that the energy system is a complex, essential system. SET theory acknowledges this complexity and recognises the need for transformability within systems. By providing flexibility in the governance of the system, adaptive governance can enable a current transformation or allow the system to transform to a new, desired state even if the original system is 'locked-in' to an undesirable one. SET theory, therefore, provides an interesting perspective for energy system governance as:

- Energy systems and ecosystems are both complex and essential systems.
- SET recognises that time limits exist in transitions.
- SET theory acknowledges the equal importance of the social, economic, political, environmental and technical factors, and the interactions between these parameters and designs solutions to complement the local resources.
- SET recognises the difference between a transition (for a desirable system with high adaptive capacity), and a transformation (for an undesirable system that has high adaptive capacity and is locked-in to an undesirable path trajectory).
- SET suggests an adaptive governance framework to create and manage transformation.

The thesis will address the research questions by assessing how NEM governance received and managed the uptake of DER in eastern Australia. The thesis will then use the results to provide recommendations for principles of adaptive governance, adapted from SET theory, for electricity system decentralisation and how adaptive governance may be applied to the GB electricity system.

3. METHODS

As stated in Chapter 1, DER is an important part of energy system decarbonisation and these distributed elements need to be incorporated into the current system. Chapter 2 has shown that energy systems are complex and involve interactions across several parameters and so may need governance to be adaptive to manage transformational change. This chapter will show the methodological processes used within this thesis to (i) assess the challenges within governance as energy systems decentralise, (ii) to establish a theoretical governance framework that enables decentralisation, and (iii) show how lessons learnt from the NEM case study could be applied to create a practical framework for adaptive governance (AG) for decentralisation in the GB energy system.

The approach to suggesting possible solutions for the challenges associated with energy system decentralisation and its governance, and identifying the theoretical framework that would best answer these challenges, was taken initially through four steps:

1. Attending meetings, workshops and conferences in GB to understand the main issues that were being discussed around decarbonising energy systems.
2. Initial desk-based research on the NEM, including past and present governance, the rise of DER and the political, economic and social implications of this rise.
3. a literature review on transition theory to understand the nature of energy system change, and
4. developing the principles for adaptive governance for energy systems, alongside points 1, 2, and 3 that would help inform the research questions, and the questions for the case study interviews.

Steps 1 and 2 identified the governance issues for decarbonising energy systems and the need for governance to be flexible to accommodate changes that may occur in any part of the system. Step 3 researched transition approaches and then identified the most relevant approach for energy system decentralisation. Step 4 then developed the principles of adaptive governance for energy systems that would inform the case study research. By following steps 1-4, the initial research was able to identify where there are gaps in current knowledge (Webster and Watson, 2002) and the major issues surrounding energy system change. The results from these four initial steps enabled the five research questions to be refined to consider why change is happening in the NEM; whether the adaptive governance principles identified in Chapter 2 would/are being beneficial to decentralisation, in comparison to the current governance approach; and the lessons that can be learnt for GB energy governance:

RQ1. What is driving the uptake of DER in Australia?

RQ2. What has been the governance response to the uptake of DER?

RQ3. Following Unruh's (2000) ideas of carbon lock-in, how does the history of the Australian path-dependent coevolution of energy systems and technology make it more or less inclined to be adaptive?

RQ4. To what extent do the principles for adaptive governance from SET theory feature in the Australia case study and if present, how have they enabled a positive contribution to the changes being seen?

RQ5 What are the regulatory and governance lessons to be learnt for GB?

A further four steps were then undertaken to assess the viability of adaptive governance for energy system change.

5. Desk-based research to identify the institutions, industries and actors where the challenges of a change to a more decentralised system, caused by the uptake of DER in the NEM, had altered their traditional operations and, therefore, to identify the most relevant actors to interview during the case study fieldwork.
6. Semi-structured interviews with government and industry representatives, NGOs and academics in the NEM States, allowing a variety of perspectives on the DER uptake and the governance responses, to inform a narrative around the rise of DER and the challenges it produced.
7. The organisation of the primary and secondary data using coding software.
8. Analysis of the coded results to create the narrative around the uptake of DER, how this was received within the NEM, and if there were aspects of adaptive governance that influenced the current changes that are occurring.

3.1 The use of a case study and the choice of case study area

Research has shown that a singular in-depth case study gives more detail of the possible interactions that can occur and that the results may be generalised to formulate insights for other similar situations (see Flyvbjerg, 2006). By completing interviews with a range of actors within the case study area, a case study is able to produce a narrative of how and why an event occurred. The use of narratives has been recommended in social and political science, as producing a story around a singular lived experience can provide a glimpse of a possible future where similar experiences may be expected (Mattingly, 1991), enabling anticipatory policy interventions (Abbott, 1992). Using both primary and secondary research, this thesis has created a narrative around the uptake of DER in Australia. Within this narrative the complexities and challenges associated with energy decentralisation, as discussed in Chapter 2, are highlighted and as such, the narrative can provide policymakers with anticipatory knowledge for future decentralisation strategies. However, there are limitations with a singular case study, and although able to provide an in-depth view of single event and therefore suggest possible solutions based on the SET framework, it would be prudent to use further empirical evidence to fully understand the interactions of a SET framework in other energy governance contexts.

To understand the dynamics and challenges of energy system decentralisation, a case study of an energy system already experiencing some decentralisation was undertaken. Preliminary desk-based research identified that the NEM is undergoing a rapid decentralisation, led by the consumer through the uptake of household DER.

Australia has four electricity systems, the largest of these systems being the National Electricity Market (NEM) of the eastern states (Figure 3-1) covering five interconnected state-based networks (the focus of this case study). The Western Electricity Market (WEM) covers south Western Australia. The Northern Territory Electricity Market (NTEM) covers the Northern Territory. Each of these systems is operated through separate markets under the National Electricity Laws (NEL). The North Western Interconnected System (NWIS) is located in northern Western Australia and is state-owned and run.

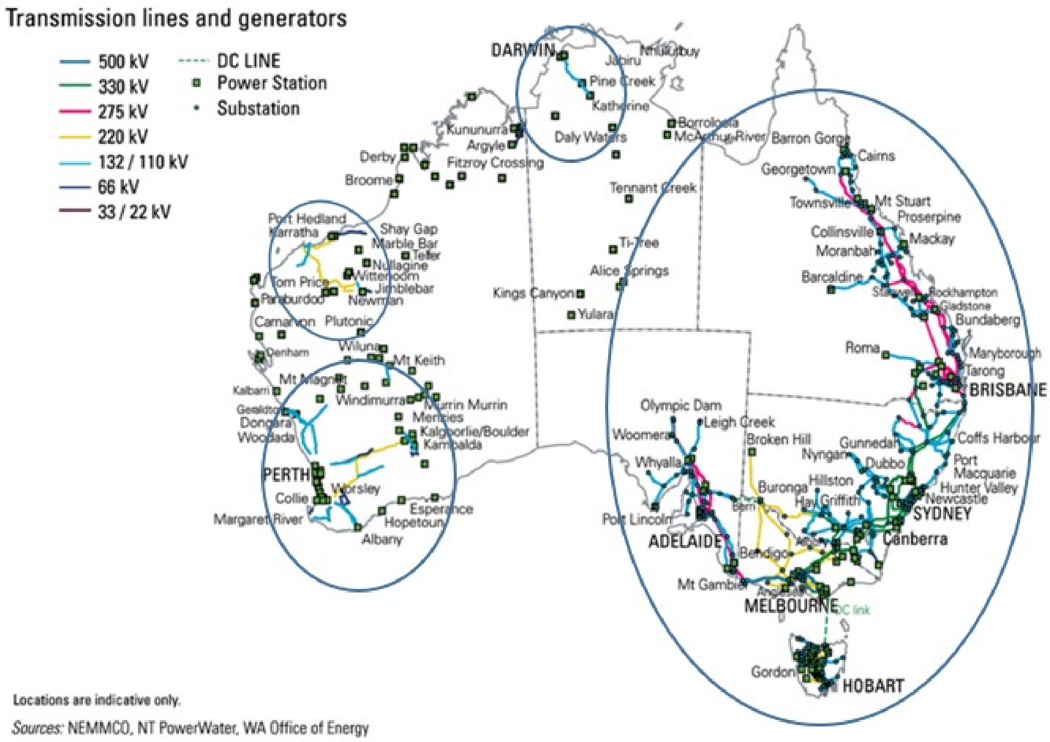

Figure 3-1 Australia's four electricity systems (Geoscience Australia and ABARE, 2010)

It is possible to take lessons learnt from the NEM case study, due to the similarities between the GB electricity system and the NEM (Chapter 5 gives an in-depth view of the governance and structure of the NEM). Both the GB and the NEM have an overwhelmingly centralised system and governance structure. Both systems have undergone reforms that have left generation and retail as competitive markets, with these markets dominated by the 'big 3'[5] in the NEM and the 'big six'[6] in GB. The privatised monopoly elements of supply, in both cases, are regulated by a national regulator, the AER in Australia, which is purely an economic regulator and Ofgem, in GB, which is both economic regulator and rule maker.

It is also possible to compare the changes in geographies between the NEM and the GB energy system. Geographical changes in the NEM occur over large distances, with physical geography remaining the same over many hundreds of kilometres before changing. In GB, the physical geography changes over much shorter distances, so although the NEM covers a much larger area, the physical and social changes that occur within the energy system boundaries are similar e.g. changes

[5] AGL, Origin, EnergyAustralia
[6] British Gas, EDF Energy, E. ON, Npower, Scottish Power, and SSE

from rural to urban, and landscape variations, so requiring DER and resources that are optimal for these particular localities.

The main difference between GB and the NEM, is that Australia has a federal system of government. The Australian federal system allows the NEM State Governments to set, or legislate, and fund State RE targets and subsequent local innovations that are beneficial to the particular region. This ability has helped some NEM States to initiate and support DER, and to gain economic and social benefits for households, businesses and industries through savings in energy bills (e.g. through self-generation), guaranteeing future energy prices (e.g. by investing in self-generation or through power purchase agreements with utility-scale RE) and by opening up new industries (e.g. installation companies and new manufacturing plants).

3.2 Methodological approach to answer the research questions

To answer the initial broad question introduced in Chapter 1, i.e. whether current energy system governance is fit for purpose to enable decentralisation and if not, what needs to be changed, five research questions were identified following the preliminary research. Addressing these questions would introduce the NEM and the current transformation that is taking place; how governance of the NEM has responded to the uptake; the history and influence of ideas, institutions and industry on the system; how adaptive governance may or may not be assisting in the current changes seen in the NEM; and what lessons can be learnt for the GB governance approach to enable decentralisation. The research questions required different approaches to the methods of acquiring data.

To inform and produce rigorous conclusions to the research questions, it was necessary to obtain data from a variety of sources. The data required was both qualitative and quantitative and from primary and secondary sources. Primary data was gathered by conducting semi-structured interviews. Secondary data was obtained via literature reviews and desk-based analysis. It is suggested that a mixed methods approach, using quantitative data and qualitative data from both primary and secondary sources, allows the qualitative data to give a greater depth and understanding of the results obtained quantitatively (Elwood, 2010). This section describes the methods used to obtain the data needed to answer the research questions.

3.2.1 Secondary research

To create a framework for governance that would allow change, transition theories were reviewed that could help to answer the challenges of change within complex systems and the difficulties of carbon lock-in. The literature review considered the theories from socio-technical transitions and social-ecological transitions and identified the transition theory that was most applicable to the changes required for a decentralising energy system.

A further literature review was undertaken to gather the qualitative and quantitative data needed to understand the challenges associated with energy system change. Qualitative and quantitative data was obtained, for both GB and the NEM, through peer-reviewed literature, industry reports and industry websites plus research from government, NGOs and the energy press. The purpose of this data collection was to develop an understanding of the issues surrounding changes within energy systems in general, both in GB and Australia, and, in Australia, to understand how these issues were affecting the NEM.

Further data collection was needed to track the progress being made in the NEM towards the integration of DER. This data collection took place between September 2016 and September 2019, to track the rapid changes that were occurring in the NEM. This data was required to highlight both the positive and negative effects of a rapid uptake of DER on energy system governance and the system itself.

Quantitative data was used to understand the economics behind DER uptake. A mix of desk-based quantitative (DER cost analysis, DER uptake statistics, published questionnaire results) and qualitative (peer-reviewed literature, industry reports and websites) data was used, to initially assess the factors involved in the uptake. Secondary research was undertaken both initially, and then continuing until September 2019, by reviewing past, current and future governance initiatives in the NEM. Events in parliament, media releases by relevant institutions, and articles from the general media were also continuously reviewed throughout the doctoral process.

3.2.2 Primary research

Through attendance at IGov and other industry, NGO, and academic workshops and conferences, information was gathered on the issues being discussed in regard to energy system decarbonisation in GB. Government consultations were followed and responded to, in particular concerning electricity distribution regulation. The insights gained from the discussions and consultations in GB, were used to inform the suggested governance framework presented in Chapter 9.

In addition to the attendance at various energy conferences and workshops in GB from 2016-2019, semi-structured interviews were undertaken with energy professionals in south-eastern Australia in 2018. Herbert (2010), suggests that the use of empirical data, such as interviews, can be used as a method to enhance and validate the data produced from the initial qualitative and quantitative literature review. Semi-structured interviews were chosen as it enabled the interviewees to give answers based around the same core questions but with the opportunity for the interview to be more open. The open-endedness offered by this method, rather than through a questionnaire, gives the research the possibility of results not foreseen from the initial data collection (DiCicco-Bloom and Crabtree, 2006). This aim of this type of open-ended interview is to obtain different perspectives on the changes happening in the energy system. This would create the narrative around the effects of system change on the social, technical, economic, political and environmental parameters of the NEM, and the dynamics shaping this change, which could then be used to inform future policy decisions elsewhere.

In total, 34 semi-structured interviews with energy professionals were conducted within 30 organisations in south-eastern Australia. The key actors in the NEM were identified during the preliminary data collection and also through recommendations from interviewees. The interviewees came from different backgrounds i.e. government, industry, NGOs and academia to give balance to the data. By interviewing a range of individuals from all levels concerned with DER (Table 3-1), the research was able to offer a broad range of viewpoints across the research questions and create a narrative that recognised the varied interactions and complexities of energy transitions. Where there is a duplication of organisations, this is due to interviews taking place within different departments of the same organisation, or in the different NEM States.

Table 3-1 Interviewees by state and organisation

State	Government	Industry	NGO	Academic
ACT	Australian Energy Regulator	ITP Renewables Energy Networks Australia	Aus. Institute of Energy Smart Energy Council	Australian National University (Energy Change Institute)
SA	Dept. of Energy and Mining Australian Energy Market Operator Essential Services Commission of SA Australian Energy Regulator	South Australia Power Networks ElectraNet	The Energy Project Uniting Communities	University of South Australia
VIC	Essential Services Commission	Jemena Ltd GreenSync AGL	Consumer Action Clean Energy Council St. Vincent de Paul Society	Victoria University (Victoria Energy Policy Centre) University of Melbourne (Aus/German Climate and Energy College)
NSW	Dept. of Energy Energy Consumers Australia Australian Energy Market Commission	AGL	Public Interest Advocacy Centre	University of Technology (Institute of Sustainable Futures)

Each of the interviews began with a brief introduction of the thesis e.g. the theory of adaptive governance, a synopsis of the research questions and why the NEM had been chosen as a case study. The interviewee was asked to sign an informed consent form which detailed the ethics procedures for anonymity and that the interviewee could withdraw consent once the study had concluded (a copy of the consent form is available in Appendix 1).

The initial introduction to the thesis was tailored dependent of the expertise of the interviewee. For example, where the interviewee had academic experience, theory was discussed in more detail, whereas for a more technical interviewee this was given as a brief overview and the relevant research questions given more priority. This allowed the interviewee to understand, and enabled the interview to focus on, where the interviewee's particular expertise could help answer the research questions and also to allow them to introduce new ideas relating to the initial research.

The semi-structured nature of the questions asked during the interviews allowed the interviewees to answer the research questions dependent on their expertise. Using this method, the answers given tended towards either the economic, social, technical or political aspect of the interviewee's agenda. For example, when asked about the effects of the rapid uptake of DER, an electricity network representative focussed on technical challenges, whereas an advocacy representative tended towards consumer protection and equity. This range of perspectives enabled the qualitative data to highlight the complex interactions that can occur as energy systems change.

Each interviewee was assigned a code (Table 3-2) showing the place of interview and their occupation e.g. S1ac is an academic interviewee from Sydney. The data from the interviews was then collated using NVivo (section 3.3.1) and assessed to understand if adaptive governance processes were involved in the rapid uptake of DER and whether adaptive governance is enabling the current changes within the system. The results of the case study of NEM energy governance, and the effects of a rapid uptake of DER, were then used to formulate lessons learnt for energy governance in GB.

Table 3-2 Affiliation of interviewees and their identification codes e.g. S5 NEM in - national government energy institution representative based in Sydney.

	Sydney (S)	Canberra (C)	Melbourne (M)	Adelaide (A)
1	Academic (3 interviewees) (ac)	National regulator (Nreg)	industry (in)	State regulator (Sreg)
2	National Government advocacy (2 interviewees) (Gad)	National regulator (Nreg)	advocacy (ad)	advocacy (ad)
3	industry (in)	NGO	industry (in)	NGO
4	State Government (Sgov)	Electricity networks (ENA)	NGO	academic (ac)
5	National Government energy institution (NEM in)	academic (ac)	Academic (4 interviewees) (ac)	Distribution network (dn)
6	State government (Sgov)		Distribution network (dn)	Transmission network (tn)
7			advocacy (ad)	NGO
8			academic (ac)	National Government energy institution (NEM in)
9			State regulator (Sreg)	

3.3 Data analysis

3.3.1 Qualitative data

NVivo software was used to analyse the qualitative data gathered during the interviews. NVivo software has been designed to support both qualitative and mixed methods research to '*organize, analyse and find insights in unstructured, or qualitative data*' (QSR International, 2017). The software can import data from a variety of sources such as Office, online surveys, web data and social media. The author is then able to use code-based software to analyse relationships in the data faster and more accurately than would be possible through other methods.

Each of the interviews was coded, and sub-coded, to find common themes throughout the data. Within NVivo the researcher is able to create a 'node' into which the relevant data can be stored. The initial nodes were the Chapter headings, informed by the research questions and based around the various aspects of complex systems as highlighted in the literature. The interviews were then coded by taking information relevant to the chapter and creating a sub-node within the chapter node. New sub-nodes were created for each new piece of information and where applicable, information was stored in a sub-node that had already been created. These sub-nodes then informed the sub-headings within the chapters, with the relevant quotes used to enhance and substantiate the secondary data, and vice versa. An example of the sub-nodes for Chapter 4 is available in Appendix II (note that after coding the chapters were moved, so Chapter 4 appears as Chapter 6 in NVivo).

3.3.2 Quantitative data

The numerical analysis for the costs of a PV and battery system was undertaken using Excel and simple mathematical methods. The results of industry questionnaires were used to understand further drivers for DER uptake. The results of the quantitative analysis are available in Chapter 4.

3.4 Conclusion

This chapter has introduced the research questions used to investigate the uptake of DER in the NEM; the governance response to this uptake; institutional and political influence over NEM governance, a transition approach to best answer any challenges that have arisen; and how lessons learnt can be applied to GB energy system change.

Using a mixed-methods approach, primary and secondary data was used to produce a narrative of energy system change in a country where a rapid uptake of DER has taken place. The results of the narrative were then used as a method to anticipate possible governance challenges that may occur in GB, as GB increases decentralisation. These results, in conjunction with the transition theory chosen from the literature review, were applied to provide a possible framework to assist in energy system decentralisation in GB.

4. DRIVERS FOR THE UPTAKE OF DER TECHNOLOGIES

Australia leads the world in the uptake of domestic solar PV. In 2018, an average of 25% of households in Australia had installed PV systems (APVI, 2019a) and the state of South Australia has one of the highest shares of variable renewable (large and small-scale) electricity generation in the world, at 42% of generation capacity (Blakers et al., 2019; Climate Action Tracker, 2018).

This thesis is concentrating on the decentralisation of energy – a central part of energy system decarbonisation – rather than the adoption of large-scale renewable energy technologies. Therefore, this chapter will describe the drivers for distributed energy resources (DER) in Australia and the NEM, and how Australia became the world leader in the percentage of households installing PV. There are multiple drivers for DER uptake in the NEM – the solar resource (section 4.1), DER subsidies (section 4.2), high energy prices (section 4.3), reducing technology costs (section 4.4 and section 4.7), climatic events (section 4.6), consumer trust (section 4.8) and consumer financial considerations (section 4.9). These multiple drivers are discussed by presenting an overview of the initial renewable energy policies that were put in place at the national and State level (other RE policy will be discussed in more detail in Chapter 6); discussing other unrelated events happening at the same time which culminated in higher than expected adoption rates; commenting on how high prices, confusing tariff structures and poor customer service have made energy companies unpopular with their customers; and discussing the demographics of PV installations.

4.1 AUSTRALIA'S SOLAR RESOURCE

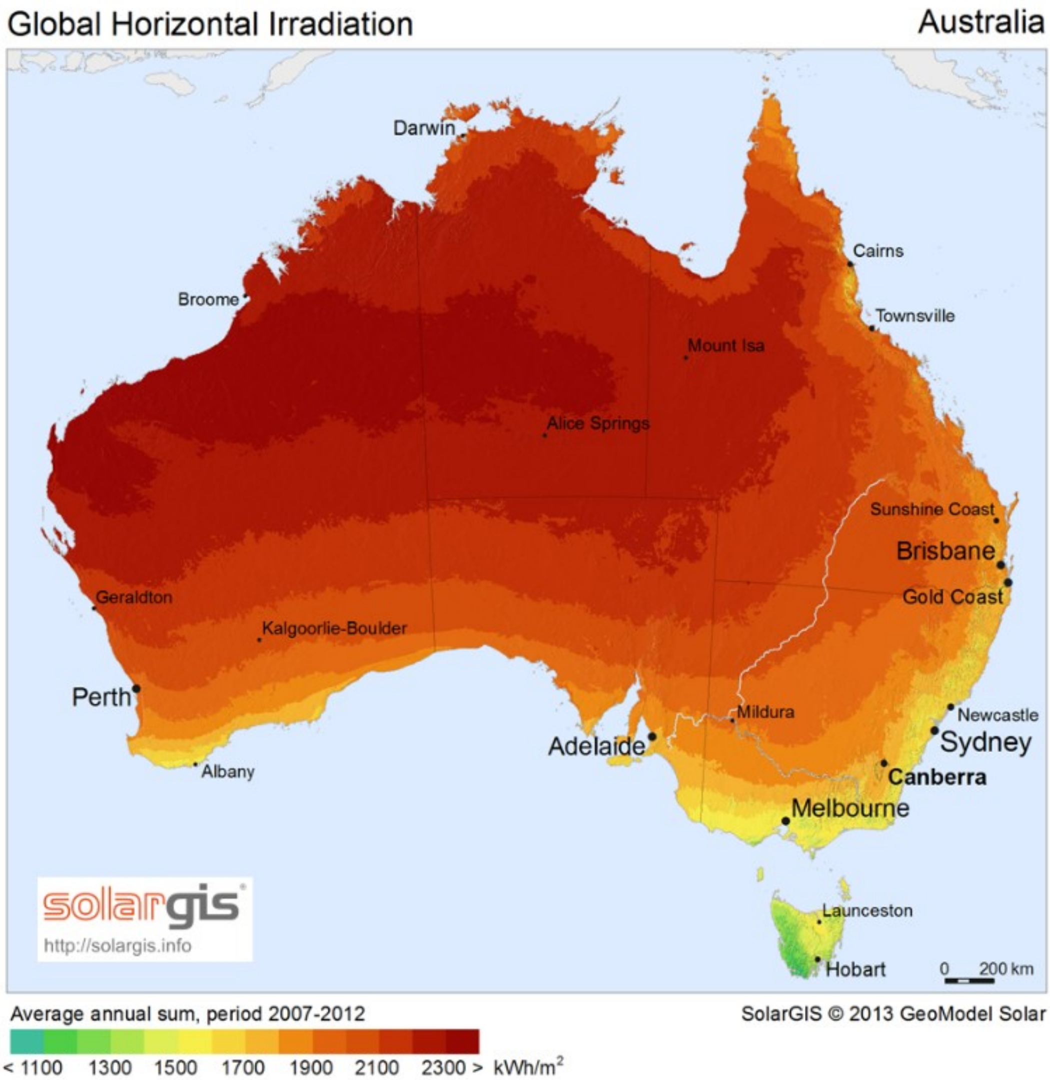

Figure 4-1 Average annual global horizontal irradiation for Australia (Solargis, 2013)

Australia has the highest solar irradiation of any continent (Figure 4-1), with solar irradiation in the NEM, between 1300 and 2100 kWh/m^2. This in comparison to GB, where average solar irradiation is between 750 and 1100 kWh/m^2 (Dhimish et al., 2018). The excellent solar resource can produce capacity factors[7] of around 30% in summer and 15%-18% in winter (AEMO, 2016a). In Australia, a 1 kW domestic solar PV system can produce an average of between 3.5 -5.0 kWh per day, dependent on location, or an average of 25-40% of a typical Australian households energy needs (Clean Energy Council, 2011).

[7] The amount of power produced, compared to the maximum power that could be achieved if the plant was able to permanently generate at its maximum rated capacity (e.g. if a 2MW wind turbine was able to generate 2MW of power, 24 hrs/day, 365 days/year, compared to its actual production).

4.2 SMALL-SCALE RENEWABLE ENERGY POLICY

In 2008 as part of their own renewable energy targets, and to encourage early adopters at a household and commercial level, each of the Australian States introduced incentives for small-scale solar (<100kW). Interviewees described the initial process of deciding on the type of incentive as lacking much deep consideration. The subsidy amount was decided on by doubling the then retail electricity price, and then creating either a net or gross feed-in-tariff (FiT) dependent on which type the State government thought would be better for consumers.

> *'They decided to do this by a straight subsidy, actually a cross-subsidy, where they would pay mums and dads twice the then regulated retail price for installing PV systems. So, for every kWh sent out, they would receive, at the time it was 44c* [the retail price]*.*
>
> Interview A1 Sreg

> *'That was actually a bit of a stuff up in NSW, where the advice was you could either have a net feed-in-tariff, where you get for the net amount of solar that you put out to the grid at 60c/kWh, or you could have a gross feed-in-tariff at a much lower level, about 20 or 30c/kWh. In the processes, they then thought, "Let's do something that really distinguishes ourselves and do 60c/kWh." "Is that net or gross?" "Which is better?" "Well gross is better." "We'll do that".'*
>
> Interview S/1 ac

The state-designed schemes were a Solar Bonus Scheme (SBS) in New South Wales (NSW) and a Premium feed-in-tariff (FiT) in Tasmania (TAS) and the Australian Capital Territory (ACT). The SBS and Premium FiT paid between 44c/kWh and 60c/kWh dependent on state-regulated tariffs for *all* PV generated electricity. South Australia (SA), The Northern Territory (NT), Western Australia (WA) and Queensland (QLD) had a net FiT which paid 44-60c/kWh for excess electricity generation that was fed back into the grid.

All State schemes were initially open to an unlimited size of domestic system but then curtailed to 5kW as a national RET scheme was designed to encourage larger RE systems (see section 6.4.1). In 2012, the schemes closed to new entrants and the tariff reduced to around 8c/kWh, as the amount of subsidy being paid was considered to be unsustainable. Registered systems installed before the 2012 deadline would receive the initial Premium or Net FiT, or SBS, until 2028. The scheme was more successful than initially planned, with the original target of 15MW met within a month.

> *'They took that bill to parliament and somewhere a couple of Greens, people in the other house here said, 'love the scheme, great idea but rather than a 5 year closed scheme capped at 15MW or whatever it was, it will be a 20-year scheme open to everyone, small business, residential customer, anyone who uses up to 160MWh per annum gets this thing', which drove somewhat of an uptake. I think they surpassed the 15MW within a month. Now we are at 800MW/750MW whatever we are at. They did close down entry to those schemes eventually but if you were on the scheme you were on it until 2028. So that subsidy thing happened, it happened in a way that was slightly unplanned and uncontrolled I think.'*
>
> Interview A1 Sreg

In 2011, the Small-scale Renewable Energy Scheme (SRES) was introduced (to run until 2030) as a measure to encourage individuals and small businesses to invest in eligible renewable energy (RE) systems (CER, 2018). SRES certificates are produced for new renewable generation by solar PV, wind or hydro and for the energy displaced by a solar water heater or heat pump over the course of a designated period. The certificates can be generated by the owner of the eligible technology, or by an installer who has been assigned the right to generate the certificate by the owner. As one certificate is equal to 1MWh, small-scale RE installers can aggregate smaller RE systems to reach the 1MWh target and pass on savings to the customer. The certificates are sold to energy retailers, who are required to surrender a certain number of certificates each year, through a spot market or a Government Clearing House (RET, 2018). The value of the certificates is dependent on the spot market price, currently $35.50/MWh. Alternatively, certificates can be traded through the government Clearing House at $40/MWh. Certificates will only be traded through the Clearing House if there are no certificates available through the spot market. The added benefit of the scheme is that it gives the Australian Energy Market Operator (AEMO) visibility of the location and density of behind-the-meter RE, which allows for better forecasting for grid demand.

4.3 Rising energy prices

In 2010-2012 there was a steep rise in the cost of energy. Various factors combined to cause this rise:

1. Unneeded network augmentation
2. retirement of old coal thermal plant and
3. switching to gas generation for gas peaking plants and baseload power at a time when global gas prices were increasing (IEA, 2019b).

4.3.1 Unneeded network augmentation

Industry forecasts had predicted an increase in electricity demand which would require new infrastructure and generating capacity (Saddler, 2017). In fact, demand fell which meant that electricity companies invested in unneeded infrastructure (ibid.). The incorrectly forecast increase in demand, allowed the electricity networks to augment their power lines for an expected increase in a one-way flow of energy. These investments then formed part of the networks regulated asset base (RAB). Criticism has been made of the fact that some of Australia's network businesses are still publicly owned (see section 5.2.2) and that it is then in the interest of the government, and as such the State's technical regulator, to increase the reliability threshold, which then allows the state government to raise revenue from an ever-increasing RAB (Kuiper, 2015).

> *'I would rather be off for an hour and a half, rather than paying $100 extra a year. So that is what we do as well saying, 'What are you prepared to pay, what are the trade-offs here?'. There is a whole load of science of figures to pay studies. But we could just say sort it, gold plate it, and then, of course, they will, and they get a return on it because it is a capital investment. So, this is what happened in the 2000s, this is what we were trying to avoid, is the gold-plating.'*
>
> Interview A1 Sreg

The return on these investments accounts for more than half of the network businesses total revenue (Saddler, 2017). This high revenue, and hence a continuing high RAB, leads to high network charges for consumers, leading to the criticism from Kuiper (2015), that state interests are in direct conflict with consumer interests. In the NEM, the network charges currently make up around 40% of customers' bills (Figure 4-2) (AEMC, 2018a), this in comparison to network charges in GB, which currently stand at 23% of the total kWh charge (Ofgem, 2020).

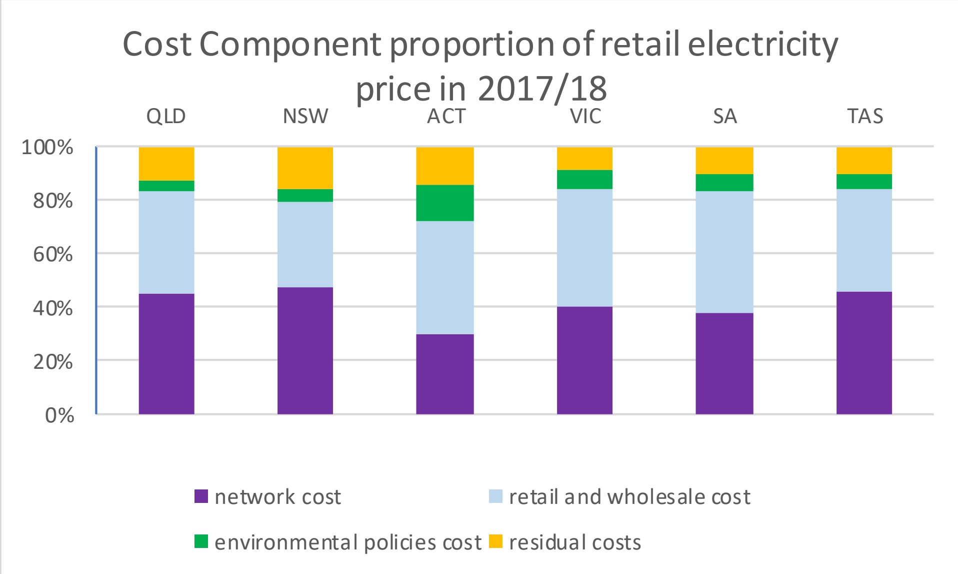

Figure 4-2 Electricity price trends 2017/18 (methodology for residual costs available in the AEMC 2018 Residential Electricity Price Trends Review (source: AEMC, 2018))

4.3.2 Retirement of old coal thermal plant and the switch to gas

In the 2000s, old coal thermal power plants were retired and replaced with combined cycle gas thermal power plants (CCGT). In Queensland between 2000 and 2010, State policy required retailers to obtain their electricity from gas generators, as the State government saw gas as a transition fuel and to take advantage of the new coal seam gas industry.

> *'In Queensland, the state government, they basically introduced a portfolio standard obligation to gas, which was 13%, then 15% on retailers, that they had to source their electricity from gas generators. So that is why there is a whole fleet of, several CCGT and some OCGT, all were built. But the Queensland government did that as a sort of incentive for the development of the coal seam gas industry. So after about two years, from about 2013-15, something like that, when there were masses of very, very cheap gas, what they call ramp gas, because as the production of ramping up there was nowhere for it to go, so it was available very cheaply for gas generators, and then as soon as the LNG came on board, the price went up and scarcity went up.'*
>
> Interview C5 ac

,

The other States also saw gas as a transition fuel, as gas-generated electricity produced fewer emissions than that from coal. Due to the Queensland government's support of the coal seam gas industry, domestic gas was abundant at this time, and so was a cheaper option for electricity generation. However, following this, there was an increase in global gas prices which, as the number of CCGT plants were increasing in the NEM, raised retail prices for consumers. The increase in global gas prices also led to the development of three LNG export projects in Queensland. These export developments ultimately limited the availability of local gas for the domestic gas market. This decrease in the supply of domestically available gas caused domestic wholesale gas prices to rise further, affecting the cost of electricity supplied by gas generation in the NEM (Oakley Greenwood, 2016)

Forecasts by the Australian Energy Market Operator (AEMO) (Figure 4-3) predict more increases for residential electricity prices in 2020, between 15-20% higher than 2016 levels. Future price rises have been forecast due to a continuing reliance on gas for future electricity supply. In particular, South Australia (SA) and Queensland (QLD) are more reliant on gas generation for baseload demand. It is also forecast that commercial and industrial users could see increases in electricity prices of 20-40% compared to 2016 levels by 2037 (Parisot and Nidras, 2016).

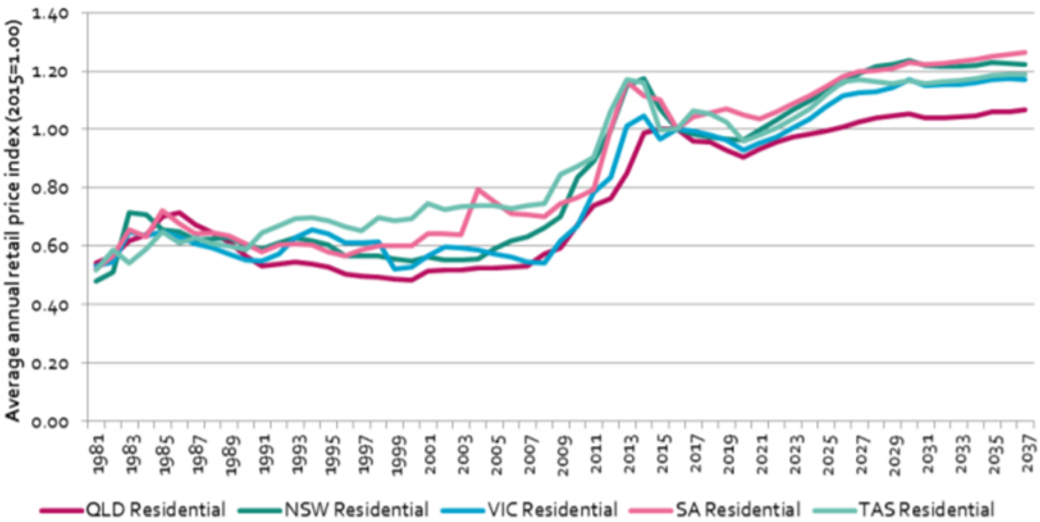

Figure 4-3 Real indexed residential retail prices - historical and forecast, neutral scenario (2016=1.00) (source: Parisot and Nidras, 2016)

4.4 Reducing costs for solar

Between the years of 2008 to 2014, the global price of solar PV modules declined by a staggering 79% (Jäger-Waldau, 2017). In Australia, prior to subsidy, average system price (the cost of PV panel plus associated equipment) fell from \$12/W in 2008 to \$6/W in 2010 and \$3.10/W in 2013 (Johnston et al., 2014) (Figure 4-4). This reduction in the cost of a system, plus subsidy from SRES payments and the generous FiT rate, saw a record capacity installed from domestic PV systems between 2010 and 2012 (Figure 4-5).

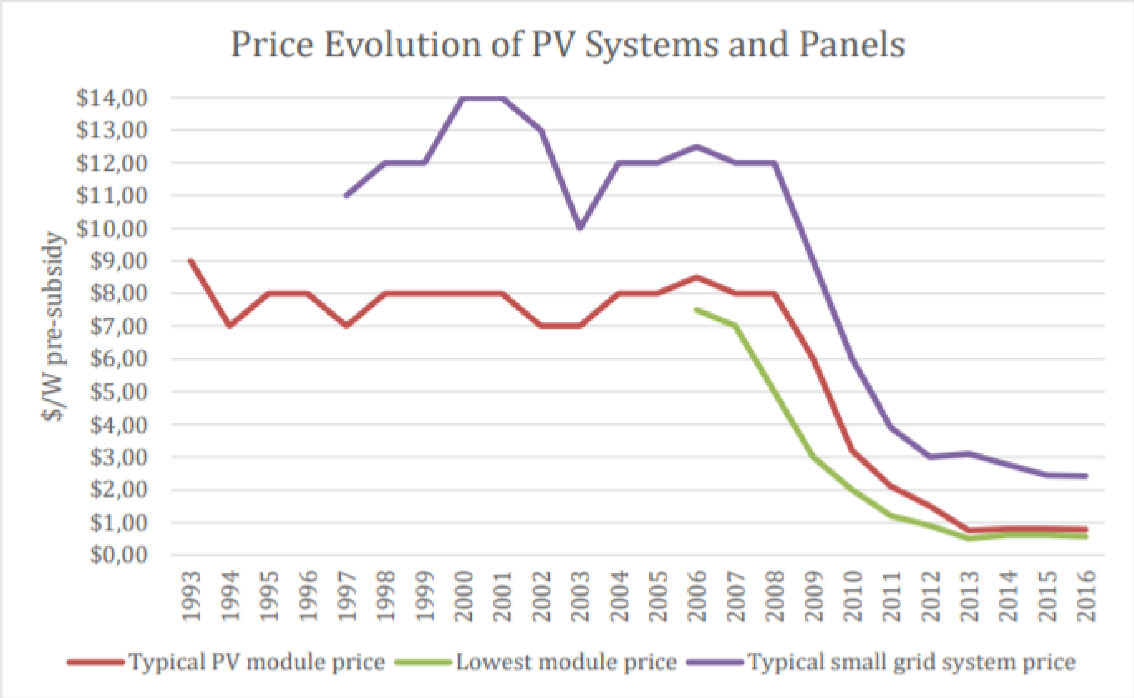

Figure 4-4 Price evolution of PV Panels and Systems (Johnston and Egan, 2016)

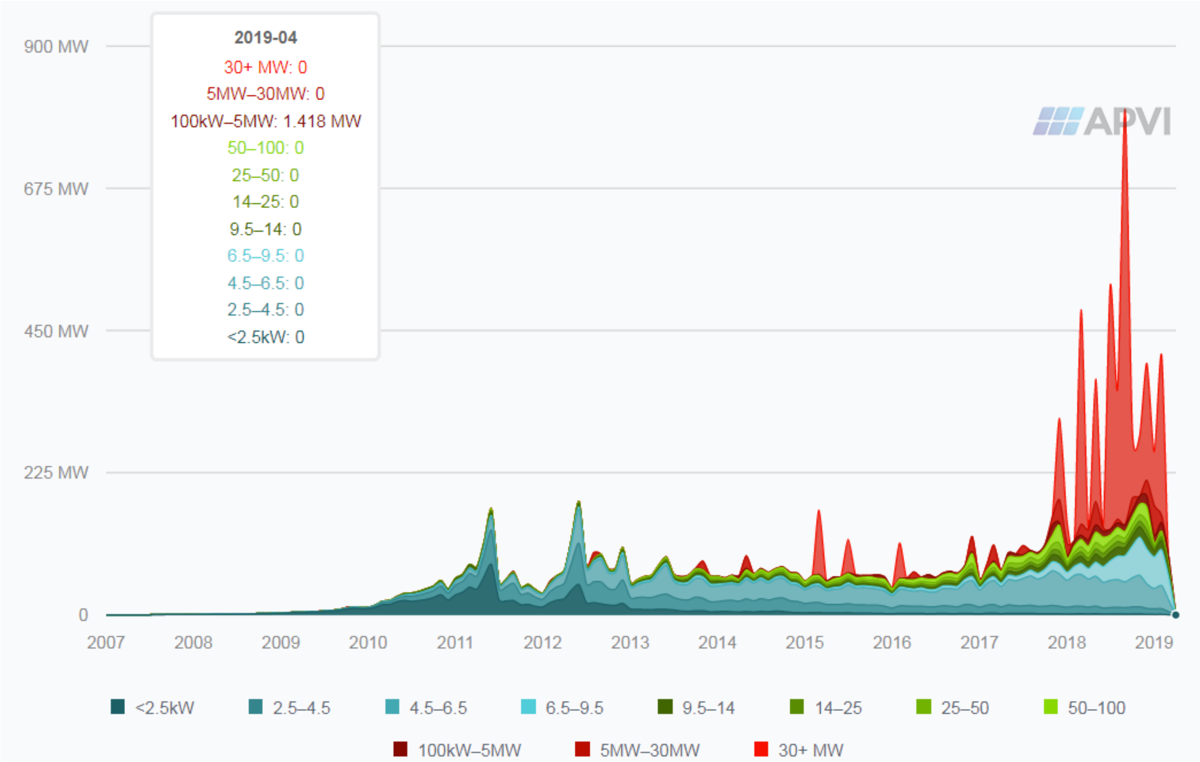

Figure 4-5 Monthly data for PV installations in Australia with the record installs for small-scale PV in June 2012 (and also showing further record installs in 2018) (Source: http://pv-map.apvi.org.au/postcode)

This 'solar rush' started a boom for the solar PV installation industry. The amount of solar PV installed between 2008 and 2012 led to 11,600 jobs being created in the installation industry (UTS, 2016). The competition between installers led to increased efficiencies in installation techniques, and helped Australia reach the lowest domestic installation costs globally (IEA, 2015).

> *'There has also been this boom and bust for them. So, although it* [varying energy policies] *has killed off the manufacturing, it meant that those who have survived have had to be really efficient. Not perhaps the smartest way to drive efficiencies, but it is an efficient installation industry and pretty low cost.'*
>
> Interview S1 ac

4.5 The unexpected success of DER

By the end of 2012, the combination of excellent resource, high subsidies, high energy prices, falling module costs and cheap installation rates saw Australia leading the world with the highest percentage of households with solar PV installed, an average of 15% of households across the country (AEC, 2016). This also meant current FiT rates would be unsustainable as more money than expected was being paid in subsidies (due to the unexpected rapid take-up of solar, with the expected 15MW being met within a month (see section 4.2)). The costs of these subsidies were paid for by all energy consumers as part of their household bills (Wyndham and Rutovitz, 2016).

As the costs for solar installations kept reducing, the states quickly sought to address the problem of high subsidies and reduced the FiT rate. The reductions in the FIT rate still left anyone installing the system under the new rate with a typical three- to four-year payback period on the installation costs of the system.

> *'The impetus in Australia for FiTs has now more or less dropped away and that is because the price of renewables, the price of solar has become so cheap, that even with the pretty small FiTs that are offered it is financially viable. So the need for FiTs is gone'*
>
> Interview C3 NGO

In 2013, FiT rates across all States were reduced and changed to a Net FiT (with the exception of Queensland) so that householders would only be paid for what they exported to the grid. Following even more reductions in the cost of a PV system, on the 31st December 2016, all SBS and FiT schemes in all the states ended, as PV system costs were affordable without the use of subsidies. Only those in receipt of the initial pre-2012 Premium FiT payments had these payments grandfathered. FiTs are now paid by the retailer with no mandatory minimum requirement. The states can set minimums or provide benchmark ranges as a guide for retailers if they wish (Table 4-1).

Table 4-1 2019 FiT rates for NEM states (Source: Energy Matters, 2019)

State	Scheme	Rate c/kWh	Max size
Queensland	South-eastern QLD: no minimum	depends on retailer	
	Rural QLD: mandatory minimum	7.448	5kW
New South Wales	Recommended benchmark range for retailers	5.5-7.2	Depends on retailer

Australian Capital Territory	No minimum	Depends on retailer	n/a
Victoria	Mandatory minimum	9.9	<100kW
South Australia	No minimum	Depends on retailer	First 45kWh per day
Tasmania	Set rate	6.671	10kW single phase 30kW three-phase

4.6 Climatic events cause further DER uptake

On the 28th September 2016, storms in northern South Australia, including tornados with wind speeds in the range of 190-260 km/h caused a state-wide blackout. The storm caused multiple network faults and downed three major transmission lines. The resulting voltage disturbances caused settings on the wind generators to reduce their output. This then required a necessary increase in imports through the Heywood interconnector from Victoria which caused a loss of synchronism and led to one of the interconnectors tripping. The frequency control ancillary services (FCAS) (see section 7.1.3.2) capability of the gas generators – which should have stopped a collapse of system frequency was unable to respond at the required speed AND the system restart ancillary services (SRAS) – which also should have stopped a collapse of system frequency – were unable to start due to unexplained failures which led to a collapse of electricity system frequency (Manitoba HVDC Research Centre, 2017). The update report (AEMO, 2017a) from AEMO, and also a recent review by the Chief Scientist, Alan Finkel (Finkel et al., 2017), have recommended that value services for FCAS and SRAS from distributed energy and other storage technologies should be investigated.

In addition, on February 8th 2017, a heatwave with temperatures of 41.6^{0}C left 90,000 homes (AEMO, 2017b) in South Australia without power as AEMO committed to load-shedding due to failures of its fossil fuel generators. The demand forecasts they had received had not anticipated the cooling demand for the period and the reduced wind power due to a drop in wind speed. A 165MW gas plant was ‘unavailable’ and unable to start-up in the time requested, needing 4 hours’ notice, leaving homes without power in the evening on one of the hottest days of the summer.

These two events happened in an Australian State which has over 30% of households with rooftop PV and in which installing combined domestic solar and storage is cheaper than buying grid electricity. As can be seen from Figure 4-5, since 2017 there has been a significant rise in the number of domestic and commercial PV installations, which can be attributed in some way to these events.

4.7 NEW STORAGE OPTIONS

At the end of 2016, there was also an announcement by Tesla that they would be introducing their new Powerwall 2.0 in Australia at the same price as the Powerwall 1. This essentially halved the cost of storage in Australia as the Powerwall 2.0 had double the storage capability. The result of this meant that in some states installing solar PV plus storage became competitive with grid-supplied electricity. The reducing costs of solar and storage in the NEM have now taken DER away from being considered a new technology. DER is now seen as a mainstream method of guaranteeing both energy reliability and affordability.

> *‘The penny really dropped for me when I was reading our Financial Review, our version of the Financial Times, a conservative, pro-market paper and it had this big half-page story in it, late last year, with two very blue-collar mine-workers sitting in their house drinking cold beers, and there was a blackout, and they were stoked they were drinking cold, refrigerated beers because they had solar and batteries. These guys didn't give a shit about the environment, this is just mainstream technology now.’*
>
> Interview S2-1 Gad

In Figure 4-6, the cost of the PV/storage system in the NEM states has been calculated for a 10 year lifetime (the average lifespan of a battery system), however, if costs were to be spread over a 20 year lifetime, QLD and TAS would also see DER costs cheaper than retail prices. These figures do not include government FiT schemes, to indicate the cost of the system assuming the customer wanted to disconnect from the grid. In SA, owning a solar and storage system is cheaper than any retail offer and has reached grid parity, a fact that was also evaluated by one of the interviewees.

> *'I did some studies when the Tesla Powerwall came out in SA. I have got a database of all the retail prices which I update every 6 hours, so I have got all the offers, there are 5300 in the NEM, so I have run these sums for 10 year Tesla and 25 year PV, PV lasts for all intents and purposes, but it doesn't matter, and as at the end of 2016 when the Tesla Powerwall came out, it was cheaper than any grid offer in South Australia.'*
>
> Interview M8 ac

In AEMO's *South Australian Electricity Report* (AEMO, 2016b), with figures based on information available until July 2016, expected uptake of combined PV and storage systems was predicted to begin slowly and not see growth until after 2020. The report also predicted that retrofit of storage systems would be uneconomical. However nationally in 2016, 6,750 storage units were installed, up from the previous year's figure of 500, and this with no government or policy support. It had been estimated that in 2017, due to the late arrival of the Powerwall 2.0 and new technology which will ease the retrofitting and installation of storage units, that Australia could install as many as 20,000 domestic scale units (Morris, 2017). A report from the Clean Energy Council (2018) using figures from SunWiz stated that the number of installations (as at the end of 2017) stood at 28,000 with 12 per cent of new PV installations in 2017 also incorporating storage, up from 5 per cent the previous year.

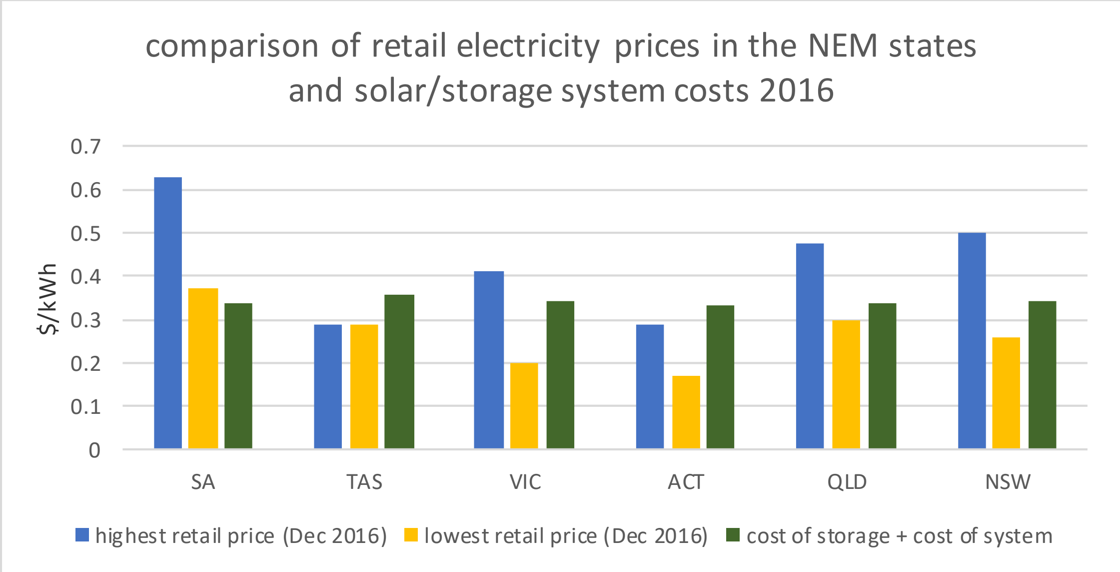

Figure 4-6 Cost of a solar/storage system (based on Powerwall 2.0 cost) assuming a lifespan of 10 years for both (after 10 years costs drop to $0), costs for PV taken from solar choice.net.au and solar resource and household electricity use for each of the capital cities calculated for each of the NEM states. No allowance has been made for FiT payments to give an idea of the economics of disconnecting from the grid (source: author)

4.8 Consumers push for more control over their energy requirements

Energy Consumers Australia (ECA), a government body representing consumers in the National Energy Market (NEM) run a biennial Consumer Sentiment Survey (Essential Research, 2017). In 2017 findings included (compared with the previous survey in 2016):

- A reduction in the satisfaction with value for money of electricity, with the decrease in the ACT at 11% and in Victoria at 11%.
- A reduction in the satisfaction of reliability across all energy markets.
- A reduction in the level of competition
- Only 21% of consumers had confidence that the energy market was working in their interests.

ECA also noted that very few customers were switching between energy companies. Reasons given for this was the huge array of deals available, with a range of discounts and different rates for paying on time or if you have solar etc. The confusion still occurred when using government comparison websites, which could return up to 20 different energy deals.

'So many, impossible to understand. I've tried to, various people over the years have tried to extract data from these organisations so they can understand bills and so on. It is deliberately complicated.'

Interview C3 NGO

'Yes, when it takes thirty-four steps to go through the Victorian Energy Compare website and then you're presented with. When you have Ron Ben David, when they released their report, their review of the market last year, said 'you shouldn't need a degree in physics to choose the best energy plan for you'. When he says, 'I couldn't work out what my best plan was'.'

Interview M7 ad

Until July 2018, retailers were able to offer discounts that, once the discount period ended, would cost the customer more than the standing offer price for electricity. Some of the discounts were criticised as they ended if the customer was late paying a bill, so effectively creating a high late-payment fee.

'I think the major thing that drives us, that we think is ridiculous is the way in which the contracts have these discounts. Marketed with discounts that last for a year, then disengage it and then fall-off and then they are applying a loyalty tax. The discounts themselves are all conditional on paying on time. So effectively it is a 30-40% late payment fee if you are a week late, or a day late.'

Interview M7 ad

The confusion of rates, and a lack of trust in energy retailers and the energy market, has driven some households to install PV as a method of controlling both the cost of energy and to give them a feeling of energy independence.

'…..it is also getting into everyone's head that solar on your roof is cheaper and I think there is also, at the household level, there is a kind of emotional thing about a desire to be more independent, to get off the grid, not many people actually get off the grid, the notion that you are a bit more independent..'

Interview M4 NGO

'And there is this perfect storm that energy providers are to blame a little, that the market has become so complex, and mainstream energy has become so expensive and has become such a pressure point now for people, that people are trying to gain some kind of control over their energy costs and so the solar industry plays very well into that.'

Interview M7 ad

Surveys conducted by the NSW government into the current uptake of storage also noted customer control as an increasing focus for installing batteries.

> *'What we were researching for the guide, was that more people were interested in it because of a sense of independence, or taking control of their energy use, as tariffs change and because it feels like a tangible way to use something you've generated yourself. It's largely being considered by people with solar panels and so it is being seen as the natural next step, and that independence was really coming through a lot.'*
>
> Interview S6 Sgov

4.9 FINANCIAL CONSIDERATIONS AS A DRIVER FOR PV INSTALLATION

The primary reasons for the majority of households to install DER are to reduce bills and manage future electricity price rises (Bondio et al., 2018) (Figure 4-7). Environmental concerns are a motivation, but financial considerations are a top priority (ibid.). The rising costs of electricity, and the idea of taking control of your energy needs, particularly benefits those households who are asset rich and cash poor (Hannam, 2019). This allows households, such as retirees and middle-income families, to raise the capital needed to install a system whilst reducing their monthly cash expenditure.

> *'So, a lot of pensioners are asset rich and income poor and get a concession which probably overcompensates them. So a lot of them have, one of the great theories for PV in areas has actually been in retirees where they get to get rid of some of their capital so that then helps them, not reduce their pension, but it permanently reduces their bills so they get a double benefit. And then they get a concession on a bill that they don't have to pay, they are not paying any money on.'*
>
> Interview A2 ad

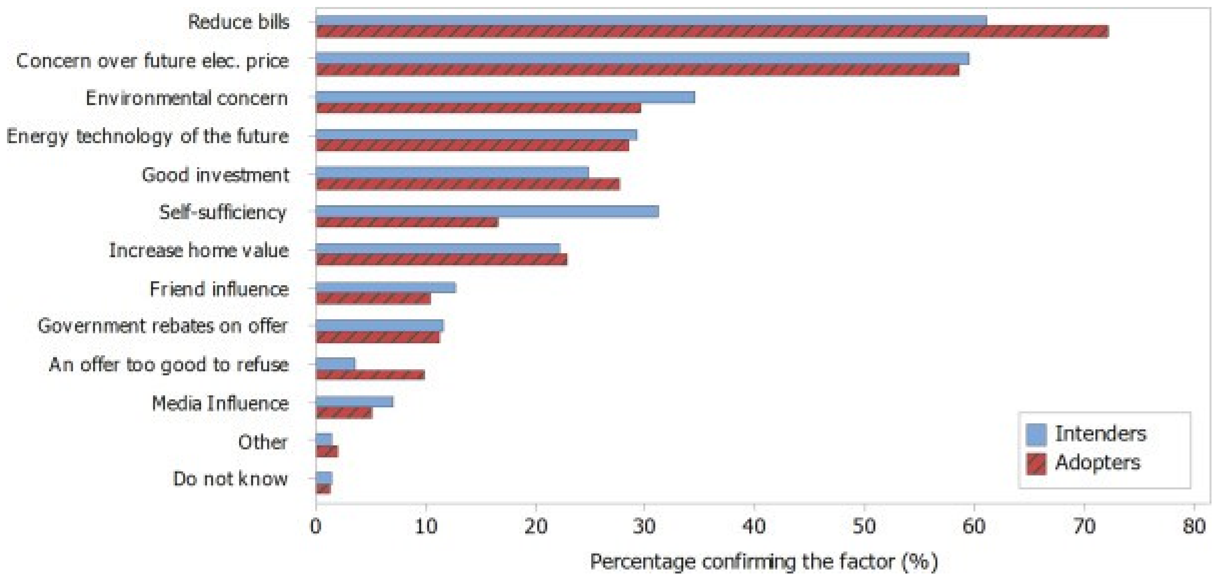

Figure 4-7 Motivational factors for adoption of PV in Queensland households 2014 and 2015 (Source: Bondio *et al.*, 2018)

The need to provide financial stability has seen an increase in the number of larger systems being installed, particularly in the 10-100kW range. This rise has been attributed to business and small commercial premises installing solar and, in some cases, battery storage, to reduce the price volatility of their energy bills (Figure 4-5) (Diss, 2017; Roberts et al., 2018).

> *'Originally it grew with very generous FiTs but those have all disappeared basically and it stands on its own two feet as an investment now. What is happening now, is that the business and commercial customers, it is becoming cost-effective for them to put in solar. So, there has been a huge rise, the strongest growing sector now is the 50kW-2MW.'*
>
> Interview A8 NEM in

4.10 Discussion

The combination of rising electricity prices, reliability concerns, consumers' confidence in the energy market at an all-time low, and the favourable economics of owning PV and storage, has seen a rapid uptake of DER in Australia. The speed of the uptake was unexpected and driven by a combination of predictable (e.g. tariffs scheme) and unpredictable events (e.g. falling costs and climatic events), leading to consequences in other parts of the system (discussed further in Chapter 7). The initial rise was in part due to the generous FiT scheme, but the falling costs of DER technologies and the low installation costs have created a market for DER that is now competitive with grid-supplied electricity, even without any government subsidy.

The favourable economics of PV in Australia helped contribute to the record installations throughout 2017 and 2018. The size of PV systems has also increased with the average system now 6.9kW due to an increase in the small business and commercial market (Figure 4-5) (AEC, 2019).

By the end of 2017, the Clean Energy Council (CEC, 2018), using data from SunWiz, reported that 28,000 battery storage systems had been installed. SunWiz estimated that 42% of this figure was in NSW, with NSW in the same period installing more rooftop solar per month than the other State (Parkinson, 2018a). To complement households existing PV generation, some States have announced plans to subsidise battery storage and estimates from the Clean Energy Council have suggested that by the end of 2019 there could be 70,000 household battery systems in Australia, accounting for 30% of the global household battery market (Clean Energy Council, 2019).

In 2019, small scale PV (systems under 100 kW), split into two categories have an installed capacity of:

- commercial systems (10-100kW) - 1611MW
- residential systems (under 10kW) - 6863.7MW (APVI, 2019b).

In 2019, renewable generation accounted for 21% of electricity generation in Australia, with 4.5% attributed to small scale (<100kW) solar PV (Clean Energy Council, 2019). Due to the lack of trust in energy companies and the need to control against possible future energy price rises, combined with the falling costs of owning DER, it can be expected that this trend, especially within the business and commercial sector, will continue. However, as will be discussed further in Chapters 7 through to 9 and has been noted in Chapter 1, trust in the energy industry will be essential if the uptake of solar and storage is to benefit *all* energy users.

Chapter 2 discussed that the introduction of new objects into a complex system, such as those described in this chapter, may create emergent or disruptive consequences that may affect the system's desired function. SET suggests that adaptive capacity is needed either within the system to manage a transition while maintaining the current desired function, or within system governance to manage a transformation to a new desired state. Government energy policy decides the desired function of the system, and the innovation capability within the system processes enables the adaptiveness of the system to react to these emergent or disruptive consequences. By following how NEM governance managed the repercussions of this unexpected event within its system processes, lessons can be learnt for how to manage a transition or transformation and to identify possible challenges that may occur in similar systems. Therefore, it is important to understand the desired function of the NEM and if/how political, economic, technical and social innovation managed the introduction of DER, and whether a transition or transformation has occurred.

4.11 Conclusion

Australia's initial FiT policy hoped to see 15MW of solar PV installed but, due to a combination of expected and unexpected synergistic events, the adoption rates were far more dramatic. The consequential effects of a rapidly expanding PV market saw a reduction in installation costs, and a competitive market created for the storage industry, further reducing the price of a household DER system. Costs are now so competitive that owning PV, and also battery storage, has reached grid parity in some localities encouraging the traditional consumer of electricity to 'take control' of their energy use. Although this can be seen as a success, in that Australia far surpassed the original intention of their policies for small-scale PV, the unexpected rapid uptake within the distributed area of the system has caused challenges within the NEM. These challenges are due, in part, to the current centralised governance structure (discussed in Chapter 5) and the influence of the coal industry on national energy policy (discussed in Chapter 6). How these challenges have affected the technical, economic, social and political parameters of the NEM is discussed further in Chapter 7 and the lessons learnt for other energy systems, discussed in Chapter 8.

5. THE AUSTRALIAN ENERGY SYSTEM AND ITS GOVERNANCE

Australia's energy systems underwent a series of reforms from the 1990s to the present time (Energy Reform Implementation Group, 2007; Hilmer et al., 1993; Parer, 2002) which have culminated in a governance structure designed to maximise the economic and operational efficiency of a centralised energy system. Further reviews (Finkel et al., 2017) have suggested new measures for reliability, security and emissions reduction in the National Electricity Market (NEM).

This chapter will chart the energy market reforms which have led to the current centralised system structure and governance and introduce the current institutions within the NEM. During the energy reforms some energy assets, in some States, remained under State ownership. This chapter will show the importance of these assets to State governments and discuss how these vested interests within electricity supply have caused energy prices to be higher than anticipated.

Multiple institutions are introduced within this chapter. For ease of identification, current institutions, and their responsibilities, have been highlighted in bold within the main text (Table 5-1 provides a summary of the institutions). A figure showing the current governance structure is available on page 92.

Table 5-1 Reference table for the current institutions operating in the NEM

Current Institution	Responsibility
COAG – Council of Australian Governments	National policy
AEMC – Australian Energy Market Commission	Rulemaking, reviews and market developments
AER – Australian Energy Regulator	Economic regulator for retail (except Victoria), transmission and distribution

AEMO – Australian Energy Market Operator	Electricity and gas system operator and transmission planner
COAG Energy Council	National energy policy
ECA – Energy Consumers Australia	Consumer advocacy
ESB – Energy Security Board	To oversee the implementation of the Finkel Review and single point of contact between the NEM and the COAG Energy Council

5.1 Electricity Market Reform

To understand the current structure of the NEM, it is necessary to look at the history of energy reform that happened within the region and began with the establishment of the **Council of Australian Governments (COAG)** in 1991. COAG members are the Prime Minister, State and Territory Premiers and Chief Ministers, and the President of the Australian Local Government Association.

In the 1990s, Australia's energy market reforms followed a time of free-market ideas that was happening both internationally and in Australia in the 1970s and early '80s, with COAG's role to drive microeconomic reform in the energy, communications, transport and water industries (AEMC, 2014). Part of this drive was to conduct a review of energy and competition policy with, in the case of the electricity industry, the facility to encourage greater connection between the states.

In 1991, the Industry Commission, in their *Energy Generation and Distribution* report (Industry Commission, 1991), found that improvements could be made to the electricity supply industry which could potentially yield a 1.25% increase in GDP. It recommended restructuring the industry from the numerous vertically integrated state-owned corporations and enhancement and extension of the interconnected systems (AEMC, 2014).

5.1.1 The Hilmer Review

In 1993, the Hilmer *Review of National Competition Policy* (Hilmer et al., 1993) suggested that to encourage competition, and be able to progress using Codes of Conduct into a new privatised era, government-owned monopoly companies should be restructured.

The reform process started as a State-based process, with each State responsible for restructuring, trialling a competitive market and providing an economic and technical regulator. Each State would follow common guidelines regarding retail, distribution, transmission and generation. The State market trials were gradually transitioned between 1991-97 to become the National Electricity Market (NEM) of the eastern States of Australia i.e. Queensland (QLD), New South Wales (NSW), the Australian Capital Territory (ACT), Victoria (VIC), South Australia (SA) and Tasmania (TAS).

In 1996, after consultation with industry, a National Electricity Code was passed (superseded in 2005 by the National Electricity Rules), which contained the market rules, to facilitate the move to the NEM. The code was contained within the National Electricity Law (NEL), which defined the statutory powers and the legal framework of the NEM, contained in a Schedule to the National Electricity (South Australia) Act 1996. Any future changes to the legal framework must be passed in South Australia first before becoming law in the other States.

As part of the new statute, two national bodies were formed - the National Electricity Code Administrator (NECA), whose functions were to monitor and enforce compliance of the code and to establish procedures and rule changes, and the National Electricity Market Management Company (NEMMCO), whose two principal roles were power systems operation and planning, and market operation and development. This was followed in 1998 by the commencement of the NEM in each of the member states (Queensland (QLD), New South Wales (NSW), the Australian Capital Territory (ACT), Victoria (VIC) and South Australia (SA), (Tasmania (TAS) joined the NEM in 2005 following the establishment of the BassLink interconnector)).

In 2001, COAG established the Ministerial Council on Energy (MCE) to oversee national energy policy to include convergence issues and environmental impacts. COAG also recognized the NEM Ministers Forum (NEMMF) comprising Ministers from the NEM states which provided policy and governance responsibilities for the NEM. During this time, COAG sought an independent review on the NEM, as there had been some criticism of the market. Some States, in particular SA, found generators having increased market power and an increase of network asset values (due to wrongly perceived future capacity and also regulated interconnectors not facing market incentives) causing a sharp rise in electricity prices (Parer 2002). This culminated in 2002 with the *Parer Review - Towards a Truly National and Efficient Energy Market* (Parer, 2002).

5.1.2 The Parer Review

The Parer Review found that, although there had been positive outcomes regarding (i) integration of markets, (ii) investment and productivity and (iii) security and reliability of supply, there were overlaps and confusion within governance and regulation. Parer (2002), recommended that new, separate, governance institutions be established for regulation and rules and the oversight of the NEM. There were also concerns regarding the gross pool market, transmission, financial contract market and issues with demand-side participation. It was also felt that carbon reduction measures were inadequate and confused, and recommended an economy-wide emissions trading scheme (ETS), with current schemes to be replaced by this ETS, but with intensive energy users excluded until all Australia's competitors introduced similar schemes, however the ETS was never introduced.

In 2003, the MCE provided a report to COAG - the Reform of Energy Markets, as a second phase of the market reform process that led to the Australian Energy Market Agreement (AEMA). Under this agreement, in 2004 there was a transition to a new governance and regulation regime. The NEMMF was to be absorbed into the MCE, with the MCE assuming their electricity market policy role. The **Australian Energy Market Commission (AEMC)** (under State law[8]) was established. They were to be accountable to the MCE, and to replace and take responsibility for, the functions previously performed by NECA, with core functions to **be rulemaking (code changes) and to undertake reviews and market developments**. It would have no

[8] *Australian Energy Market Commission Establishment Act 2004* (SA).

regulatory function, as the newly formed **Australian Energy Regulator (AER)** would now undertake this role (under Commonwealth law[9]).

The **AER** would now have responsibility for the **economic regulation of the electricity wholesale market and transmission networks** and key rule enforcement functions. Under the new National Electricity Law (NEL) and National Electricity Code (NEC), the AER would **undertake the electricity (and later gas) regulatory roles** from the Australian Competition and Consumer Commission (ACCC) (remaining a constituent part of the ACCC whilst operating as a separate legal entity), and that previously undertaken by NECA. The AER function was to **regulate prices for the transmission networks, reviewed on a five-year basis, to ensure that network expenditure satisfied one of two conditions, either that which would be deemed necessary to ensure reliability standards or to maximise the economic benefits to producers and consumers of the NEM**, out of all feasible options identified (ACIL Tasman 2010). NEMMCO would remain responsible for the operation and administration of the power system and the electricity wholesale spot market of the NEM.

For electricity transmission, new planning functions were developed to include an Annual National Transmission Statement (ANTS), regulatory tests including the economic benefits of increased competition, regulatory tests for assessing wholesale market boundaries and market-based incentives for transmission performance. There was also a call for options for a demand-side response pool within the NEM and a cost-benefit analysis to

- '*Encourage efficient provision of reliable, competitively priced energy services to Australians, underpinning wealth and job creation and improved quality of life, taking into account the needs of regional, rural and remote areas;*
- *Encourage responsible development of Australia's energy resources, technology and expertise, their efficient use by industries and households and their exploitation in export markets; and*

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[9] *Trade Practices Amendment (Australian Energy Market) Act* 2004 (The *Trade Practices Act 1974* (Cth) has been replaced by the *Competition and Consumer Act 2010* (Cth)).

- *Mitigate local and global environmental impacts, notably greenhouse impacts, of energy production, transformation, supply and use'* (Ministerial Council on Energy, 2003).

Demand-side response was finally introduced in 2018, as a Demand Management Incentive Scheme (DMIS) (this is described in more detail in Section 5.1.4).

5.1.3 The Energy Reform Implementation Group

In 2007, the Energy Reform Implementation Group (ERIG), established by the COAG Energy Council to recommend further reforms to the energy industry, presented its final report to COAG - *Energy Reform, the way forward for Australia* (Energy Reform Implementation Group 2007). It found that there were three main threats to competition i.e. (i) barriers to market entry, (ii) governance inadequacies and (iii) regulatory inadequacies. ERIG suggested that these threats would hinder the economic success within the national energy industry. Following this review, in 2008 the **AER** also became the **economic regulator of electricity distribution networks** in the NEM and regulated the 11 covered distribution networks.

The following year it then also took responsibility for retail functions within the NEM to include:

- gatekeeper for authorisation and exemptions
- publishing standing tariffs
- undertaking monitoring and enforcement in the areas of: customer financial hardship, compliance with terms of regulated contracts and rules, marketing conduct, issue guidance to market participants on the application of the new framework and the AER's enforcement strategy (AER 2008).

In 2009, the **Australian Energy Market Operator (AEMO) took on the role previously undertaken by NEMMCO and also became the gas market system operator in NSW, ACT, QLD, VIC and SA**. Part of its function as operator was also as **transmission network planner** (TNP) with regulation for the TNSP's by the AER and to **publish an annual National Transmission Network Development Plan**

(NTNDP) (to replace the ANTS) which would **include future development strategies for the networks**.

In 2011, the National Energy Customer Framework (NECF) was formally established which contained the new National Energy Retail Law (NERL), the National Energy Retail Regulations and the National Energy Retail Rules. This new legislation was to be passed nationally to replace state- and territory-based energy retail laws to harmonise protective legislation and reduce operating costs for the energy businesses operating across different states, and from 2012 regulated by the AER. Currently, four of the country's States and Territories have adopted the NECF (ACT, SA, QLD and NSW). For the remaining State's (VIC, TAS, NT, WA), of which VIC and TAS are the only NEM States, energy retail continues to be regulated by the State regulator.

As part of COAG's streamlining initiatives, it merged the MCE with the Ministerial Council on Minerals and Petroleum Resources (MCMPR) to become the Standing Council on Energy and Resources (SCER) with the MCE's responsibilities for energy efficiency moved to the Select Council on Climate Change (SCCC). In 2013, these two national bodies were merged to better integrate energy and climate policies and became the **COAG Energy Council**.

In 2015, **Energy Consumers Australia (ECA)** was established as a non-for-profit advocacy set up by the COAG Energy Council and funded through AEMO **to represent the long-term interests of residential and small businesses customers within the NEM**. It also **provides advice on energy issues to consumers and represents their views to the Council**. They work in conjunction with stakeholders from the energy industry, energy ombudsman, government and market bodies, the research community and media (ECA, 2016). The current governance structure of the NEM is depicted in Figure 5-1.

5.1.4 The Finkel Review

Following a blackout of SA's power system in September 2016 (as discussed in Section 4.6) the federal government undertook a review of the governance of the NEM. The review was undertaken by the Office of Australia's Chief Scientist – Dr Alan Finkel. The review - An Independent Review into the Future Security of the

National Electricity Market: Blueprint for the Future (Finkel et al., 2017) - made recommendations on the themes of:

- **increased energy security within the NEM** for increased penetration of variable renewable resources, including valuing frequency response, synthetic inertia, demand response and voltage control, and also cybersecurity due to the increase of IT services within the system;
- **policy stability** with recommendations for a long-ranging Clean Energy Target (CET) which would see certificates issued for all types of generation, with more certificates issued for the least polluting technologies;
- **efficiency within the gas markets** to ensure that electricity generators can maintain reliability of supply
- **improved system planning** to include a transmission and distribution plan to recognize areas of future economically viable VRE penetration, also a review of regulation to remove the incentives for networks to prioritise over non-network solutions
- **rewarding consumers** including the facilitation of a DER market and a change in role for the distribution networks to provide a platform for new technologies
- **stronger governance** to include the establishment of an **Energy Security Board (ESB**) **to oversee the implementation of the plan and to be a single point of responsibility and accountability between market institutions and the Energy Council**. This area will also review the rule-change process to accommodate the rapidly changing energy market.

In total there were 50 recommendations contained within the main points above. In July 2017, the review was presented to the COAG Energy Council for approval and 49 out of the 50 recommendations were approved. The council concluded that the CET would need further consideration. The **ESB** was appointed in September 2017 and consists of the CEO from each of the AEMC, the AER and AEMO and an independent Chair and Deputy Chair. At the end of 2017, the ESB announced plans for a National Energy Guarantee (NEG) instead of the recommended CET. The plans have now been dismissed and there is currently no national energy policy in place for large scale renewable generation post-2020, or for any emissions reduction.

In 2017, the AER announced its Demand Management Incentive Scheme (DMIS) and innovation allowance mechanism for distribution network service providers (DNSP). The scheme would incentivise the DNSP to deliver non-network solutions that would lead to savings for retail customers and open competitive markets for new business models such as DER aggregators (AER, 2017). The innovation allowance mechanism would be a fund for innovative projects based on demand management and efficiency.

AEMO published its first Integrated System Plan (ISP) in 2018 (AEMO, 2018a). The ISP identified (i) areas of transmission investment to include the scoping of an interconnector between SA and NSW; (ii) renewable energy zones (REZ) which had transmission capacity available and also that may require transmission upgrades; (iii) the value of DER to the NEM and to electricity customers; (iv) power system requirements for a grid that had increased renewable penetration and (v) short-, medium- and long-term developments required to enhance the NEM for the transition to renewable generation.

In 2019, a new steering group - the Distributed Energy Integration Program (DEIP) - was initiated (ARENA, 2019a). The DEIP brings together industry and organisations involved in the energy system and clean energy transitions. Following the rise in DER in Australia, the group seeks to deliver a program aimed at maximising the benefits that DER could deliver, through the use of a Steering Group, workshops and collaborative forums.

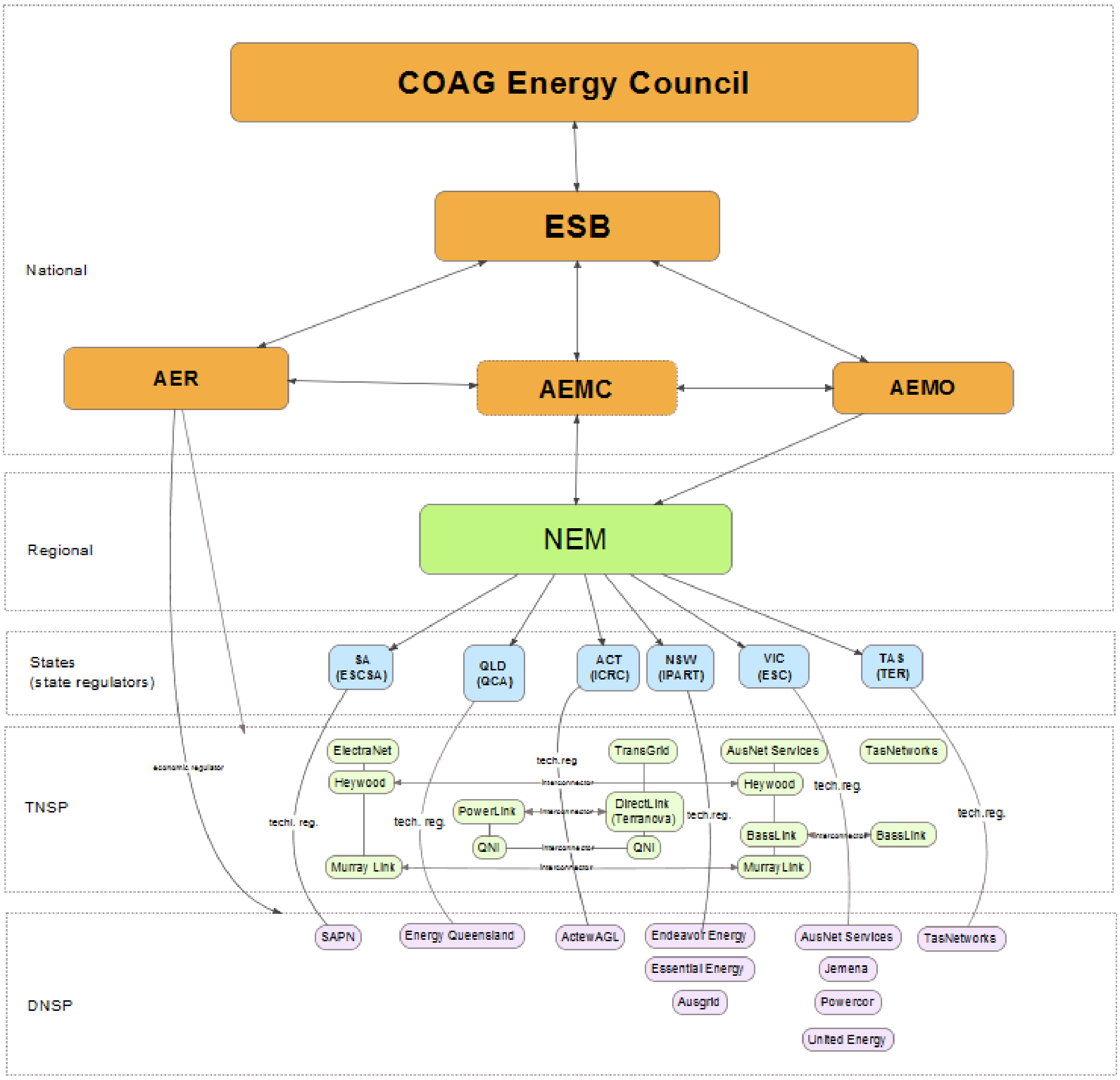


Figure 5-1 Electricity network governance structure of the NEM in eastern Australia showing national, regional and local governance. The arrows indicate channels of communication and responsibility. (Source: Author)

5.2 The National Electricity Market

The NEM is now a transmission and distribution grid covering 5 interconnected state-based networks (SA, TAS, VIC, NSW (including the ACT) and QLD), covering a distance of approximately 5,000 km, regulated by the AER, with the energy market operated by AEMO under the rules created by the AEMC. AEMO operates an energy-only gross pool market with 5-minute spot prices averaged for half-hourly periods in each of the six states. Bids are taken for each of the six trading intervals and the averaged spot price is received by all generators dispatched in the trading interval. A recent rule change, which will take effect in 2021, is to reduce the settlement period from thirty minutes to five minutes to provide a better signal for investment into the market for new technologies and business models, such as batteries and demand response (AEMC, 2017). It has been suggested that this change will also reduce the 'gaming' of the half-hourly settlement by gas peaking generators and should, therefore, reduce prices (McConnell and Sandiford, 2016; Parkinson, 2016). Risks in price volatility are reduced using hedges, options and futures contracts (AEMO, 2016(c)).

5.2.1 Supply networks

Ownership of transmission and distribution assets within the NEM is shared between private and state actors (Table 5-2). Queensland's transmission and distribution assets are state-owned, New South Wales still has part ownership of two of the three distribution businesses and Tasmania's transmission and distribution is state-owned.

Table 5-2 NEM States network ownership and regulatory roles (AER, 2013)

	QLD	NSW	ACT	VIC	SA	TAS
Transmission	PowerLink (public)	TransGrid (private)	TransGrid (private)	AusNet Services (private)	ElectraNet (private)	TasNetworks (public)
Distribution	Energy Queensland (public)	Endeavor Energy (50.4% private, 49.6% public) Essential Energy (public) Ausgrid (50.4% private, 49.6% public)	Actew AGL (private)	AusNet Services (private) Jemena (private) Powercor (private) United Energy (private)	SAPN (private)	TasNetworks (public)
State regulator	Queensland Competition Authority (QCA)	Independent pricing and Regulatory Tribunal (IPART)	Independent Competition and Regulatory Commission (ICRC)	Essential Services Commission (ESC)	Essential Services Commission of South Australia (ESCOSA)	Tasmanian Economic Regulator (TER)
State regulatory responsibilities (energy)	Solar FiT rate (regional Queensland only) Administration and monitoring of supply licences network safety and reliability standards	Solar FiT guidance Administration and monitoring of supply licences network safety and reliability standards	Solar FiT guidance Administration and monitoring of supply licences network safety and reliability standards	Retail pricing Solar FiT rate Administration and monitoring of supply licences network safety and reliability standards	Solar FiT guidance Administration and monitoring of supply licences network safety and reliability standards	Retail pricing Solar FiT rate Administration and monitoring of supply licences network safety and reliability standards

Regulation for energy supply (generation, distribution, transmission and retail) is primarily the responsibility of the AER. However, the state regulators still have a responsibility in ensuring compliance with the codes, rules and licensing agreements and setting network reliability and safety standards. State regulators are also responsible for either setting a mandatory FiT for solar or recommending a guide FiT for the energy retailers. Victoria's Essential Services Commission and the Tasmanian Economic Regulator still regulate retail pricing due to not joining the NECF (Table 5-2). The regulation period for transmission and distribution is dependent on when the state transferred its regulatory powers from the state regulators to the AER. Currently, there is a misalignment between both transmission and distribution regulatory periods, and also within transmission and distribution, with limited synchronisation of any of the regulatory periods (Table 5-3).

This misalignment between regulatory periods was raised by some, during the interviews for this thesis, as a challenge. As business plans are assessed at different times, this led to difficulties in creating competition between the businesses as the benchmarking process was limited. Also, should changes be required within regulation, this would then apply to different States at different times allowing positive changes to benefit some customers sooner. One interviewee suggested that aligning the distribution and transmission in each state would ease the joint planning that is needed due to changing energy flows on both the transmission and distribution networks.

> *'…we actually thought it made more sense to align the transmission and distribution in a region which could help the interplay when you are involved in joint planning at that level.'*
>
> (A6 tn).

Table 5-3 Regulatory periods for electricity transmission and distribution (AER, 2018a).

State/Territory	Service Provider	Regulatory Control Period	
		Date	Length
Electricity Transmission			
Vic	Ausnet Services	1 Apr 2022 - 30 March 2027	5 yrs
Qld	PowerLink	1 Jul 2022 - 30 Jun 2027	5 yrs
NSW	TransGrid	1 Jul 2023 - 30 Jun 2028	5 yrs
SA	ElectraNet	1 Jul 2018 - 30 Jun 2023	5 yrs
Vic/SA	MurrayLink	1 Jul 2018 - 30 Jun 2023	5 yrs

Tas	TasNetworks	1 Jul 2019 - 20 Jun 2024	5 yrs
NSW/Qld	DirectLink	1 Jul 2020 - 30 Jun 2025	5 yrs
Electricity Distribution			
Vic	CitiPower, Powercor, Jemena, AusNet Services, United Energy	1 Jan 2021 - 31 Dec 2025	5 yrs
Tas	TasNetworks	1 Jul 2019 - 30 Jun 2024	5 yrs
NT	Power and Water	1 Jul 2019 - 30 Jun 2024	5 yrs
NSW	Ausgrid, Endeavor Energy, Essential Energy	1 Jul 2019 - 30 Jun 2024	5 yrs
ACT	Evoenergy	1 Jul 2019 - 30 Jun 2024	5 yrs
Qld/SA	Energex, Ergon Energy, SA Power Networks	1 Jul 2020 - 30 Jun 2025	5 yrs

5.2.2 Vested interests in the NEM

Although the energy industry underwent privatisation, not all energy assets in the NEM are privately owned. The states of NSW, QLD and TAS still have energy assets under public ownership. Tasmania's energy system is fully state-owned. In NSW the government have part-ownership of two of the three distribution businesses. QLD owns the transmission and distribution businesses and 65% of the state's generation capacity. Due to the extreme rural nature of QLD's electricity system, the state government subsidises the rural electricity customers through its government-owned retail business, Ergon Energy (QCA, 2019), which is part of the Ergon Energy Network (Ergon Energy, 2019). This allows rural Queenslanders to pay a regulated retail price (as the prices based on actual costs would be unaffordable). Apart from customers in the south-east of QLD, who can buy electricity supply from a competitive retail market, the only retailer available to QLD customers is Ergon Energy. As well as the economic element, the political element also needs to be considered as revenue from the State-owned energy assets helps to fund State expenditure on education, health and welfare.

> *'So the treasury department in each of these states, massively, are the most powerful in each bureaucracy, will basically look at the Minister in the eye and say, 'Look I understand that we need to improve energy efficiency, or we need to introduce some measures to manage demand, but if you do this minister, we are not going to sell as much electricity, and how are going to fund the hospital you just talked about?'*
>
> Interview C3 NGO

The State governments who still have some ownership of network assets (NSW and QLD) have seen a benefit from increasing network reliability. As discussed in section 4.3.1, increasing reliability allows the State-owned network to invest in assets which increases the value of the regulated asset base, and therefore the regulated return on this investment.

The introduction of the DMIS (Section 5.1.4) for the DNSPs will incentivise the distribution networks to reduce capital expenditure. The reduction in capital expenditure will result in cheaper retail costs for customers but will also reduce the revenue from the regulated rate of return for the publicly owned networks. However, the revenue from the incentive scheme should counteract this loss in revenue, particularly for Queensland, which has a high rate of DER ownership and a majority rural customer base.

Some have argued that the NEM and its current governance structure was world-renowned, but due to the current changes to generation technologies and ownership through a rapid uptake of DER, and the lack of clear national energy policy, the NEM is currently experiencing a deterioration in its operation (Simshauser, 2018).

> *'We have pooled an entire architecture of lawyers, regulators and others around a 1990 model and all this stuff, who does that and why? It does need a refresh.'*
>
> Interview A1 Sreg

The rise of DER has created a need to reform the energy system so that DER can work alongside centralised assets and help to ensure system reliability and security, which would also create benefits for DER owners.

> *'…things have changed, and it is not this very simple business as usual model anymore, so we are not in a steady-state by any definition. So, decision making, this very rigid decision-making process, trying to deal with this very volatile industry'*
>
> Interview M9 Sreg

The Finkel review, following the system black event, suggested that the NEM would need further reform to ensure the reliability and security of the energy system. The introduction of the ESB was seen as a way to bring together the governance institutions to help reach a common goal – that of a reliable, secure electricity system which would benefit customers and allow the inclusion of new, clean technologies, but there has been resistance to the reforms due, in part, to incumbent interests within the current institutions.

> *'…the view that within the institutions, the role of the different institutions, the one which is the big obstacle is the Energy Market Commission and one person in particular, the chair, the chief executive who designed the original scheme.'*
>
> Interview C5 ac

The political and economic interests of the States have led to difficulties with legislative changes within the NEM. Any changes to legislation have to be agreed upon by the COAG Energy Council. The membership of the council includes ministerial representatives from the national and State governments. This has led to State politics becoming linked to energy legislation and the vested interests of some States slowing the legislative changes needed for a rapidly changing system.

> *'So, you have got this whole national framework with State ministers still thinking they are responsible and so intervening in various ways. So this very rigid system, operating on a very volatile market, then the political context which was meant to enable that rigid system, is not enabling it in the way that was envisaged 10 or 12 or 15 years ago when all of this was being set up.'*
>
> Interview M9 Sreg

The vested interests and incumbency within energy (Lockwood et al., 2017; Lowes et al., 2017), and as seen within the NEM, makes change difficult. The difficulty comes from the fact that unless there is a change to the rules and regulations within the system – how the companies make a profit – then there is no need for the incumbents to do anything differently (Mitchell, 2008). Changing the way these actors operate will require leadership from government, but vested interests within some of the State governments have slowed the rule-change process in a period when rapid change is needed.

> *'But sometimes things get very slow because they have to get signed off by all the state ministers and the federal minister and if a couple of them disagree then it doesn't get through and that can slow things down enormously. Particularly since, you have even got on top of that, you have got other issues like some States own most of the electricity system, where in other States it has been privatised. So there will be different interests at play dependent on if the government is the major shareholder or if they are the regulator.'*

Interview M4 NGO

The vested interests of State governments in other areas of the energy system have also led to differing State renewable energy targets (RET), and this is discussed further in section 6.4.4.

5.3 Discussion

The culmination of the Hilmer, Parer and ERIG reviews, shows the evolution of the NEM from State-based electricity grids, markets and regulation, to the current top-down, centralised governance structure (Figure 5-1) designed to maximise the economic and operational efficiency of the electricity system. Although the Hilmer review also attempted to introduce decarbonisation through a Clean Energy Target, the current desired function of the NEM does not include decarbonisation within its remit (AEMC, 2019a) but concentrates solely on reliability and affordability. However, national and State energy policy incentivises the use of RE in the energy system, and is discussed in the following chapter.

For energy systems to change from their current, fossil fuel-based, centralised structure to one which is decarbonised and increasingly incorporates decentralised assets, it has been suggested that the governance of the system will also need to change (Mitchell et al., 2016; Stirling, 2014b), and that in order to manage a transformation, this governance would need to be adaptive (Walker et al., 2004). There has been some form of change from the Finkel review, with the creation of the ESB and the implementation of the ISP and DMIS, and the DEIP is a welcome addition and could be seen as a move towards more adaptive processes, as suggested by SET theory (Folke et al., 2005; Hodbod and Adger, 2014; Walker et al., 2004). However, due to the rapid changes that are currently happening at the distributed level of the NEM (see Chapter 4), governance of the NEM is becoming unfit for purpose and more governance changes, such as the DEIP, may be needed, and quickly, to allow for the positive inclusion of DER.

Due to the vested interests of some State governments and the level of incumbency within the NEM institutions, it could be suggested that the NEM is in a state of carbon lock-in, as described by Unruh (2000). While Stirling (2014b) suggests that transformational institutional change is needed to overcome this incumbency, SET suggests principles that allows transformation to occur, moving the system to a new desired state. However, moving to a new desired state e.g. decarbonised, may be difficult to apply when institutions and governments are benefiting from the current system. The lack of a decarbonisation objective for the NEM suggests that the NEM institutions do not see a need to change the desired function of the system, so limiting the transformational and institutional change needed. It may be that the NEM institutions expect that the adaptive capacity within the system is able allow for a transition without the need for major changes to system governance?

5.4 Conclusion

As can be seen from the history of Australia's energy system and the reforms that have happened within the NEM, the energy system is in a state of constant evolution and so the governance surrounding the system needs to reflect this. Unlike the historical transitions discussed in Chapter 2, the current shift to a decentralising system, as described in Chapter 4, is happening much more rapidly, and therefore governance will need to be adaptive to allow for this rapid change.

The Finkel review is an attempt to make further reforms to allow the system to gain the benefits that decentralisation may bring, whilst providing energy security and reliability. The creation of the ESB has allowed the institutions of the NEM to work together towards the Finkel review goals, although there is some incumbent resistance to change. The ISP allows for long term planning, the DMIS is an avenue for new business models to enter the market and the DEIP will allow collaboration and learning for the incorporation of DER. The Finkel review recognises that the energy system is changing, and makes recommendations for new institutions, new regulatory procedures, and new markets, and could be considered a national vision for the NEM. However, by not agreeing on a CET, or any other emissions policy, or having any RET past 2020, there is no urgency on implementing the Finkel recommendations, suggesting that there is limited governmental support towards transformational change, which could be attributed to the incumbency and vested interests within the NEM institutions and state governments.

6. THE COAL INDUSTRY IN AUSTRALIA AND ITS INFLUENCE OVER ENERGY POLICY

The previous chapter introduced the various institutions within the NEM and the duties of these institutions. Within the chapter, it was noted that the COAG Energy Council, which is ultimately responsible for the country's energy policy, is not only concerned with the electricity industry and therefore its decarbonisation agenda, but also with other energy industries, such as petroleum, gas and coal. The chapter also recognised that despite recommendations within two major reviews of the NEM, the Australian federal government is reluctant to introduce any of the suggested emissions reduction policies. This chapter will introduce, and discuss, how coal industry influence within Australian politics has created a form of 'lock-in', as discussed within transition literature (e.g. Folke et al., 2010; Unruh, 2000), and how the federal system of government has allowed some States to partly overcome this lock-in.

Australia was one of the last countries to sign to the Kyoto protocol, not ratifying the agreement until December 2007 (Parliament of Australia, 2010) when there was a change of government from the right-wing Liberal coalition party to the centrist Labor Party, under Kevin Rudd. In 2016, Australia finally ratified the Paris Agreement. Despite Australia ratifying both the Kyoto Protocol and the Paris Agreement, due to their support of the coal industry, the current government has shown reluctance to create any new emissions or renewable energy policy to replace the current Renewable Energy Target, which ends in 2020. The lack of current national climate policy means that Australia may not meet its Paris targets (Climate Action Tracker, 2018; Murphy, 2019b; Blakers *et al.*, 2019; Hare, 2019).

The coal industry's influence over Australia's energy and climate policy can be traced through its role in Australia's social, political and economic history (Baer, 2015; Peel et al., 2014); it's present importance to Australia's GDP as Australia's leading energy export, with 90% of Australia's black coal production exported to the Asian market (Office of the Chief Economist, 2016); and coal being the dominant resource for electricity generation in the NEM (Department of the Environment and Energy, 2018). However, Australia's federal system of government has enabled some States to introduce State renewable energy targets (RETs), counter to the national government's position. This chapter will briefly trace the history of coal in Australia (section 6.1) and how the co-evolution of coal and the energy industry has influenced Australia’s energy policy (section 6.4).

6.1 A BRIEF HISTORY OF COAL IN AUSTRALIA

> ‘*We are coal, we are underpinned by coal exports. The concept of the world moving off coal is a frightening prospect for Australia.* ‘
>
> Interview C3 NGO

The first coal mines were established in New South Wales (NSW) in 1801. Coal mines and timber became the property of the Crown as colonial Britain saw the wealth of coal in the NSW area as an enabler of steam shipping in the global south (Baer, 2015), an important revenue source for Great Britain. Over the following years, the other States established their own government-run coal mining companies and coal became an important resource for shipping, rail and power in the Asian Pacific rim. Promoting further industrialisation, Victoria (VIC) began generating electricity from coal, a policy which was soon copied by NSW, Queensland (QLD) and Western Australia (WA). Following WW2, the mining industry was seen as a way to develop nationally and internationally, and in the 1950-60s Australia opened a new market, exporting coal to Japan (Baer, 2015).

Australia is now one of the world’s largest coal producers (Lucas, 2016) and since the 1970s it has concentrated its efforts on the coal export market (Figure 6-1), principally to Asia.

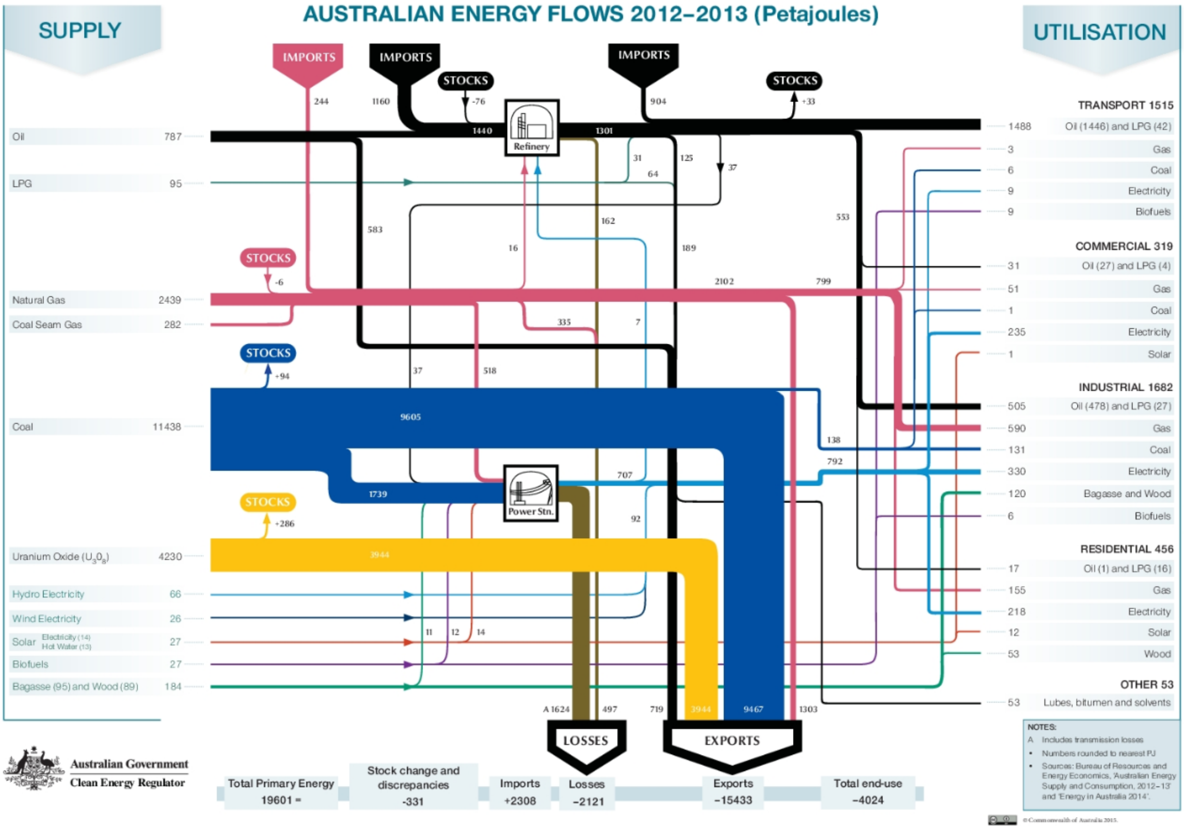


Figure 6-1 Australian energy flows 2013-14. The majority of energy in Australia is exported, primarily coal exports (CER, 2015)

All political parties, at both the federal and State level, have subsidised infrastructure projects, such as electricity generation, ports and harbours to support the coal industry (Baer, 2015; Peel et al., 2014). Government support for the coal industry *had* been unilateral and as one commentator noted (referring to 2007),

> '*There was Marcus Ferguson who was the resources minister for the Labor Party and Ian MacFarlane was the Resources Minster for the Coalition, and basically, they were like best mates in a way. They weren't best mates, but they were. If you just looked at a quote and you said, 'Is that Labor or Liberal?', you could never tell.*'.
>
> Interview C3 NGO

At its peak in 2012, Australia's coal industry employed more than 63,000 people and generated $210 billion in export revenue (Lucas, 2016). Demand grew from markets in China, India, South Korea, Japan and Taiwan for thermal coal for electricity generation and metallurgical coal for the steel industry. Since 2012, global demand for coal has been falling (Lucas, 2016; Sharma, 2019) but Australia is still seeing an increase in its exports (Department of the Environment and Energy, 2018) (Figure

6-2) as demand from the Asia regions continues (IEA, 2018). Some States continued to provide subsidies to increase coal production for the expected rise in exports (Peel et al., 2014).

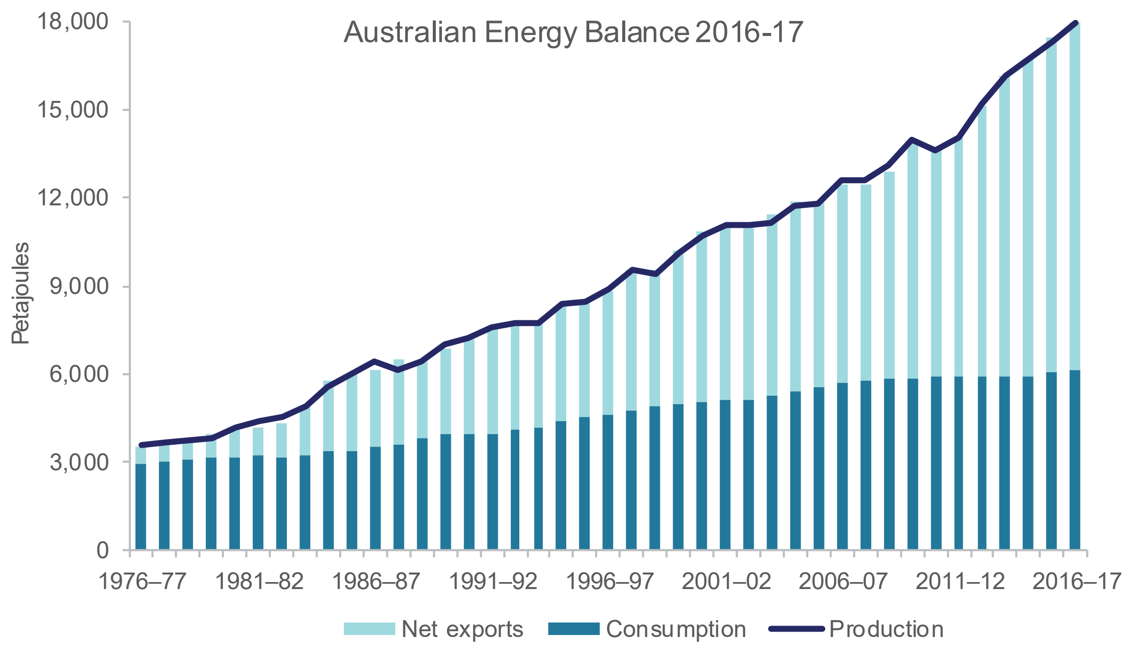


Figure 6-2 Australian Energy Balance, Australian energy statistics, table J (Department of the Environment and Energy, 2018)

6.2 Coal and the States

> '*The coal industry is a massive part of the economy, especially in Queensland, and the election revolves around Queensland, it always does. In the last several elections, whoever wins Queensland, wins.*'
>
> Interview C3 NGO

Australia has a federal system of government and coal remains an important income source for the State governments. The national government sets the general sales tax (GST) and income tax, the revenue from which is then distributed between the States. The State and Territorial governments can gain additional revenue for their treasury from other sources. These sources include mining leases and permits, as well as government-owned energy utilities, such as network businesses and electricity generation (Baer, 2015).

New South Wales and Queensland have the majority of the country's coal mines, with royalties accounting for 10% of government revenue for Queensland (Government of Queensland, 2018) and 90% of all mining royalties in NSW come from coal (Cleary, 2015). The importance of coal to the revenues of State and national government has put the coal industry in Australia in a powerful position.

> *'those big mining and the coal industry and other stuff have got the ears of government. The traditional industries who are really ... they have embedded themselves in terms of donations, when you look at what is going on in America it is the same sort of thing, and it is a vested interest for them'*
>
> Interview C4 ENA

6.3 Coal and electricity generation

The abundant supply of brown and black coal led to coal being the dominant source of fuel for electricity generation in Australia (Department of the Environment and Energy, 2019). Australia has one of the highest per capita emissions profiles due to the carbon intensity of its energy system (Lucas, 2016). In 2014-15, 63% of Australia's electricity generation in the NEM was provided by coal (Office of the Chief Economist, 2016). In 2018, this had risen to 67% (Department of the Environment and Energy, 2019) despite the closure of a major coal generator in Victoria and Australia's commitment to meet the decarbonisation targets of the Kyoto Protocol and the Paris Agreement.

Generation sources for each state are made up mostly of coal and/or gas, except for Tasmania whose primary source of electrical power comes from hydro (Figure 6-3). In Queensland, the state owns almost 50% of the coal generation assets (Queensland Government, 2019).

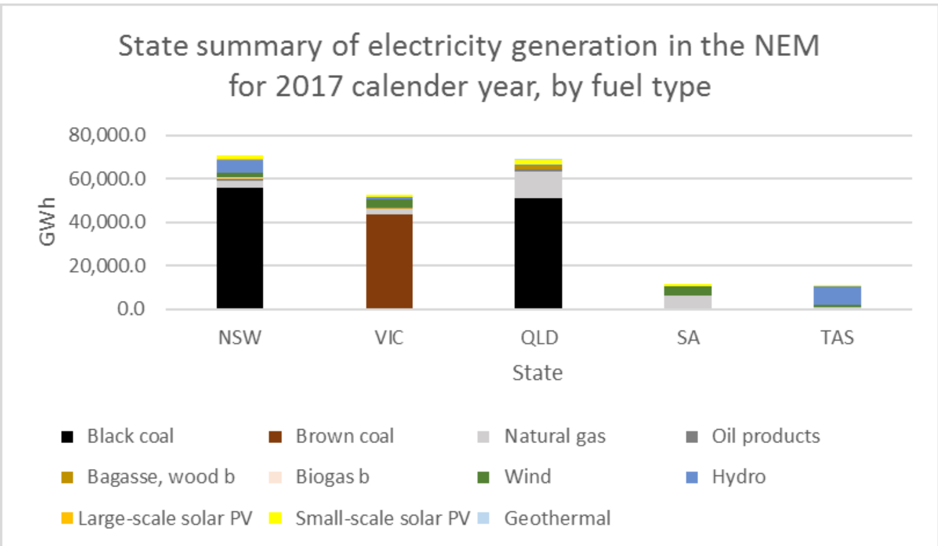


Figure 6-3 Electricity generation by fuel type, and by state and territory, 2016-17 (Department of the Environment and Energy, 2018)

In contradiction to the need to phase out coal by 2050 (IPCC, 2018), the national government are promoting coal power plants as a means to provide security and reliability to the Australian energy system (Liberal Party of Australia, 2019a) as a source of baseload power generation, and its ability to provide inertia (see section 7.1.3).

Although cheap as a fuel stock in Australia, the falling costs of solar, wind and battery storage (Johnston et al., 2014; Lazard, 2018) has meant that renewable technologies are now economically competitive with new-build coal plants. The growth of renewable generation in Australia, and government policy towards new-build coal, has caused controversy within the industry. AGL, one of Australia's largest 'gentailers' (retailers who also own generation assets), is due to close its Liddell coal power plant in 2025. Rather than replace Liddell with a new coal power plant, AGL recommended replacing the capacity shortfall by using renewable and dispatchable technologies, such as renewable generation (e.g. solar or wind), batteries and modular gas generators (see Dunstan et al., 2017). AGL stated that it would be uneconomical for them to continue operating Liddell and that coal plants are the wrong technology for the changing energy system, yet the present government are attempting to broker an arrangement with AGL to keep the plant open past the decommissioning date (Yaxley and Lowery, 2017).

> *'So we made the decision to close Liddell for a couple of reasons, the first is the carbon risk, and the second is as power plants get towards the 50 year age thing they need to be shut down because they are less reliable, but also it is the wrong technology for the changing market. So, in Australia, you have got more non-firm or variable renewables coming in. You have got a reduction in energy demand, but you have got capacity demand still being quite robust if not increasing. So, by definition, that means the type of plant you want in the market is quick-start, flexible, dispatchable, not a baseload coal-fired power station.'*
>
> Interview S3 in

The expected continued use of coal for electricity generation from the Asia region (IEA, 2018) has led the Queensland government to negotiate with the Adani coal mining company about underwriting a controversial new coal mine in the Galilee Basin to de-risk the investment (#StopAdani, 2019; Murphy, 2019b; Slezak, 2017; West, 2017). However, other private major and minor coal mining producers have been postponing expansion plans due to (i) the reduction in the global coal export price, (ii) the uncertainty of the overseas markets, (iii) environmental sustainability and climate concerns, and (iv) the economic viability of coal versus renewable generation (Cleary, 2015; EIA, 2019; Lucas, 2016). Increasingly, even as state governments have continued subsidising the coal industry ($17.6 billion between 2008-14 (Peel et al., 2014)), the threat of stranded assets is becoming an increasingly real prospect (Lucas, 2016). Yet, despite the uncertainty of the future of coal in a global context, the energy and climate policies of the federal government, and some States, still reflect support for the country's coal industry.

This section has shown that Australia continues to support the coal industry despite ratifying the Paris Agreement and the uncertainty of the overseas export market. Although burning coal for electricity generation is one of the principal causes of climate change, the importance of coal to the revenues of both the National and State governments has caused ambiguity in the support for renewable energy in Australia, dependent on the political leanings of the serving government at both national and State level. This will be discussed further in the next section.

6.4 AUSTRALIA'S RENEWABLE ENERGY POLICY

6.4.1 The Renewable Energy Target

Although not ratifying the Kyoto protocol in 1996, in 1997 Australia's Liberal-National Coalition government, under the leadership of John Howard announced a Mandatory Renewable Energy Target (MRET) in their statement '*Safeguarding the Future: Australia's response to Climate Change'* (Howard, 1997). The MRET stated that retailers would be expected to source an extra 2% of electricity generation from renewable sources by 2010, an additional 9,500 GWh above the 1997 baseline. This is in comparison to the European Union, which at the same time had set itself a target of 12% of energy consumption to be met by renewable sources by 2010 (EUR-Lex, 2007). In 2000, the Renewable Energy Target (RET) under the Renewable Energy (Electricity) Act 2000 was passed. The Act commenced in January 2001 and was to run until 2021. The Act applied a certificate trading scheme to encourage new entrants of clean generation into the market. The scheme required electricity retailers to surrender a certain number of certificates per year. Each certificate is equivalent to 1MWh of renewable energy generation (CER, 2016).

The MRET target was achieved in 2006, but the Howard Government made no announcements to increase the target. Following this stagnation, the states of Victoria (VIC), South Australia (SA) and New South Wales (NSW) voluntarily committed to State renewable energy generation targets with VIC – 10% by 2016, SA– 20% by 2020 and NSW – 10% by 2010. In 2009, the new Labor Government, led by Kevin Rudd, announced an increase to the MRET to 20% of total generation, or 41,000 GWh, now to end in 2020. The improved MRET scheme also extended the certificate scheme to include domestic renewables.

In 2011, the MRET was split into two parts. The Large-scale Renewable Energy Target (LRET) was introduced to encourage the growth of large-scale renewables to achieve the majority of the 2020 target of 41,000 GWh. The Small-scale Renewable Energy Scheme (SRES), which ends in 2030, is uncapped and introduced as a financial incentive for distributed generation and heating solutions (CER, 2016). Regulation and administration for both the LRET and SRES are carried out by the Clean Energy Regulator[10].

In 2015, the now Liberal-National coalition government requested a change to the LRET following a reduction in forecast electricity demand, and The Renewable Energy (Electricity) Amendment Bill 2015 was agreed. The amendment was delivered as the original target of 41,000 GWh would be more than 20% of total energy output by 2020 (because of reduced demand), the agreed total the MRET was intended to deliver (Froome, 2015). The Liberal-National coalition (who regained power under Tony Abbott from Labor in 2013) had originally sought to reduce the LRET to 27,000 GWh but this was raised to 33,000 GWh as a compromise to the Labor opposition and the renewables industry.

6.4.2 Emissions reduction

In both the Parer review (Parer, 2002) (section 5.1.2) and the Finkel review (Finkel et al., 2017) (section 5.1.4) there were recommendations regarding emissions reductions. However, the use of either a carbon price or an emissions reduction

[10] Established 2012 as an independent statutory body under the *Clean Energy Regulator Act 2011*

policy has not been forthcoming, partly due to the success of the Liberal campaign against the 'carbon tax'.

> *'The Tony Abbot campaign against, on what he successfully characterised as a Carbon Tax, was so successful. It is difficult to convey to someone who wasn't here just how unbelievably successful that was and how badly Labor managed to defend their position. So, Tony Abbott just hammered on that issue and the legacy role will last for years to come'.*

Interview C3 NGO

After Australia finally ratified the Kyoto Protocol in 2007, the Labor government proposed an emissions cap and trade scheme. The scheme was not passed through parliament and it was not until 2011 that the Gillard Labor government was able to pass a carbon pricing scheme. The scheme became a major theme in the 2013 federal election with Tony Abbott, the Liberal leader suggesting that if the Labor party were to stay in Government then the price on carbon would cost Australian families $550 per year (Griffiths, 2013). Abbott's view had the backing of the Minerals Council and little support for the scheme was issued from the business community.

> *'….the business community did a terrible job of sticking to its guns during the Tony Abbott anti-carbon price debate. The business community always had said that they wanted a well-designed emissions trading scheme. They got that, and even though that was still their policy position, just because of the intensity of the political fight here, no one stuck to their guns. They didn't kind of counter their position, but they went silent.'*

Interview S3 in

Interviewees also noted that the success of the Abbott campaign has meant that any sort of carbon price, or emissions scheme, is still considered to be too politically risky, which can be seen within the Government's rejection of any type of emissions or RE policy.

> *'I think the challenge that is coming from the current commonwealth government is there are political constraints within their own party, so they can't have a carbon price, they can't have a permanent trading scheme'*

Interview A2 ad

> *'So, we had Bob Hudson supporting renewables for a long time even though Carbon Price is something you can't talk about at all here, otherwise you get gunned down.'*

Interview A7 NGO

Following the rejection of the Clean Energy Target in the Finkel review, the ESB proposed a National Energy Guarantee (NEG), which would include an emissions obligation and a reliability obligation. However, the emissions obligation was removed from the NEG and remaining policy now concentrates on reliability, which, for the national government, means investment in extending the life of the country's coal and gas generators (Murphy, 2018b).

6.4.3 National energy policy

In the 2019 federal election, there was a definitive split in the energy policies of the two major parties. There was a deeper commitment from the Labor Party to decarbonisation, as their Energy Policy Action Plan showed (Australian Labor Party, 2018). Labor committed to 50% of energy coming from renewables by 2030 and net zero emissions by 2050. The Liberal Party answered this by stating that '*this reckless policy will damage our economy and cost local jobs*' (Liberal Party of Australia, 2019b). The Liberal Party vowed to back investment in new reliable power generation (coal-fired generators) which they believe would ensure lower prices for customers. This split between parties regarding energy and climate change saw the 2019 federal election with energy as one of the major manifesto items for all parties (Belot, 2019; Chang, 2019; Potter, 2019). However, even though 84% of Australians in a recent poll stated that '*the government should focus on renewables, even if this means we may need to invest more in infrastructure to make the system more reliable*' (Lowy Institute, 2018, p.13), the Liberal-National Coalition government have remained in office. Currently, apart from the SRES, which runs until 2030, the current government have no plans to renew, or further, the country's large-scale energy policy, or commit to any emission reduction scheme. It has been suggested that State policy and the use of AEMO's Integrated System Plan (ISP) will now become the primary means for Australia to adhere to its climate change commitments (Parkinson, 2019a).

6.4.4 State energy policy

Counter to the federal government inaction on climate and energy policy, some of the NEM States have announced renewable energy targets (RET). Queensland have announced a RET of 50% by 2030, despite its vested interests in the coal industry and generation (Department of Natural Resources, Mines and Energy, 2019). Victoria has a legislated target (VRET) of 25% renewable generation by 2020 rising to 40% by 2025 (Victoria State Government, 2019). The ACT is to source 100% of electricity from renewable sources by 2020 (ACT Government, 2016). SA had a RET of 50% of electricity generation to be renewable by 2025. Following a recent change of State government, the target in SA has been dropped, but pipeline projects and current installations mean that SA will have 75% of electricity being provided by renewable generation by 2020 (Parkinson, 2018b). NSW currently has no RET in place but has a renewable energy action plan (NSW Government, 2018) to encourage investment (the efficacy of these targets is discussed further in section 8.2.1.1).

Due to the decision of the Victorian government not to join the National Energy Customer Framework (NECF) (see section 5.1.3), electricity retail pricing is still regulated by the Victorian State regulators – the Essential Services Commission (ESC). Not joining the NECF has allowed the Victorian government to legislate an energy efficiency program as part of the VRET, the Victorian Energy Efficiency Target (VEET). This target requires retailers to acquire and surrender Victorian Energy Efficiency Certificates (VEEC) which are given for energy efficiency products and services within households.

Interviewees explained that part of the reason for the decision not to join the NECF was the Victorian mandated smart-meter roll-out. They suggested that, as they were the only State to have smart meters, retail regulation decided by the AER may not create the value that could be obtained from the smart meters. Victoria is now the only state in which all households have smart meters installed, which has enabled some of the new products and services that qualify for VEECs.

> *'…because the government invested in smart meters, a big driver for this program was to actually show some benefit back to the community'*
>
> Interview M6 dn

6.5 Discussion

The coevolution between coal, energy and State energy policy has meant that the current energy system in Australia, and energy policy, is 'locked-in' (Unruh, 2000) to the incumbent interests of the coal industry and, for some States, a vested interest in protecting coal for generation (see sections 6.2 and 6.3). SET literature has suggested that if a system is 'locked-in' to an undesirable state then the governance of the system will need to be adaptive (Engle, 2011; Foxon et al., 2009; Walker et al., 2004) to counter this lock-in. It has also been suggested that to counter the inertia of the governance institutions then institutional change will be required (Mitchell, 2008; Mitchell et al., 2016; Stirling, 2014b).

However, there is contradiction between support of the coal industry and support of DER between some State governments, and the national Government is supportive of the coal industry in general. This is understandable from a macroeconomic point of view, as coal is a substantial contributor to Australian GDP, provides additional revenue for the State governments and employment opportunities in rural areas. However, the effects of climate change are currently being felt in other parts of the economy, such as increased droughts causing hardship in the farming community (BBC, 2018), with droughts particularly affecting the states of NSW, QLD and SA[11]. As well as drought, the bleaching of the Great Barrier Reef is affecting tourism (Swann and Campbell, 2016). In the 2019 federal election, these effects led Australians to decide, among other considerations, which economic benefit would be greater to them – the coal industry or the environment. The vote went to the support of the coal industry with the Liberal-National coalition winning by an outright majority of 77 seats to 68 for Labor in May 2019 (76 seats were needed for a majority win) (Sonali, 2019).

Australia ratified both the Kyoto Protocol and the Paris Agreement, but unless Australia reduces its coal use for electricity generation it is unlikely to meet its Paris commitments. A recent report from the Australian National University suggested that, if renewable generation carries on being installed at its current rate, then the Paris target could easily be met (Blakers et al., 2019), an idea that was echoed by the Prime Minister (Murphy, 2018a). However, due to the current government's backing of the coal industry, and the lack of large-scale renewable energy policy past 2020, it is unlikely that the current rate of installation *will* continue (Hare, 2019; Skarbek, 2018). Estimates of an increase, rather than a decrease, in emissions above 1990 levels have been predicted (Climate Action Tracker, 2018).

[11] a further effect of the drought, at time of writing, has been the ferocity of the bushfire season of 2019-20 (Gergis and Cary, 2020), which may have considerable effect on future elections

This support of the coal industry suggests that the NEM is being resilient to the emergent change of DER. For policymakers in the NEM who are supportive of the coal industry, growth in RE generation (whether within the NEM or globally) is considered to have a negative economic effect on Australia's GDP and, as such, is an undesirable element. In this case, the current coal-based system will continue to be the desired system and therefore, the adaptive capacity within the system (its resilience) is protecting coal-based generation.

Australia's energy policy has been inconsistent. The Liberal Party's amendment to the LRET, and their unwillingness to extend targets once they have been reached, shows their lack of commitment to the decarbonisation process. This is then countered by Labor support for decarbonisation (although a recent article suggests that even Labor policy is too cautious to meet the IPCC recommended target of 1.5ºC (Dooley, 2019)). The changing of governments, and the swing between the levels of support for decarbonisation, has left Australia with investment uncertainty, particularly for large-scale renewable energy projects.

The inconsistencies of energy policy at the national level has encouraged the States to set, and fund, RETs. As discussed in Chapter 4, State RETs have contributed to greater penetration of small-scale renewable technologies, at differing rates depending on the investment by certain State governments. However, the current centralised system of NEM governance, which has been established to maximise the economic and operational efficiency of the energy system (discussed in Chapter 5), is now struggling to cope with a system that is increasingly becoming more decentralised at an uneven rate, dependent upon State policy. There is now a contradiction between the inertia of the centralised system's governance (due to the carbon lock-in (Unruh, 2000) of the NEM institutions), and State renewable energy policies (contributing to an unexpected and emergent change). This contradiction between state and national energy policy also affects the desired function of the NEM, where national government supports the current function (perhaps assuming a transition) while some States would like the desired function to include decarbonisation (perhaps needing a transformation). Whether this disagreement is detrimental to the NEM is discussed further in the next chapter.

6.6 CONCLUSION

Decarbonisation of the NEM will not be an easy task due to the complex interactions between the coal industry and the economic, social, political, technical and environmental aspects of the Australian energy system.

Environmental concerns, the changing resources for electricity generation, and the climate and energy policies of Australia's export markets, has created uncertainty in the future of coal in Australia, yet coal is still being supported by the current government. There is now a split between the right and centrist political parties regarding their support of the coal industry, and the need to reduce Australia's emissions. An election win for the Liberal-Coalition in 2019, has allowed the coal industry to continue its influence over Australian climate and energy policy. However, despite the vested and incumbent interests of the coal industry in the energy system and its governance, the federal system of government has allowed some States to create renewable energy targets, counter to the national government's position.

7. CHALLENGES OF DECENTRALISATION THROUGH DER

In Chapter 4, the speed of uptake and the amount of DER was unexpected, which changed the structure of the NEM from electricity being generated by centralised generation assets, to a combination of centralised and decentralised generation assets, so altering system operation. In Chapters 5 and 6, the centralised governance structure and the vested interests of some State governments were discussed. This chapter will show how decentralisation in the NEM, led by the consumer through a rapid uptake of DER, has created challenges within the social, economic, technical and political spheres, and the difficulties created due to the limited ability of NEM governance to adapt to the unexpected outcome of such rapid change.

To demonstrate the interactions between each of the social, economic, technical and political system aspects this chapter will be structured under the themes of (i) challenges to system operation, (ii) the changing role of the customer and (iii) grid optimisation for reliability, security and affordability.

This chapter introduces how the increasing decentralisation of generation in the NEM has led to challenges to the physical operation at a system-wide level (Section 7.1); how the role of the customer is changing and how it needs to be valued to enable this decentralisation to benefit all electricity customers (Section 7.2); and although decentralisation has created challenges, how enabling decentralisation can also be the solution to these challenges (Section 7.3). This chapter then discusses how the current governance of the system is finding it difficult to adapt to decentralisation, in the time needed, to create an electricity system that benefits all electricity customers.

7.1 CHALLENGES TO SYSTEM OPERATION

As DER increases on the electricity system so this raises technical challenges for the market operator and the electricity networks. This section will look at some of the major technical challenges that have been encountered, due to the high levels of DER changing the system operation, and the governance responses to these issues.

7.1.1 Demand profile

As more domestic solar PV generates electricity, so it alters the shape of the operational demand curve. The effect of PV is to 'hollow out' the demand from grid-supplied electricity during the peak daytime hours. As the sun sets, so domestic PV generation reduces, leading to a steep rise in demand in the early evening (Figure 7-1). This change in the demand profile has created a peakier profile, or 'duck curve' (or as one commentator mentioned '*it is starting to look more like a giraffe*' (M9 Sreg) due to the larger dip in the centre of the curve as solar uptake increases), and so meeting this change in profile requires changing the type of generation assets needed. In a system dominated by coal-fired power generation - which is slow to react to changes in demand - more flexible, quick start assets, such as gas generation and battery storage, are needed to meet the change in profile (see section 6.3).

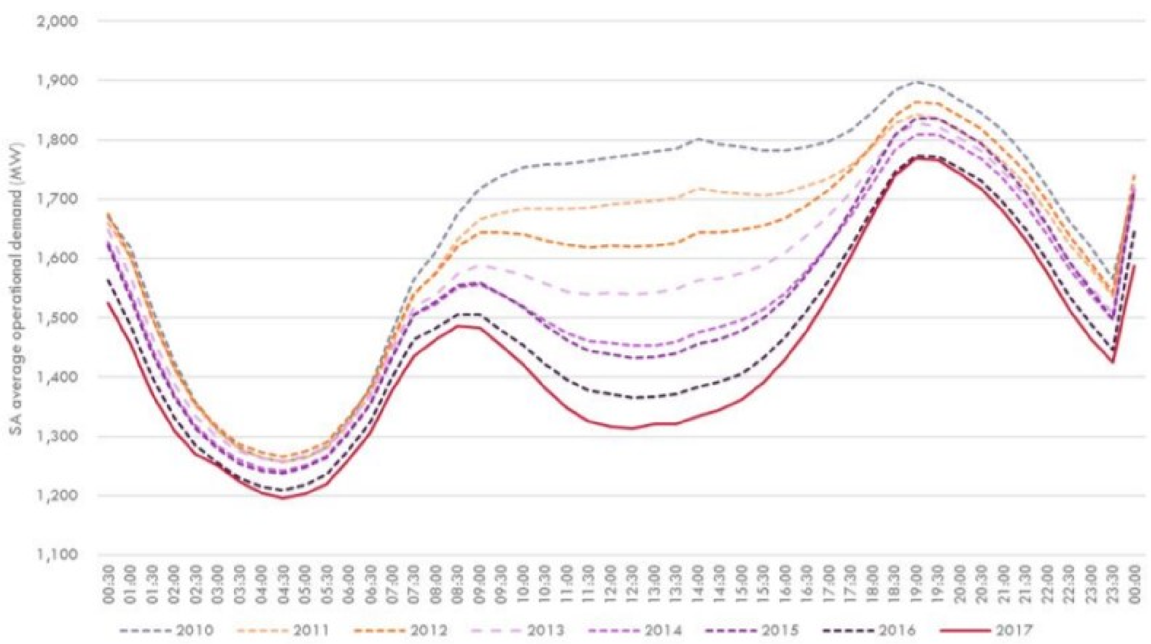


Figure 7-1 The effect of growing rooftop solar on the average operational demand profile for grid generated electricity in South Australia (Source: AEMO, 2018)

The growth of DER has also reduced the maximum demand for grid-supplied electricity, which used to be on hot summer days, to meet the demand for air-conditioning, and moved to the early evening. This can be seen clearly during a record event in Queensland where actual demand for electricity during a particularly hot summer period was reduced, as DER was able to meet the record demand, limiting the pressure on grid-supplied electricity (AEMO, 2018c).

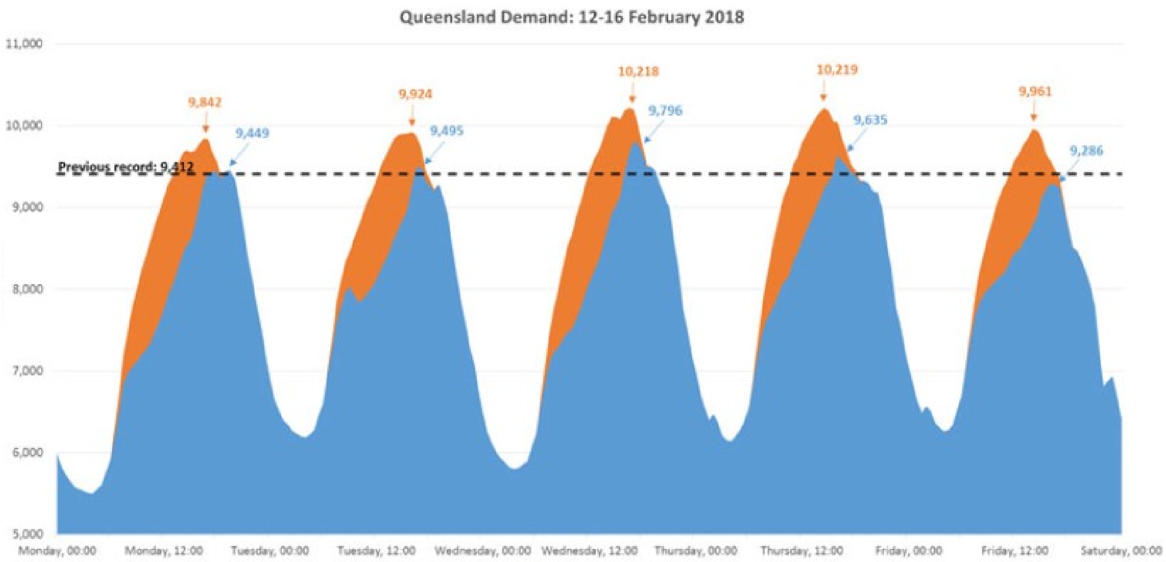


Figure 7-2 Queensland's grid demand on 12-16 February 2018 (shown in blue). Actual demand (shown in orange) would be much higher without the effect of reduction from domestic solar PV (Source: AEMO, 2018b).

The change in demand profile has meant that visibility of DER i.e. the location and capacity of DER known to the system operator, is becoming an important consideration for the reliable operation of the NEM.

7.1.2 Visibility

Historically, there has been a lack of visibility on the low voltage (LV) parts of the distribution network due to little, or no, monitoring. There is also an absence of coordination of DER, all of which are causing concern for the distribution networks and AEMO. As the majority of change is happening in the distributed part of the system, the visibility of these areas is becoming an important consideration.

Currently, as part of the SRES (see section 6.4.3), PV installers provide the Clean Energy Regulator with small-scale technology certificates. The certificates enable the networks and AEMO to see the scale and density of domestic and small commercial PV installations in each locality. AEMO uses weather and behavioural forecasting data to assess how much of the expected demand will be met by local generation, and therefore the subsequent requirements for grid supply.

Currently, there is no such scheme in place for batteries, making them essentially invisible to AEMO, causing forecasting issues which in turn can lead to problems matching supply and demand, and therefore frequency instability (see section 7.1.3.2). The SRES is due to end in 2030 which means that any small-scale (<100kW) PV installations after this date will also be invisible to the networks and AEMO.

> *'So, the visibility issue is something for us, and the controllability. We forecast in SA, on some periods on some days, we will have negative demand. Negative demand by about 2023-25 that period there. So that situation will become uncontrollable if there is not some change there.'*

Interview A8 NEM in

In reaction to the challenges that would be associated with visibility, AEMO has been obligated by the AEMC, following a rule change, to implement a register for DER in the NEM (AEMO, 2019b). The rule change commenced on 1st December 2019. The rule requires that the network providers must supply AEMO with information about the DER connections to their network. The register will then use this information, plus information obtained from the Clean Energy Regulator (CER), through the SRES scheme, to create a central register of DER. The information will be available to AEMO and the networks to assist in forecast and network planning.

Although the new rule change was welcomed by stakeholders in the NEM, there was a consensus, during the case-study interviews, and the preliminary and secondary consultation process from AEMO, that there was a possible compliance issue (AEMO, 2019c).

> *'…then the question is how do you actually enforce people to register them. So, you could have a register, but no one actually registers anything, then as there is no subsidy there is no incentive to register.*

That is what we are looking at, as a complementary legislative thing, to say that installers have to register and there will be an obligation on the installer, with a compliance framework around it with technical regulations.'

Interview A2 ad

When a DER register becomes live, AEMO would be relying on the installers, or customers, to provide information to the networks of small-scale DER connections which would then become available for the DER register.

'So, we are having to think more creatively, how do you get obligations or incentives on electricians or other installers? How do you take it down to that next level? How do you get that information from customers? There are already obligations for customers to advise this information to distributors when they do a connection, but there is only 30% compliance at best.'

Interview S5 NEM in

The networks currently have no method to ensure compliance from installers to provide information, and there is little incentive for installers of DER, particularly domestic storage technologies to become accredited (as there is no similar scheme to the SRES in place for storage technologies). The stakeholders agreed that while, in principle, the register would be valuable to both themselves and the market operator, unless there was complementary legislation to enforce compliance, that the register would do little but become a central document for the fragmented information that was already available.

7.1.3 System reliability and security

As can be seen in Figure 7-2, the growth of DER has the effect of reducing demand from grid-supplied electricity, which can assist in system reliability, by providing extra capacity during peak events. However, system reliability must also ensure that voltage levels across the system are kept stable. Security of the electricity system must also be maintained by safeguarding system frequency and system strength.

7.1.3.1 System voltage

Electricity transmission and distribution networks are designed to transport electricity at particular voltage levels. Disturbances to the voltage levels, either by increasing or decreasing voltage, can cause the system to shut down. If local demand is being met by local generation through DER connected to the distribution network, this reduces the need to import electricity through the transmission network.

> *'Just to reiterate, currently, our average demand in SA is about 1400-1500MW, it is only a small system. Peak demand, the highest demand ever experienced is about 3300MW, but that was some years ago. Now it is about 3000MW during the summer. Then, of course, the big thing now is minimum demand on the transmission grid. It always used to be around 1000/900MW, it has now been under 600MW, and the AEMO forecast suggests that, by the not to distance future, certainly within a decade, we will reach the point where it becomes zero, or less than zero at certain times of the day.'*
>
> Interview A6 tn

The reduction in the need for imported electricity reduces the loading on the transmission line causing voltage levels to rise, which then requires the lines to be switched off to keep the voltages stable. Switching off the transmission lines has the resultant effect of reducing the amount of synchronous generation available for system strength (see section 7.1.3.2) and voltage regulation.

A similar effect is felt on the distribution network, as voltages are expected to drop along the lower voltage distribution network due to the household loads on the network. The network was designed for a one-way flow of electricity with households closest to the substation, or the transformer, receiving electricity at the higher end of the allowable voltage range and with those at the further end of the distribution line receiving the lower allowable range. As households generate and transport electricity this changes the way that the network is being used, creating a two-way flow on the network. This can cause problems when networks have been designed to run at a particular voltage level, creating issues at the transformer or substation if distribution network capacity limits are breached.

'..suddenly you have got to leave some load to be pushing in, so as you go along the wire, rather than the voltage going down it is going up, so all of a sudden people at the end of the line are at over-voltage, and you actually see this in data, where systems disconnect when it goes above 250V, so you have an overvoltage problem.'

Interview M5 ac

'So the profile at the moment looks like, as most of it is getting used, so really quite negative, whereas that was on a distribution transformer, that was 125kW which was starting to get close to 125kW in a reverse direction on very highly saturated wires, and that causes upstream problems as well that is predominantly about voltage rise in low voltage networks.'

Interview A5 dn

Recognised as a cause for concern (AEMO and ENA, 2019), many of the interviewees suggested that smart inverter technology should be used for voltage control and cited a project being undertaken by the Institute of Sustainable Futures at The University Of Technology in Sydney – Networks Renewed (Dwyer et al., 2019) - which trialled the business case for behind the meter inverter controlled voltage regulation. The results of the trial showed that there was a positive business outcome for customers, and the networks, in using behind-the-meter smart inverter technology, but that there were regulatory problems to overcome before being able to capture the market value that aggregated household services could deliver.

A possible solution to voltage regulation and frequency control using grid-scale batteries is being trialled by ElectraNet, the SA transmission company. For the trial, the network company would own, install and maintain a large battery to use for FCAS and voltage regulation on part of the network. As only a small proportion of the battery would be needed for these services, this would allow the network company to enter a lease agreement for the remaining portion of the battery with an energy retailer, or community group, for storage and generation services. Using the battery this way would improve the regulated benefits for the customer, as it improves the reliability of supply, and also for the network as the fast frequency response would relieve constraints on the interconnector, whilst also giving the network both regulated and unregulated income from the project. The Dalrymple Project (ElectraNet, 2019) is currently being trialled with funding from the Australian Renewable Energy Agency (ARENA) and with AGL leasing the competitive market element. Although able to be accommodated in the current rules, the AER has raised issues around the need for separation between the regulated income for the networks, and services that can be provided by a competitive market (ibid.). The need for networks to be able to earn unregulated income was seen by one interviewee as an important consideration in a future where there was a possibility of the networks becoming deregulated due to the outside competition with current network services.

> *'So, I am a strong believer that we will become deregulated, it is just a when question. So despite my arguments about why customers might want to remain connected to the grid, I think once you get to grid parity, so once a customer has got a choice, that is a similar price to grid electricity, well why would you want the overhead, and it is a massive burden on society, the regulatory burden of our industry, why would you want that?'*
>
> Interview A5 dn

The interviewee suggested that as people are, and become, able to generate and store all, or most, or their energy needs, then the cost to the customer of charges for unneeded infrastructure would be too great and that alternative competition with the traditional distribution networks would become available. This would then relieve the need for regulation of the distribution networks as they would no longer be a monopoly, and as such the costs would no longer need to be charged across all customers.

7.1.3.2 System frequency and system strength

The frequency of the electricity system is essentially the 'speed' that the system runs at, which in Australia is 50 Hz. Frequency is maintained by matching supply and demand across the network, something that is becoming increasingly difficult due to the amount of household generation and storage. An unchecked change in frequency levels in the system will result in a 'system black' where the entire system may fail, as was seen in South Australia in 2016 (see section 4.6). To give the system time to respond to unexpected changes in frequency, system inertia is needed. Inertia provides a small amount of time to respond to the disruption of grid frequency caused by changing loads or generation, this is referred to as system strength. Currently, the majority of inertia is provided by synchronous generators burning fossil fuels to produce steam, which in turn spins a large turbine to produce electricity. The rotors of the fossil fuel generators spin in synchronisation to the grid frequency (at the same speed) and provide, or absorb, kinetic energy from the grid in the event of a deviation of grid frequency. The stored kinetic energy within the rotational mass of a turbine provides the inertia, which allows the grid operator the time to react to faults on the grid, by preventing power system failure through the use of fast frequency response mechanisms such as FCAS (Frequency Control Ancillary Services), where loads or generation are required to ramp up or down.

As more DER and other RE is connected to the electricity system, so the levels of synchronous generation are expected to fall leading to a lack of inertia on the system. Keeping the required levels of inertia on the grid requires changes to the wholesale market to create a market for flexibility.

> *'So, the issues that we are finding with low amounts of synchronous generation, you get into the problems with inertia, frequency control, and system strength. System strength is proven to be the most severe of those issues. System strength is really about how synchronous the system is, and how much synchronising torque is applied to keep things synchronised.'*

Interview A8 NEM in

> *'…So, the rate of change of that decline becomes more pronounced if you have less inertia, and that is what is happening now. So, you have less synchronous generation online, which is where that inertia is typically coming from, and more asynchronous wind and solar.'*

Interview A6 tn

> *'...So how you get the flexible, dispatchable generation, how you get the inertia and all that stuff, and how you keep those in the market, is the big debate at the moment...'*

Interview A8 NEM in

Wind and solar are asynchronous as they are connected to the grid via invertors, which can supply power but not inertia. Wind turbines *can* provide inertia by using alternative methods of grid coupling (Morren et al., 2006) but this reduces the power output of the turbine which has economic and supply considerations and is not currently being used. Solar PV is unable to provide inertia due to the lack of moving parts. Battery storage can provide some synthetic inertia capability but not currently at the speed required to provide grid stability.

The challenges associated with an increase of variable renewable generation (VRE) on system strength led to a rule change being initiated in September 2016, which commenced in September 2017, that required the Transmission Network Service Providers (TNSPs) to maintain minimum levels of inertia (AEMC, 2018b). Currently, the minimum levels of inertia are being met by fossil fuel generation and have resulted in the curtailment of renewable generation to prevent system strength issues (AEMO, 2018d).

> *'They have limited the amount of wind to 1295MW, in terms of actual generation for the moment. They are also now requiring three or four synchronous generating units on at all times. So, this is now requiring them to use their powers of direction to require units to stay on when they otherwise would have shut off. That comes at a cost. We are just working through that at the moment.'*

Interview A6 tn

To prevent the loss of clean generation, there have been trials to use synchronous condensers to provide inertia (ElectraNet, 2018). Synchronous condensers were originally used to provide voltage control in the early days of electricity. They are a spinning mass, and so able to provide stored kinetic energy, but are not connected to a load or a generator, and so have been recommended to provide the inertia needed as more asynchronous generation is attached to the grid.

> *'It can be provided by contracting with fossils to keep running or you could invest in syn cons, that would be...syn cons are relatively cheap. You are not burning fuel to spin them, once you are spinning them you have got friction inertia, friction losses are the only thing that really is a thing. So, they are relatively low cost to run and they provide these services.'*

Interview A2 ad

'So, we're now coming to a conclusion that the most cost-effective way of dealing with the system strength issue is to invest in some synchronous condensers on our network, and that is what the discussion tomorrow with AEMO is all about. So that could be an investment in four or six units. It is like old technology becoming new again. We used to have synchronous condensers on our network in the '40s and '50s to manage voltage, and now they are finding a new use.'

Interview A6 tn

Although an increase in DER has meant a reduction in inertia across the system, DER *is* able to be used for frequency control. The Hornsdale Power Reserve in SA has proven that battery storage can provide fast frequency response (FFR) at a superior level than traditional services (AEMO, 2018e).

'It has actually exceeded expectations; it has been very good. We were working on that a minute ago. We are going to write a report in few weeks time on how it has performed. Its frequency control is far better than a conventional power station, it is almost instantaneous.'

Interview A8 NEM in

There have also been trials for the use of wind turbines to provide FCAS (AEMO, 2018f). The trials were developed to improve the competitiveness of wind generation while increasing the supply of system security services. The trial has led to the market operator providing additional guidance for invertor connected DER within the Market Ancillary Service Specification (MASS) (AEMO, 2018g).

A rule change was initiated in 2015 to change the financial settlement of the NEM from 30 minutes to five minutes (AEMC, 2017). The rule change acknowledged the evolution of IT systems, metering and data collection that has happened over the past 20 years since the 30-minute settlement rule was first introduced. The rule change will also maximise the investment potential of batteries and other FFR technologies, such as gas peaker plants and demand response. The rule change was made in November 2017 and is due to be implemented on 1st July 2021. It is expected that creating a market that rewards FFR providers will improve the reliability and strength of a grid which anticipates a large VRE/DER penetration.

In conjunction with the 5-minute rule change, the ESB is consulting on possible changes to the NEM market design post-2025 (ESB, 2019). The consultation recognises that the NEM is rapidly changing and seeks to create a market design that will support reliability and meet the needs required by the changing generation mix. Following the consultation, a market design for the appropriate scenario will be developed from the beginning of 2020. At the end of 2020, the ESB expect to either recommend measures to adapt the existing design, or to recommend moving to an entirely new market design, that will '*provide the full range of services to customers and deliver a secure, reliable and lower emissions electricity system at least-cost*' (ESB, 2019 pp. 5).

7.2 The changing role of the consumer

The rise of DER in Australia has created a much more dynamic energy system, one where the role of the consumer has changed, from a passive consumer of energy to an active participant in the energy system – a prosumer. The amount of installed capacity of household and small commercial PV has meant that, at present, the second largest electricity generator by capacity in the NEM, is rooftop solar PV (see Figure 7-3) (CER, 2019).

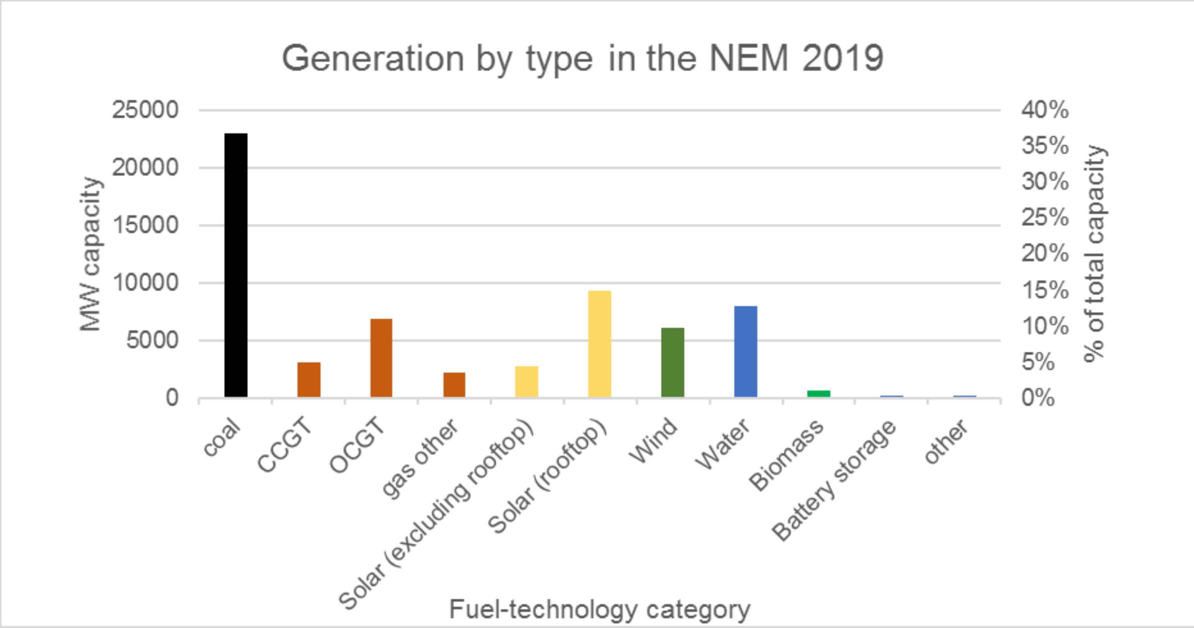


Figure 7-3 Generation capacity in the NEM by fuel/technology type 2019 (source: *AEMO, 2019c; CER, 2019)*

Recognising that there is an increasing shift in power, from the incumbent, centralised generators towards the household distributed generator, the design of the future energy system should increasingly see the customer taking a central role.

> *'So, they forget that consumers are driving this now, so it doesn't matter what your FiTs or your policy settings are now, it is driven by the consumer, so it will have to change.'*

Interview A1 Sreg

> *'…the customers are right in the centre because suddenly they can make choices they couldn't before, and suddenly all these commercial and corporate entities are now on the outer circle saying, 'how can we keep ourselves relevant in this environment?"*

Interview M3 in

The central role of the customer needs to be recognised by the governance of the energy system, as the customer now has the ability to shape the energy system in either a negative or positive way. As has been discussed previously, energy is now an essential part of everyday life, so it is imperative that the impacts of DER result in a positive outcome for *all* energy customers and that the customer's role in the future energy system is valued.

7.2.1 The consumer's ability to cause a 'utility death spiral'

Consumers demand for self-generation was partially initiated by rising electricity costs (see section 4.3). Further increases in the price of energy, in part due to situations such as curtailing RE and using traditional generation for inertia (see Section 7.1.3.2), makes the installation of DER more attractive to customers and could lead to the possibility of Australia undergoing a 'utility death spiral' (Box 7.1). A utility death spiral occurs as an increasing number of householders generate their electricity, which reduces the amount of revenue available to pay for the fixed costs of the system. To pay for these fixed costs, prices need to be increased, resulting in the remaining customers facing the increased prices. These increased prices then make self-generation viable for those customers able to install DER, and so on, until the utilities are unable to recover their costs.

BOX 7.1

Utility death spirals

The concept of a utility death spiral is not new. Initially, it was concerned with the rising costs of retail electricity leading to a reduction in consumer demand from switching or self-generation as a new era of competition began within the electricity industry (Costello and Hemphill, 1990). Henderson (1986), theorized that in order for a market to be unstable, and therefore allow a death spiral to occur then the fixed cost fraction of a customer's bill, the network charges, would need to be in the region of 50-66% , something which is currently happening in Australia (AEMC, 2016). The threat of the utility death spiral has re-emerged in Australia as DER, primarily residential PV, has become competitive with grid-based electricity due to high electricity prices and the costs for PV installations falling.

Simshauser and Nelson (2012) suggest that, with the rise in uptake of DER, the death spiral effect could also occur because of the comparative rise in peak demand when PV generation is not available. This rise in peak demand requires investment in new peaking plants, poles and wires but less customer revenue from which the utilities are able to recoup costs, causing a rise in prices and more defections. It is also argued that a death spiral may occur when disruptive competition enters the marketplace, in this case a synergistic wave of requirements such as technological advancement combined with social need and policy and business development (Graffy and Kihm, 2014).

Authors discuss, that in order for a death spiral to occur a ‘perfect storm’ of requirements is needed i.e. inflexible pricing structures, large defections and the distribution networks and suppliers unable to change their behaviour (Costello and Hemphill, 2014; Laws et al., 2016).

Articles suggesting solutions to death spirals give a purely economic solution, which would allow the incumbent generators and networks to operate in a ‘business as usual’ scenario (Eid et al., 2014; Felder and Athawale, 2014; Simshauser et al., 2011; Simshauser and Nelson, 2013). No mention is made of the decarbonisation targets that instigated DER policies originally and the suggested solutions appear to discourage its further uptake. In order to meet future decarbonisation targets, DER will be essential, as will designing rates to encourage this (European Commission, 2015). This requires new ways of optimising the value of DER for system operation while recognising the changing role of the consumer.

The ability of customers to cause a death spiral was not seen as an issue for concern by some interviewees, as the benefits of being connected to the grid would outweigh the costs of becoming self-sufficient.

> *‘I think in Australia, maybe years ago, there was a lot of talk about the death spiral and people coming off the grid and then there's more costs for those remaining etc. etc., and there was real doubts about will we even need a grid 20/30/40 years. I think we have very much moved on from that at the moment, but people do see that the grid has a role to play, a different role, it is really the glue that holds all these things together and allows them to trade and communicate. It is an enabler.’*
>
> Interview A6 tn

> *‘I just think the whole death spiral thing is just a bit overstated. Has anyone come up with anything, well it is two or three years later, has anyone said, 'there’s the evidence, the death spiral is happening'?’*
>
> Interview M4 NGO

'I think that it's a good headline but it's a bit overblown because the cost of batteries doesn't make it cost-effective.'

Interview S1 ac

However, with the costs of DER reducing, and in some States DER achieving grid parity (Figure 4-6), other interviewees suggested that it is entirely plausible that many of the NEM households *would* be able to reduce their reliance on grid-supplied electricity to a point where they are no longer contributing economically to the energy system, or they are able to rely on an off-grid system.

'One [Powerwall] and you would only need to buy 5-10% power from the grid. When you have got down to 5-10%, your volume is so small that the grid cannot sustain a price that will get back sunk costs. So you have already done the death spiral. There is now a massive write-down of assets. It is happening already.'

Interview M8 ac

'You will be able to buy a package where you get a big chunky PV system and big chunky battery and a small generator and the generator will keep you going for those 2 or 3 days a year when you are really running out of power….. Put it this way, 2 years ago I would have said, 'Grid defection, maybe 15 years', and now 'distinct possibility in 5 years' possibly at the outside if there were,.....The thing is we keep being startled by the speed of the costs declining.'

Interview C3 NGO

It will become essential that the value of being grid-connected is understood, not only to provide grid services for those with DER but to prevent costs to non-DER consumers rising to unaffordable levels.

7.2.2 Customer engagement

Although there was disagreement about the possibility of a 'utility death spiral', there *was* agreement that customers were lacking engagement in how the optimisation of DER would benefit all energy consumers.

'We've gone down that path with the death spiral and it is true that they do all need the grid, but you have got to explain why. It is not that you need it

for the power, it is the other services and products that can be provided to you, but there are all these other options for you if you stay. But again, you have got to make it palatable for them, you have got to design the system to allow that. If you just say we are going to keep the same system and you just have to stay on board, then, of course, they will want to go, there is no point.'

Interview C4 ENA

Research for the OPEN Energy Networks report (AEMO and ENA, 2019) has shown that the additional services that DER can provide, such as reserve capacity and demand response, would help to reduce costs of electricity supply to all customers. Providing these services requires the customer to becoming engaged with the energy market and the services that DER can offer. However, many interviewees suggested that customers were not interested in engaging in market services and that as they could generate virtually all of their energy requirements, there was little need for them *to* become engaged.

'When you get 95% of your production from your battery and a solar system on your roof, what do you care about the National Energy Market, what does it mean to you?'

Interview M8 ac

'There is a lot in Power Transformers too about how much is predicated on consumer engagement in energy policy and what a folly that is. I think Victoria [smart meter roll-out] *is a fantastic case study for where you can potentially end up if you set your direction with the built-in assumption of high engagement from a consumer base.'*

Interview M7 ad

The lack of engagement, combined with the continual reduction of DER technology costs, makes it understandable that AEMO and the ENA are concerned about '*the limited window of opportunity*' (AEMO and ENA, 2019 pp.9) that is available to gain the grid benefits from DER (Smith, 2019) and to persuade consumers that engaging in the energy system will benefit them. Persuading customers to engage requires that customers trust the energy industry and institutions to act in their best interests.

7.2.3 Customer trust

Another of the drivers for the uptake of solar was the lack of trust that customers have of the energy industry and institutions, and the desire for energy independence.

‘We are really trying to find a way and take this out of this kind of esoteric kind of debate and get it across to consumers about why you need it, because as far as they are concerned in Australia, the feeling is, ‘I have been screwed my network, costs going up by 70% real in 10 years, my best opportunity is independence of some kind.”

Interview S1/2 ac

‘But there is a bit of a lack of trust, but I think if you can make it so consumers see a real big difference on their power bills and it is automated and you build it from there, it will start to be effective, and they will choose who they operate with. Who do they trust? Maybe someone else who is more trusted and has that consumer interface and just does contracts with energy businesses, it is hard to know.’

Interview S5 NEM in

Yet, an engaged and trusting prosumer will be a key requirement to resolve the technical, economic and social challenges attributed to an increased use of DER (AEMO and ENA, 2019).

Acknowledging the difficulties associated with consumer engagement and trust, and also to make use of the Victoria smart meter roll-out, Jemena (one of Melbourne’s DNSPs) trialled a household demand response initiative – Power Changers (Jemena, 2019). The trial required both DER and non-DER customers to use behavioural methods, such as pre-cooling of the home or increasing air conditioner temperatures, to reduce electricity demand during peak events. An important result of the trial was that the customers had more understanding of how customer actions could affect the network and that the trial was a valuable first step in both the network and the customer understanding and communicating with each other.

‘Well that's the thing, it's a toe in the water. It's a building up of relationship, a building up of their understanding of what is going on and why we need their help. We are building a relationship we have never had in the past. We have always sat in the background, under a rock, no one is talking about us. So, this starts to get that meaningful relationship starting to happen. Now after that progresses for a while maybe, you know, and we want to test this too, maybe they will feel comfortable with us cycling on and off their air conditioners and delivering greater impact through that, but we don't know. We have got to try those things out through the process, but it didn't make sense to start with that because you just go ‘Big Brother!’.’

Interview M6 dn

7.2.4 Customer protections

Another focus for many interviewees was that as customers become central to the energy system, national consumer protections and technology standards would need to be reviewed to recognise the changing energy system and the role of prosumer within that.

> *'Obviously one of the most exciting things going on at the moment is seeing these models emerge. Whatever the model, is that the customer in metronomic consistency, can get the same local self-protections and services and so forth.'*
>
> Interview M9 Sreg

> *'Whether you have got that thin connection to the grid, a normal one or no connection, customers expect the same sort of service. They need the same protections. How do you regulate that effectively but without too much retained, but with appropriate connection? All those standards really. What is an essential service?'*
>
> Interview S5 NEM in

One aspect of decentralisation that is particularly relevant for the NEM is that, in some rural areas, creating a microgrid will improve reliability and reduce costs for all customers. Currently, rural customers are served from long distribution lines, which can be several hundred kilometres long and which require expensive maintenance. Removing these lines will then reduce O&M costs for the networks and, as the cost of connection is spread equally among all the States' customers, reduce energy prices for everyone. Consumer protections, in this case, need to be updated to reflect the limited competition and the right to be connected to an essential service.

> *'We need consumer protections for people who disconnect from the grid before we start encouraging people to disconnect or allow networks to disconnect them. So, there is a bunch of discussions going on about reliability frameworks, price protection, consumer frameworks etc. etc.'*
>
> Interview M4 NGO

The AEMC has recognised that there is a need for changes to the National Electricity Customer Framework (NECF)[12] (AEMC, 2019b). The changes made to the legislation are to ensure that customers can access the new business models that will become available while ensuring that customers are adequately protected. A

[12] The NECF applies only in the NEM states (excluding Victoria and Tasmania) and is the legislation that regulates the sale and supply of electricity and gas to retail customers.

review was undertaken in October 2019 to update consumer protections so that they are fit for purpose for new household demand response and DER (ibid.).

The AEMC also undertook a review of the regulatory frameworks for stand-alone power systems (SAPS), which includes both microgrids and individual systems (AEMC, 2019c). The review is closely aligned to the rules for consumer protections within embedded networks and requires the networks to ensure that, if SAPS are more economically efficient than a wired connection, then appropriate consumer protections and service standards are maintained.

7.3 Grid optimisation for reliability, security and affordability

In the previous sections, the challenges of increasing DER penetration have been highlighted. As discussed, the solutions to many of the challenges caused by increasing DER penetration can be met by new technologies, new business models, new markets and a changing role for the customer. Many of these solutions require the customer to change their behaviour and become engaged with the energy system, all of which will require the customer to have trust in the energy industry. Within the solutions, there was also a need to review the rules and regulations so that NEM governance can be optimised for the inclusion of DER i.e. working for the benefit of both the consumer and the grid while ensuring that energy remains secure, reliable and affordable.

Optimising governance for DER requires reviewing the current rules and regulations and how customers will pay for energy in the future. This section will highlight some of the trials and solutions currently being discussed in the NEM that may provide the social, economic and technical benefits needed for this optimisation.

7.3.1 Network regulation

Currently, network charges are decided by a five-year price control. The network companies deliver their business plans to the AER which then assesses the plans and advises the networks on their allowed revenue for the coming five years. The

AER uses incentive-based regulation based on the revenue cap for their operating (OPEX) and capital expenditure (CAPEX). Should the network spend less than their future OPEX/CAPEX estimate, e.g. by more efficient use of their resources, then they are rewarded by 'keeping the difference' between the allowance, and vice versa should they overspend (AER, 2014). This method of regulation has resulted in some 'gaming' of the system with the regulator.

> *'So, if you look at it purely from a strategic perspective. If that is what we think we really need, why wouldn't you put in something higher? Because if that is what we really need and the regulator cuts that, then you have got less than what you really need. That has always been the regulatory game, so we were quite upfront with Paula about that, that there was a real issue of trust here.'*
>
> Interview A6 tn

To reduce the amount of gaming between networks and the regulator, one of the Victorian network companies have been trialling a new method of producing business plans - the New Reg process (AER, 2018b). This process requires the network company to work with a Consumer Forum, a knowledgeable forum with representatives from industry, and also from the residential and small commercial sector. Working *with* the Consumer Forum the networks produce a business plan for the expected spending in their distribution area over the next five-year period. This is then scrutinised by a national Consumer Challenge Panel, before being sent to the regulator. The premise of this more customer-centric network regulation is to allow the network to work more closely with *all* their customers and to give the customers a stronger voice in the business plan process. By producing a plan in this much more transparent way it is hoped that 'gaming' around the business plan process would be reduced, as the AER would be more amenable to agreeing the suggested revenue figure. The method also allows the network to gain a more meaningful relationship with its customer base. This process is currently being trialled with AusNet services, a Victorian DNSP, who have spent the last 18 months in a series of 'Deep Dives' with their customers, and have prepared a draft proposal for their Customer Forum (AusNet Services, 2019). The final plan is due to be submitted to the AER by 31st January 2020.

As discussed in previous sections, many of the solutions trialled for creating a viable DER market to alleviate grid and market challenges were impeded by the current rules and regulations. As part of the 2019 Economic regulatory framework review, the AEMC has released a report, *Integrating distributed energy resources for the grid of the future* (AEMC, 2019d). The report recognises that networks need to be incentivised to change the way they operate i.e. use non-network and smart solutions to alleviate grid constraints and to become a platform for the coordination of DER services. There are currently no penalties, or incentives, for DNSPs who either constrain off or increase hosting capacity for DER. The report recognises the difficulty of visibility on the LV network and expects that an incentive scheme for DNSPs '*may need to be implemented over some years'* (AEMC, 2019b, pp.28). However, this '*some years*' is contrary to a '*limited window of opportunity'* recognised by the ENA and AEMO (AEMO and ENA, 2019, pp.9) and which is discussed further in section 7.4.

7.3.2 Paying for the grid

In a DER enabled grid, prosumers will be able to invest in generation and storage technologies and optimise their investment to gain revenue by selling services to the energy market. This type of optimisation will reduce electricity prices for all customers. However, even with DER helping to reduce prices there is still the question again around the death spiral scenario i.e. if prosumers are now earning revenue from grid services, requiring them to be attached to the grid, who is paying for the fixed costs of the grid?

> *'You read a lot of this, like the Network Transformation Roadmap and you walk away from that saying, 'We are all going to end up rich. People will pay us to use electricity and they will pay everyone.' But it actually doesn't work, someone has to pay for the stuff.'*
>
> Interview A4 ac

Currently, revenue for the fixed and variable costs of electricity supply and generation is collected from customers through their energy bills, via a charge per kWh. Some retailers now also charge a standing charge to cover the fixed costs of network charges. The costs of electrical transport are socialised across State customers so that all customers, within that particular State, are paying an equal amount regardless of the actual cost of connection, or how they are using their capacity. The problem now being discussed by energy professionals in Australia is, how to have cost-reflective pricing that will benefit all customers? Some interviewees suggested that the standing charge also needs to reflect the amount of demand i.e. the amount of network capacity a household requires, as well as the amount of energy they used.

> *'I think the death spiral concept was really around trying to make sure that if you are going to charge a fixed charge it has to be based on demand, not just that everyone pays the same. So, if you are a household, particularly in Australia where you have huge air-conditioning penetration, you have at the moment got some relatively low-income households subsidising high-income households because the price is on energy, not demand.'*

Interview S3 in

The time and location costs of energy were also highlighted as an area for debate, as energy use and customer export may either help or hinder the grid.

> *'If you could earn money from your excess electricity at a time when it is going to help the network deliver the power quality, power reliability and energy that is their role. If you can add some value, and they will pay you some money, then that's what we are talking about. How can we facilitate that kind of transaction?'*

Interview S1/2 ac

The networks have started including a demand charge for peak hours in some of their tariff structure statements (AER, 2019), but these types of demand charges have been criticised as not truly aligning to the customer's contribution to peak demand with the amount paid on the customer bill (Passey et al., 2017). It has also been suggested that having various time-of-use, capacity limits and demand charges on bills is confusing for the customer (CSIRO, 2018; Markham, 2019).

'When we did some work with SAPN a couple of years ago, on principles for pricing reform …. There were four key things that came out of it, but the most prevalent one was simplicity, let's just keep it simple.'

Interview A3 NGO

Some of the interviewees felt that the best solution to cost-reflective pricing would be a simple, monthly payment. The payment would allow customers to enter a contract, similar to a data contract for a mobile phone, based around their expected maximum usage or maximum capacity requirement.

'There's some bigger changes, and as we move towards this infrastructure energy where it is all about capital and there is little fuel costs as part of the equation, is the natural move then toward it is just a fixed price, lump sum, like your internet? You buy the gold membership to AGL Club and you get your stuff. If that is where we are heading, then maybe a lot of this more nuanced stuff isn't quite so relevant to the government'.

Interview A3 NGO

Cost reflective pricing is seen as a method of allowing all energy users to pay their 'fair share' towards grid costs, and also as a method of flattening out peak events. The increased political power of the household solar owners, due to their numbers, may create difficulty for policymakers and the regulator if solar owners feel that their contribution to decarbonisation is not recognised. The imperative is then to design a pricing mechanism that is seen as fair by all users of the grid.

'The fall-out of trying to unwind volumetric benefits to solar households are incrementally getting it through. But you have had utility commissioners sacked. A guy in Nevada was sacked for introducing a proper cost-reflective pricing. The solar lobby went completely mental, 'this is a tax on the sun, tax on solar.'

Interview S2/1 Gad

7.3.3 Optimising DER for grid and customer benefits

Optimising DER is the solution to many of the challenges mentioned. Using a separate distributed energy market would allow customers who have DER installed to deliver grid benefits to the system, which would then reduce electricity costs for all customers (AEMO and ENA, 2019). There are initiatives to create a distributed energy market (DEM) in the NEM, with four market models under consultation. The consultation is questioning which framework would be optimal for both the customer and the NEM, whether it should be AEMO led, independent or using a distribution system operator (DSO) model (ENA, 2017b), with either the DSO running a local market or the DSO communicating to AEMO. The independent DSO model would not require the distribution networks to change their current role. Within each of the scenarios, the DSO has different characteristics and levels of management dependent on the model chosen. Each of the models would require a review of the National Electricity Rules and network regulation, and to establish operating standards or guidelines.

7.4 THE FUTURE GRID

This chapter has introduced some of the challenges of DER penetration, some of the innovations that have stemmed from meeting these challenges, and how the changing role of the consumer will require changes to the way networks are regulated and paid for. It is recognised by the institutions of the NEM that the optimisation of DER (i.e. allowing innovation in business and technology to create the services needed for the new prosumer, which in turn will reduce prices for all consumers), may alleviate the grid and cost pressures that the NEM is currently experiencing. Utilising smart systems, such as Virtual Power Plants (VPPs) (AGL, 2017; Government of South Australia, 2017), DER can gain entry into the wholesale market. Distribution energy exchanges (ARENA, 2017) can operate a distribution level market which can operate synergistically with the wholesale market. Using smart meters can enable household demand response initiatives reducing the need for network augmentation (Jemena, 2019). Utilising a smart grid will give the prosumer the ability to reduce costs for all customers.

As mentioned previously, the value of the smart grid has been recognised by AEMO and the ENA in a recent report (AEMO and ENA, 2019). Within the report, AEMO also acknowledged that, due to falling costs and global emission policies, the market for storage and other DER technologies, and enabling technologies, was increasing rapidly. The speed of uptake has meant that there is a '*limited window of opportunity to reposition our electricity system to deliver efficient outcomes to customers'* (ibid., pp.9). The report acknowledges that without effective coordination of DER, then AEMOs ability to maintain the effective operation of the NEM within secure operating limits will decrease.

> *'So we really, at AEMO, we really believe we have to ramp up the distributed energy resources area because we kind of see it as a major potential benefit, and if we can make demand more flexible it is going to be really helpful with a lot of renewable energy on to the system. On the other hand, if we don't do something it will actually be a problem. So, you have a solution and your worst problem.'*
>
> Interview A8 NEM in

A major consideration is that many of the solutions to the challenges in the NEM are reliant on customer engagement and trust. For DER benefits to be realised, DER needs to be visible to the market operator, helping to create a new flexible system. As such, visibility would increase the adaptive capacity of the physical system by allowing for social, technical and economic innovations to capture new value for both the system, through flexibility, and for the customer, through equity. As householders own the majority of DER in the NEM, gaining this visibility requires customers to trust the institutions and industries of the NEM. To gain customer trust, NEM governance may need to increase the transparency and legitimacy of its decision-making. Within SET, authors suggest that this transparency and legitimacy can be achieved through an increase in customer involvement in the decision making processes (e.g. Nelson et al., 2008; Westley et al., 2011), and a move to New Reg (AER, 2018b) may be a method to achieve this.

Within each of the sections above, solutions to the challenges of a highly saturated DER grid have been suggested, but within each of the solutions comes a need to review the rules and regulations, and either apply for a rule change; or establish an entirely new rule; or cause the regulators to decide whether a solution fits within the current regulations; or whether changes are needed within the regulatory system. Adaptive governance recognises that the rules and regulations need to have a high adaptive capacity, so able to respond quickly to changes within the system, achieved through increased innovation capabilities, something that is also recognised in the AEMC. What has also been noted, both within the interviews and within possible changes to the NECF, is that to encourage the 'correct' solutions, coordination will also need to provide boundaries in which the solutions/innovations may operate and that this may take the form of consumer protections. The AEMC has initiated reviews into the rulemaking process to allow for swifter rule changes (AEMC, 2018c) and has also recommended a regulatory 'sandbox' to be created (AEMC, 2019e). The sandbox allows innovative proof-of-concept trials facilitated by relaxing the regulatory requirements. The creation of the sandbox, in conjunction with a faster rulemaking process, may allow new concepts faster access to the market, thus increasing the innovation capabilities within the NEM, with changes in the NECF providing the boundaries in which these innovations may operate.

To complete the recommendations of the Finkel Review, changes are needed to the rules, regulations and to system and market operations in the NEM, and particularly in the distributed level. The ESB is embracing this by suggesting creating an entirely new market designed around flexibility (ESB, 2019). The AEMC has recognised fourteen separate reviews that need to be undertaken around markets, pricing and regulation to enable DER (AEMC, 2019d). However, as mentioned previously, the AEMC has suggested that a review of regulation '*may need to be implemented over some years'* (AEMC, 2019b pp.28), contrary to the current speed of change in the NEM and also contrary to adaptive governance principles which are anticipatory rather than reactionary.

The many reviews needed, to make the changes within governance that can optimise DER for the benefit of all customers, will all take time to complete, and time is no longer on Australia's side. The Northern Territory's state-owned Territory Generation has already had to write-down assets, due to the reduction of revenue from their customer base because of the increased uptake of solar (Territory Generation, 2019). Synergy, Western Australia's state-owned generation and retail arm, have also posted huge losses, again citing the increase in household solar and reducing levels of revenue, as one of the reasons for the losses (Synergy, 2019). With Australia's rooftop PV installations setting another equal record for September 2019 of 180MW, there is no sign of the rooftop boom slowing down (Parkinson, 2019b).

There is some recognition of the effect that increased DER has on system operation and the need to engage with customers. AGL, for example, are attempting to change their generation assets away from coal and towards more flexible generation (Dunstan et al., 2017) so allowing themselves to keep relevant in the changing market. Some of the distribution and transmission companies are trialling new regulation methods and new business models to improve their customer engagement (AusNet Services, 2019; ElectraNet, 2018; Jemena, 2019). Whether the work now being undertaken in Australia will be completed in time to allow the changes happening within the NEM to be equitable is still unsure, as governance is struggling to match the current speed of the changes occurring at the distributed system level.

To achieve a DER enabled grid, in a way that will allow innovation to flourish, and be equitable for all energy users, there will need to be changes to the governance of the NEM. It is questionable whether some aspects of the current system and its governance are fit for purpose for an energy system undergoing rapid change. If the governance of the NEM does not adapt quickly, matching the rapid changes that are taking place, then the future, as one regulator described, could end up becoming '*this never-ending game of whack-a-mole*' (M9 Sreg).

7.5 Conclusion

What the NEM case study has shown, is the unpredictability and complexity of change within energy systems. In the case of the NEM, the economics of falling technology costs, combined with high prices and a distrust of the energy industry, have created challenges within the energy system. Renewable technologies and accompanying business models are now competing (and in some cases winning) with the incumbent utilities.

Customer preferences have caused the energy system to become decentralised more rapidly than anticipated, which has created system and governance challenges. The speed of system change in the NEM has left NEM governance in a constant state of reaction as the institutions try to ensure that DER can remain a positive part of the energy system. As AEMO and the ENA have stated (AEMO and ENA, 2019), DER is an essential component of a decarbonised grid, and the challenges of incorporating DER can be met by through new and innovative methods to gain the value that DER can bring, which needs changes to governance.

This chapter has highlighted the effects of a rapid change to an energy system, and the challenges this causes within all the different system parameters. The NEM has shown how a system needs to be nimble to react to these changes wherever and whenever they happen, to deliver efficient outcomes for customers in the time required. How this may be achieved is discussed in the next chapter.

8. AN ADAPTIVE GOVERNANCE FRAMEWORK FOR CHANGE WITHIN ENERGY SYSTEMS: LESSONS FROM THE NEM

This chapter uses lessons learnt from the NEM case study to create an adaptive governance framework that may assist in enabling decentralisation in the current energy system. This is achieved by first assessing whether the NEM needs to undergo, or is undergoing, a transformation, rather than a transition and how this relates to the carbon lock-in of NEM governance, as discussed in Chapters 5 and 6. The presence of adaptive governance principles in the NEM are assessed by reviewing the DER uptake discussed in Chapter 4, the governance reactions to this uptake, and the associated challenges, discussed in Chapter 7 (the results are illustrated in Table 8-2, page 167). The framework suggested at the end of this chapter combines the principles of adaptive governance as suggested by SET literature with the practical examples from the NEM case study, to create an adaptive governance framework for practical application that may assist in energy system decentralisation.

Section 8.1 discusses the current governance structure of the NEM and whether a transformation is needed (or is happening). Section 8.2 then discusses innovation in the NEM in relation to the adaptive governance principles of SET theory. Based on lessons learnt from the NEM, section 8.3 suggests an adaptive governance framework for the decarbonisation and decentralisation of energy systems, such as that in GB.

8.1 IS TRANSFORMATION HAPPENING, OR NEEDED, IN THE NEM?

In Chapter 2, it was discussed that a system would need to either transition or transform dependent on whether the system in question was a desired system or locked-in to an undesirable cycle. Deciding whether the NEM needs to transition or transform, or is currently undergoing a transformation, depends on its resilience. If the system is resilient and therefore has a high adaptive capacity, is the current system able to absorb desired changes to the system and undergo a transition, or has it become locked-in to an undesirable path (Smith and Stirling, 2010; Westley et al., 2011)?

To decide whether the current system is resilient, it is necessary to assess if the current changes seen within the NEM have affected its function, structure, identity and feedbacks. If the changes are affecting these areas of the system, does the system have the adaptive capacity required to maintain the desired system, so allowing a transition to occur? However, if the system resilience is causing the system to be locked-in, and a desired change is unable to occur, or causing challenges within the structure, identity and feedbacks, so affecting the systems desired function, then this suggests that a transformation may be needed, or is occurring. In this case, SET suggests that governance will need to be adaptive to enable the transformation or to allow the system to transform to a new desirable state (Folke et al., 2005; Walker et al., 2004).

The following sections will discuss whether a transition or transformation is taking place in the NEM. Section 8.1.1 will describe the desired function of the NEM, then discuss if changes within the structure (section 8.1.2), identity (section 8.1.3) and feedbacks (section 8.1.4) are affecting this desired function and, therefore, whether a transition or transformation is happening or is needed (section 8.1.5).

8.1.1 Function

The government of Australia regards the NEM as an essential service, and its desired function is to provide an affordable, secure, and reliable electricity supply to customers (Government of Australia, 2019). These desired functions are delivered by government policies decided on by the COAG Energy Council and managed by the institutions who create the rules and regulations around the generation, costs and supply of electricity to the NEM customers (section 5.1). Any changes within the structure, identity and feedbacks of the NEM will need to guarantee that the basic function of the NEM will be protected.

As discussed in Chapters 5 and 6, due to the current national government's support of the coal industry, there are no national targets for decarbonisation. However, there are decarbonisation targets at State level, which suggests there are conflicts of interest for the desired function of the NEM, dependent on the viewpoint of the social actors within the system i.e. whether or not the desired function of the NEM should include decarbonisation.

8.1.2 Structure

The current structure of the NEM is one which is dominated by centralised generation and supply and an accompanying centralised governance structure (see Chapter 5). Although small-scale solar is currently the second-largest generator by fuel type in the NEM, centralised generation (including large-scale renewable generation such as wind and hydro) still accounts for 84% of total capacity (see section 7.2 & Figure 7-3) with the current centralised governance structure complementing this centralised system (Figure 5-1). The current trajectory for increasing decentralised generation in the NEM is expected to continue, caused by falling technology costs and an expected rise in energy prices. This is changing the physical structure of the NEM to a system which has a combination of both centralised and decentralised assets.

Similar to the emerging physical structure, the political structure of the NEM is a combination of centralised and decentralised decision making. The States are able to legislate and fund RETs (section 6.4.4) and implement State-based incentives/funding for 'green' projects if they wish (e.g. SA's VPP). The State-based incentives for DER were one of the drivers for the uptake of DER initially and it could be suggested that this decentralised approach to decision-making helped enable the emerging decentralised physical structure.

8.1.3 Identity

The majority of electricity generated in the NEM currently comes from fossil fuels, with coal being the largest fuel source (Figure 6-3). This carbonised system is being protected, in some way, by the lack of national decarbonisation policy. For Australia to meet its emission reduction targets, then the NEM will need to decarbonise, which is recognised by the NEM States that have a positive decarbonisation agenda.

The dominant renewable energy technology in the NEM is currently household solar PV, combined with an increasing amount of battery storage, which has mainly been delivered through State policy, and is reducing the demand for coal-generated grid-supplied electricity. As DER is the dominant RE resource in the NEM, this is changing the identity of the NEM at the distribution level, to a system that is increasingly becoming decarbonised

It could be suggested that as a DER owner, the identity of the customer can also be considered. The customer is now also a generator as well as a consumer – a prosumer. As a prosumer, the customer can have a positive effect on the desired function of the NEM. Through services such as aggregating DER, or using IT or smart services, the prosumer is able to offer network and market services to the NEM, so reducing wholesale prices, and in some areas reducing the need for network augmentation (AEMO and ENA, 2019). By becoming active and engaged in the energy market - through the use of new innovative business models such as aggregation, virtual power plants or microgrids (AEMC, 2019f; AGL, 2017; Government of South Australia, 2017) - a prosumer can have a positive effect on the desired function of the NEM by reducing costs for *all* electricity customers and also helping to maintain system security and reliability. However, should a DER customer *not* wish to become a prosumer, and instead choose to become independent, as discussed in Chapter 7, this may have negative consequences to the NEM functionality.

8.1.4 Feedbacks

Changes to the structure and identity of the current system and its actors will change the physical, economic and political feedbacks of the system.

8.1.4.1 Physical and economic feedbacks

Within the physical system, as demand for a centralised energy supply is reduced, so the infrastructure needed to supply and transport energy must support decentralisation, protecting the desired function by ensuring an affordable, secure and reliable supply of electricity for all electricity customers (see chapter 7, section 7.3). This change in the physical system then creates changes in the energy economics of the system.

At the wholesale level, DER has altered the NEM system operation so that flexibility services are required to complement the variability of RE generation and change in demand patterns (see chapter 7, section 7.1.1). This change in operation requires new types of generation, moving away from traditional 'baseload' generation, such as coal, to more flexible generation such as battery storage, hydro or CCGT. The transition within the market has changed the investment strategies of some of the large energy companies, such as AGL (Dunstan et al., 2017), but has also led to some incumbent interests resisting the change (see chapter 6, sections 6.2 & 6.4.3).

At the distribution level, introducing a distribution level market, and the new business models around coordination of DER for the distribution market (ENA, 2017b), creates questions around how customers should pay for being connected to a more dynamic system. Pricing for energy will need to consider those who wish to be prosumers, those who wish to be energy independent and those who are unable to become involved in a decentralised market. It is now the value of the connection to the grid that needs to be considered, rather than the amount of energy being consumed (see chapter 7, section 7.3.2).

8.1.4.2 Political feedbacks

Within the political processes, as larger amounts of households install DER, so there is added pressure on State governments to acknowledge the wishes of a large proportion of voters. This can be seen most clearly during the recent election of a Liberal Coalition government in SA. Although national policy for the national Liberal Coalition government is one of climate change denial and backing of the coal industry (see chapter 6, section 6.4.3), due to pressure from the large number of solar owners in SA, the new State Liberal government gave backing to VPP projects for social housing and offered new battery storage subsidies to households (Parkinson, 2018c).

8.1.5 Is the NEM undergoing a transformation?

The traditional function of the grid has been to supply an affordable, reliable, and secure, one-way flow of electricity to the consumer at the end of the low voltage distribution line. DER has changed the identity and structure of the NEM, from fossil fuel-based to one that is coming increasingly decarbonised at the distributed level, combining centralised and decentralised generation and requiring behavioural change from its customers, from a passive consumer to an active prosumer. These changes have altered the feedbacks within the system, all of which require changes within governance to maintain functionality.

As seen in Chapter 7 and discussed here, the increasing levels of DER on the NEM have caused challenges to the desired system function. There have been challenges associated with security and reliability as self-generation and export have disrupted the system operation and design. Visibility issues are causing challenges to matching supply and demand, and subsequently, issues concerning frequency and inertia. There have been issues regarding the affordability of energy for those that are unable to install DER, and pricing reforms have been suggested to ensure that the PSO is upheld. For prosumers to affect the NEM function in a positive way there are assumed levels of consumer engagement with the energy market.

Engaging in the energy market requires the customer to have a level of trust in the NEM institutions and utilities, something which is currently very low (see chapter 7, section 7.2.3). If the level of trust that the NEM has with its customers does not improve, and DER owners cannot be persuaded to engage, then DER owners can have a negative role in the desired function of the conventional system. By being 'energy independent' customers can reduce the amount of revenue for the traditional utilities causing further price increases for those unable to install DER (Box 7.1) as well as asset write-downs for some utilities (Synergy, 2019; Territory Generation, 2019) and the possibility of a 'utility death spiral'.

DER is now the largest RE generator in the NEM, but NEM governance is still tailored towards the traditional centralised structure i.e. a passive consumer receiving electricity at the end of a top-down, centralised electricity system, with the markets, rules and regulations built around the efficient, traditional operation of the centralised system. Maintaining the desired function of the system in the conventional top-down manner has required curtailing the amount of large or small-scale RE generation connected to the grid (see chapter 7, section 7.1.3.2 & 7.3.1), which allows the current government to maintain their support of the coal industry.

There have been issues with the federal government who are insisting that coal-fired generation is the only method to ensure reliability in the NEM, against the recommendations from some actors within the NEM institutions and industry (see chapter 7, section 7.1.3.2). The national government's support of the coal industry and the traditional centralised grid, combined with the lack of any decarbonisation policy past 2020, has left the States to initiate their own decarbonisation targets which support the use of DER, thus creating a grid which is becoming increasingly decentralised. The conflict between some of the NEM states and the national government, in relation to the desired function of the NEM, has caused challenges, as without any effective vision or coordination from central government (see chapter 6, section 6.4.4), this decentralisation has affected the desired function of the NEM.

If the changes that are taking place in the NEM are applied to the definitions within SET literature, the NEM and its governance would be assessed as being resilient i.e. the adaptive capacity within the system, rather than allowing for change, is perpetuating the existing structure and function, creating lock-in. For example, the ability of system actors to influence energy policy, rules and regulations (such as the federal government’s and some State government’s support of the coal industry and coal generation) is slowing the speed at which changes to governance can be made compared to the speed at which change is occurring. This allows the traditional centralised system to operate in a traditional manner but is causing challenges when trying to incorporate decentralisation, such as issues of visibility of DER, voltage regulation and system security. There is resistance to change by the incumbent regime as current NEM rules and regulations favour the centralised, fossil-fuel elements of the system and so the introduction of DER into this system is causing a loss of system functionality. An increase in decentralisation in a system that is protecting the centralised elements has affected the function, and changed the structure, identity and feedbacks, of the system. Had the adaptive capacity within the system been able to incorporate the new, emerging decentralised assets without a loss of system functionality then a transition could occur. However, the lock-in within the NEM institutions, the support at State level for DER and the lack of adaptability has affected this desired function and so the changes happening in the NEM could be better described as an unmanaged, bottom-up transformation. This type of transformation, although destabilising the existing regime and forcing change, is causing problems for the desired function of the system. To ensure that the transformation that is happening at the distributed level can be incorporated successfully, then SET literature suggests that this type of transformation needs to be managed and that adaptive governance is needed to achieve this fundamental change.

Although some reports and recommendations suggest a more adaptive style of governance (AEMO and ENA, 2019; AER, 2018b; ESB, 2019), these have yet to be acted upon. It is the current inflexible, centralised structure of NEM governance, combined with a lack of a national decarbonisation agenda and coordination within a rapidly evolving system, which is ultimately affecting system functionality. This has left the NEM in a position where there are questions around the reliability, security and affordability of an essential service, a service which still may yet undergo a 'utility death spiral'. It is the resilience of the current system which is leaving governance of the NEM with a '*limited window of opportunity*' (AEMO and ENA, 2019 pp. 9) in which to achieve the adaptability of governance needed to enable the decentralised transformation. This suggests that NEM governance needs to become more adaptive to facilitate the transformative change, which is being recognised, in differing degrees, by the NEM institutions (AEMC, 2019; AEMO and ENA, 2019; ESB, 2019). The question then is how to design energy system governance to be adaptive to enable decentralisation and to deliver the required outcomes, and are there positive, as well as negative lessons, to be learnt from the NEM?

8.2 ENABLING DECENTRALISATION

SET theory suggests, that to enable transformation, adaptive governance should encourage innovation from the lower levels in the areas of policy, technology, economics and society; and that these areas of innovation are coordinated to meet an overarching strategic priority. SET highlights the importance of social capital within the adaptive governance process, as social capital increases participation and representation in the policymaking process, leading to greater transparency and legitimacy and therefore trust.

In the previous section, it was discussed that the NEM is currently undergoing a transformation at the distributed level of the system. This suggests that some innovation has occurred for this transformation to happen. For a transformation to be enabled within the system, then the other adaptive governance processes of a national vision and coordination also need to be present. The following sections will assess what, if any, adaptive processes there are currently within the NEM by discussing the areas of policy (section 8.2.1), technical (section 8.2.2), social (section 8.2.3) and economic innovation (section 8.2.4) and, if there is innovation, how and whether this innovation is being coordinated to achieve an overarching aim, and the importance of this in achieving a fully adaptive governance process (section 8.2.5).

8.2.1 Policy innovation

Several authors suggest that local policy can be considered as a hypothesis, with the actions taken from the policy as experiments to achieve a desired aim (Nelson et al., 2008; Westley et al., 2011). Local policy may have different meanings dependent on the area or country in which it is being defined. In the case of the NEM, DER uptake was encouraged by the use of State policy and so, as an example of how local policy can be used to encourage change, State policy is to be considered as local.

In Chapter 4, the use of State RETs, FiTs and SBSs to encourage DER and the success of this policy, was discussed. Section 6.4 introduced Australia's current RET and commented on how it is due to finish in 2020, leaving Australia with no overarching national RE or emissions scheme. However, due the federal system of government, each State can set their own RET (see section 6.4.4). This decentralised policy process allows the State governments to enact or legislate energy policy at a State level (Table 8-1) e.g. to help achieve the targets as set out for Australia within the Paris agreement or to follow the Finkel recommendations. By being able to create RETs and associated energy policy at State level, the State governments can link these to other State-level priorities. State policies could be considered as being more locally representative than national policy and, therefore, more acceptable to the public.

Within the theory for adaptive governance, authors suggest that when deciding on local policy that the effect of political influence should be diluted (Folke et al., 2005; Nelson et al., 2008; Schultz et al., 2015). As each of the States has its own elected state government, and some of these governments can gain revenue from the coal and energy industries, the effects of politics on energy policy are noticeable. Although each State has set a RET, how effective this will be may depend on whether there is either a legislative target or recommendations (Table 8-1). SET also suggests that policy should be coordinated to meet an overarching aim (Nelson et al., 2008; Westley et al., 2011). NEM State policy, and how a national vision would assist in diluting political influence, will be discussed in the following sections.

8.2.1.1 Current State policy for decarbonisation

Currently all the NEM States, except for SA, have a RET. The ACT has legislated a target of 100% of its electricity to be met by renewable generation by 2020 (ACT Government, 2016). Victoria has a legislated target of 50% of energy to come from RE by 2030 (Victoria State Government, 2019). New South Wales and Queensland have suggested targets of 20% by 2020 (NSW Government, 2018), and 50% by 2030 (QLD Government, 2016), respectively. Tasmania expects to reach 100% of energy produced by RE by 2022 (Tasmanian Climate Change Office, 2017) (Table 8-1).

Both VIC and the ACT, which have Labor governments that have positive decarbonisation agendas, have set legislation and introduced schemes that will benefit their State, not only for achieving decarbonisation but also for employment opportunities from RE by increasing industrial investment within the State. Queensland, although a Labor seat, has an ambitious target which is not backed by legislation. The 50% RE target appears to be a nod to the environmental concerns over the Great Barrier Reef (see section 6.5), but the lack of legislation around the target seems to be trying to appease Queensland's strong coal lobby and the State government's vested interests in mining and the electricity infrastructure (see section 5.2 & section 6.2). QLD has also introduced new rules regarding the installation of solar that requires only qualified electricians to handle, as well as install, solar panels for solar farms (State of Queensland, 2019), increasing construction costs to levels that reduce the competitiveness of solar with coal generation. The lack of legislation, and new rules, have led some to question the legitimacy of the Labor government's 50% renewable energy target (Parkinson, 2019c). In NSW, the vested interests in mining leases and the State's position as one of the largest coal producers could also be attributed to the low RET and lack of ambitious investment in RE.

SA has legislation in place, but no new target was set for RE past 2020 following a change in government. However, due to the investment strategies of the previous Labor government, pipeline projects and current installations means that they will achieve a 75% RE penetration by 2025, easily exceeding their previous 50% RET (section 6.4.4).

TAS already has a high penetration of RE due to the majority of its electricity generation coming from hydropower (Figure 6-3). State government initiatives intend to increase hydro and wind power and to act as 'The Battery of the Nation' by improving interconnection between the island the mainland (Potter et al., 2018).

Table 8-1 Policy and legislation for state RET (ACT Government, 2016; NSW Government, 2018; QLD Government, 2016; Tasmanian Climate Change Office, 2017; Victoria State Government, 2019)

State	Renewable Energy Target	Legislation and RE policy initiatives	Party affiliation
ACT	100% by 2020	Electricity Feed-in (Large-scale Renewable Energy) Act 2011 (ACT) Next Generation Energy Storage (Next Gen) Program Community Solar Scheme (opened 2015 for 1MW capacity) The Renewable Energy Industry Development Strategy	Labor
VIC	50% by 2030	The Renewable Energy (Jobs and Investment) Amendment Bill 2019 (Vic) Climate Change Act 2017 New Energy Jobs Fund The Renewable Communities Program (RCP) Solar Homes Program	Labor
NSW	20% by 2020	Solar Power Purchase Agreement (PPA) Program Growing Community Energy Grants Program Clean Energy Knowledge Sharing Initiative	Liberal
SA	No state target	Climate Change and Greenhouse Emissions Reduction Act 2007 (South Australia) Grid Scale Storage Fund Home Battery Scheme	Liberal
QLD	50% by 2030	Advance Queensland Solar 150 investment program Renewables 400 reverse auction	Labor
TAS	100% by 2022	Battery of the Nation pumped hydro plans Tasmania's Climate Change Action Plan 2017-2021 (Climate Change 21)	Liberal

State government's manifestos and policies are representative of their political Party's national objectives, but at this more local level must also be accountable to local priorities and requirements. Although non-governmental participation in State policymaking is not a formal requirement, the State government can be more influenced by local issues than the federal government, in either a positive or negative way. An example of a positive influence on State policy can be seen in the SA election in 2019. In the run-up to the state election, both the Labor (pro-RE) and Liberal (pro-coal) party made election promises to continue the incumbent Liberal SA governments VPP trial following the election and both Parties made election promises to introduce subsidies for battery storage (Parkinson, 2018c). The effect of previous government policy has meant that in SA, large- and small-scale RE is now heading on a trajectory that would be difficult to stop and has meant that RE receives support from both of the major political parties (ibid.).

Innovation in policy at State level has not produced the same positive results in every state in Australia, particularly in NSW and QLD in which coal plays a significant role (see section 5.2 & section 6.2), and as such vested interests within the local government, and the need to protect local jobs, continue to play a part. The difference between the States can be attributed to the lack of an overarching vision and lack of coordination to reach the vision. Having no national RE or decarbonisation policy (see section 6.4.3) leaves the States with no real necessity to provide legislative RE targets. State RETs and funding for projects are arbitrary, based purely on State government acknowledgement of whether RE and DER will be beneficial to State residents, business and industry and the State government's decarbonisation agenda.

8.2.1.2 National policy for the decarbonisation of the NEM

At a national level, the Finkel review (Finkel et al., 2017) made recommendations for the future security of the NEM. Forty-nine of the fifty recommendations within the review were approved by the COAG Energy Council, however, the CET was not (see section 5.1.4). Following the 49 recommendations has given the NEM an overall vision for the direction of the NEM, and has allowed AEMO to create plans, such as the Integrated System Plan (ISP) and the Distributed Energy Integration Plan (DEIP) (see section 5.1.4) for the integration of RE and DER.

The Finkel review sets out a plan for the NEM to achieve decarbonisation and the integration of DER while maintaining the security of the NEM. The ESB has been appointed to oversee the implementation of the approved Finkel review recommendations (see section 5.1.4) and as such is acting in a coordination role between the national NEM institutions. However, there is no coordination between the States and the national institutions other than for technical coordination through the market operator, which is due to the necessity of maintaining reliability and security within the NEM, and the positive outlook for decarbonisation from the current leadership of AEMO (see section 8.2.3.3), rather than through any formal obligation.

What is lacking in the NEM, is a legal duty or timeframe for the national and State governments to achieve the vision that has been set out within the Finkel Review, which would have been provided by the Clean Energy Target had it been approved. The lack of a legal duty or timeframe, and therefore policy coordination from a Clean Energy Target, has diluted the effect that the Review may have had. The COAG Energy Council are currently consulting on a Strategic Energy Plan (COAG Energy Council, 2019), which is to provide a '*strategic focus and clarity of direction to market bodies and market participants*', but by currently having no national target for decarbonisation the only timescale, and subsequent coordinating factor for the NEM, is the rapid transformation that is happening at the customer level, which has left the ISP and the DEIP, as the only current 'policy' available.

8.2.2 Technical innovation

In Chapter 4, the drivers for the current DER uptake were discussed. This initial uptake has required further innovation in the technical sphere to enable the decentralised grid. The need for technical innovation to combat challenges arising from DER uptake saw a change in the regulatory process. In September 2019, following a rigorous consultation process, the AEMC introduced a regulatory sandbox as part of the 2019 *Electricity network economic regulatory framework review* (AEMC, 2019g). The sandbox arrangement was seen as a vital constituent to allow proof of concept testing in a more flexible environment. The sandbox provides an enquiry service for innovative trials to assess feasibility under the current rules and regulations. It then allows trials to operate with a regulatory and rules waiver where the trials can be seen to have a potential positive customer benefit within the NEM, although there is no mention of low-carbon or zero-carbon within the feasibility rules (ibid.).

Innovation funding for Australia is currently provided by ARENA. ARENA was established in 2012 by the Australian Renewable Energy Agency Act 2011. ARENA's A-lab initiative created a process in which the NEM institutions and the ECA can assist participants to develop innovative technologies and business models for RE. At present, there is a total of Aus$1.46bn being provided to 486 projects across all the Australian States and Territories. Projects funded by ARENA are required to share learning from the trials through their Knowledge Bank (ARENA, 2019b). Projects, such as those in the Fringe of Grid (FOG) portfolio (Ekistica, 2018), have enabled lessons learnt for a rule change for Standalone Power Systems (SAPS). This rule change followed on from an initial submission in 2017 from Western Power. The initial rule change was rejected due to the broader requirements the AEMC felt needed to be investigated but have since been provided by the ARENA funded FOG projects. The SAPS rule change provides a new regulatory framework for the provision of standalone systems where this would lead to cost savings for electricity networks (AEMC, 2019c).

ARENA has funded other projects that have value in enabling grid decentralisation. The Digital Energy Exchange (DeX) project is now undergoing a live trial as part of the SA VPP (ARENA, 2017) and the Hornsdale Battery is undergoing feasibility testing for battery storage to be configured for FCAS provision (AEMO, 2018e). ARENA has been a vital constituent in providing funding for the various technical trials that are currently helping the institutions and industry of the NEM towards decarbonising the Australian energy industry and the integration of DER on the grid. It is expected that the ARENA funded trials, which will soon also receive institutional support through the new regulatory sandbox, will be essential to the system transformation (ARENA, 2019c). The new regulatory sandbox should assist with faster rule and regulatory change for projects which show a customer or service benefit.

ARENA funded projects, and soon those that participate in the regulatory sandbox, have an obligation to share knowledge. Knowledge gained from trials, through either success or failure, is one of the principal values of innovation trials. Within AG, policy as hypothesis suggests an increase in experimentation, with knowledge sharing as a vital method of increasing social capital (Dietz et al., 2003; Nelson et al., 2007). In the case of technical innovation within the NEM, ARENA and now the AER, are acting in a coordinating role, with an obligation for trials to show customer benefits or better services, and the results of the trials made publicly available. Adaptive governance suggests that the actions taken from local policy should be seen as experiments which can then be diffused or scaled-up (Folke et al., 2005; Westley et al., 2011). Lessons can be learnt for AG processes from the manner in which ARENA has enabled technical experimentation and the method in which ARENA's Knowledge Bank has enabled separate trials to be bought together, such as with the FOG portfolio, that led to the rule changes for Standalone Power Systems.

However, funding for ARENA is due to end in 2022 and the current government has not issued any statements to suggest that it will continue funding the agency. This would then leave the AER, with its direction set by the AEMC, as the only method for integrating and coordinating technical trials in the NEM. AG suggests that an increase in social capital would come from knowledge networks, such as those conceived by ARENA, and that these networks should be politically independent (Folke et al., 2005; Nelson et al., 2008; Schultz et al., 2015). As is discussed in the following section, the lack of outside participation within the AEMC, and so subsequently their influence over the AER, leaves little transparency and legitimacy within the institutions, and so the technical innovation process may become subject to influence from incumbent industries.

8.2.3 Social innovation

One of the important aspects of AG is the increase in social capital which is achieved through increased participation of non-governmental and industry actors within local and national organisations and institutions (Dietz et al., 2003; Folke et al., 2005; Schultz et al., 2015). An increase in social capital would also provide greater opportunities, through increased diversity (Granovetter, 1973), for transformative leadership which would be able to recognise and identify opportunities and constraints (Folke et al., 2005).

8.2.3.1 Encouragement of local actors

The most pronounced social innovation within the NEM is that DER uptake has changed the focus of industry and institutions from one where the customer is seen as a consumer of energy who is suppliant to the will of the market, to one who can become a prosumer and have an active role in the energy system (see section 7.3). As a consumer, the customer had little influence over the energy industry. Decentralisation of the system through the uptake of DER has now changed this role, and as a prosumer, the customer now has the ability to either have a positive or negative effect. Energy customers are the instigators and the focus of the transforming energy system. The role of the prosumer needs to be valued by the industries and institutions within the NEM (see section 7.4) so that decentralisation has a positive effect on the affordability, security and reliability of an essential service.

8.2.3.2 Increasing representation and participation

Currently, representation and participation in the NEM comes from electoral influence over state policy, trials for new business models such as the VPP, and the consultation process used for changes to rules, regulations and standards. There were criticisms in the interviews of the lack of outside representation in the AEMC and although the ESB is welcomed as a new institution to bring together the views of the NEM institutions, there is still a lack of representation from NGOs or customer advocacy.

> *'And the problem with the AEMC is that they are a bunch of unelected quangos who have no accountability whatsoever in our experience. So they just simply ignore consumer advocacy...'*
>
> Interview M7 ad

The ECA is a governmental organisation for consumer rights, yet they have no representation on the boards of the AEMC or the ESB. Board members of the ESB and the AEMC are industry and network representatives, with two of the AEMC board members having been instrumental in Australia's previous energy reform, which created the current centralised system (AEMC, 2019h).

Within the institutions and industry, there has been a trial to improve inclusivity within decision-making processes. The AER's New Reg trial in Victoria (see chapter 7, section 7.3.1) required the distribution network to create a customer forum, which represents customer perspectives and whose members have a range of skills and experience. This type of customer representation intends that the future network expenditure plans would take advice and recommendations from the forum and would be more closely aligned with the future needs of the local customer. As the expenditure plan would have included an independent and rigorous customer focussed process, it is expected that the regulator would be more agreeable to the proposed expenditure budget.

Also in Victoria, the Power Changers trial by Jemena (see section 7.2.3) encouraged behavioural change to reduce expected peak events. One of the results from the trial was the building of a new relationship between the network and the customer of understanding, communication and trust.

8.2.3.3 Enabling transformative leadership

The main source of positivity for energy system change within the institutions has come from the leadership of AEMO. The appointment of Audrey Zibelman as CEO of AEMO was described by interviewees as a '*breath of fresh air*' (C3 NGO) in one case and recognised by another as the '*biggest single source of change within the institutions*' (C5 ac) of the NEM.

Previous to her appointment, Ms Zibelman was instrumental in the design of the New York: Reforming the Energy Vision (NY REV) program which sought to create fit-for-purpose governance for sustainable technologies (New York State, 2014). The fit-for-purpose governance would include changing system operation and regulation, encouraging new business models and creating a system which would be founded around the wishes of its customers. Ms Zibelman's recognition of the complexities of energy system change was seen as a positive step for the NEM.

> *'I think there's some positives, we do have limited interaction with AEMO, but I think their new leader, Audrey Zibelman, is a much more, a person who is alive to the consumer and social impacts of energy market policy and regulation, just from the way in which she conducts herself and speaks and the direction they are taking. That is positive.'*

Interview M7 ad

AEMO has been supportive of the many trials that have taken place, including the SA VPP (AEMO, 2019a) and the Hornsdale FCAS Project (AEMO, 2018f), and have worked closely with the ENA on the Open Energy Networks program which seeks to construct a market for DER (AEMO and ENA, 2019). AEMO has also included a new market design which recognises flexibility as part of the ESB's Post 2025 Market Design consultation (ESB, 2019) and for a register of DER to increase the visibility of DER on the Networks (AEMO, 2019c). Other AEMO led and joint projects include the ISP and the DEIP which are, as mentioned, the only current plans for the integration of renewable energy and DER currently available (AEMO, 2018a; ARENA, 2019a).

The federal system of government in Australia has allowed transformative leadership within the NEM through the government of South Australia. As previously mentioned, the long-standing Labor government, under the leadership of Jay Weatherill, created a stable policy landscape for RE generation and DER. Generous FiTs in the state helped towards the rapid uptake of DER which saw gird demand reduce. This reduction in demand, coupled with an increase in large-scale wind and solar, enabled SA to meet the capacity shortfall that was left by the closure of the Northern coal-fired generator (AEMO, 2018h). The legacy of the Labor leadership in SA has now created a political landscape for energy that has reached a tipping point. Even if a new state government wished to slow down the transformation that is happening, it is now not possible to do so.

SET literature suggests that transformative leadership is an important part of the transformation process (Engle, 2011; Folke et al., 2005; Gupta et al., 2010). Increasing participation and representation in the governance process will increase diversity so leading to more opportunities for transformative leaders to appear (Granovetter, 1973). Although there are moves to increase participation within the institutional framework, these are currently only within regulation for the distribution networks and are only being trialled with one of the thirteen distribution companies in the NEM. There is still no representation on the boards, or the executive leadership, of the AEMC or the AER of a consumer advocate or NGO and, without the leadership of Audrey Zibelman, it is doubtful that AEMO would be as progressive as they are. Considering the changing role of the customer in a transforming energy system, the lack of customer representation within the NEM institutions is concerning.

8.2.4 Economic innovation

DER has enabled new methods of buying and selling electricity. Within the NEM there have been new initiatives such as aggregation of particular storage technologies to produce a virtual power plant (e.g. Sonnen, 2019 and AEMO, 2019b). There has also been the use of blockchain technology to introduce peer-to-peer electricity trading (e.g. PowerLedger, 2019). These new methods, enabled by IT, have changed the feedbacks of the system and have allowed DER customers to become prosumers, which is beneficial to all NEM customers.

This change in the role of the consumer to a prosumer has changed the electricity flows on the network. This has then changed how the networks need to operate the system. Current regulation is focussed on economic efficiency to ensure that the amount networks are charging customers is fair. Future regulation of the networks will need to focus much more on enabling decentralisation, with the customer as the central focus, rather than just on economic efficiency. The most economically efficient way for the networks to answer the challenges of decentralisation would be to disallow DER connections, so reducing congestion and voltage issues. This would not, however, help towards decarbonisation and would increase costs for those customers unable to install DER. Changes are needed within regulation, to incentivise the networks to find alternative solutions for the decentralisation challenges that benefit the decarbonisation agenda and affordability for all customers.

8.2.4.1 Network regulation

In 2014, the AER proposed regulatory reform to move to more incentive-based regulation, incentivising the network companies to improve efficiencies (AER, 2014). This package of reforms did not, however, reduce the ability of the network companies to 'game' the system and did not incentivise the inclusion of DER (AER, 2014). There were also the problems associated with technical regulation being in the hands of local governments, some of whom had vested interests in gold-plating the networks and so increasing the value of their regulated asset base (see section 5.2.2). The network companies were also critical of the AER as, even if they had shown an increased consultative approach to assessing future revenues, they felt the AER would always reduce their expected revenue allowance (see section 7.3.1).

The New Reg process (AER, 2018b), which is currently being trialled, is seen as a solution to many of the problems that the regulators and the networks are currently experiencing. Having a revenue assessment process, which undergoes an extremely rigorous customer consultation, ensures that the individual network company tailors their revenue proposals to suit the local area requirements, and so putting the customer at the centre of the networks business plan.

The need to have a more decentralised approach to network regulation, which the customer forum allows, is particularly relevant in the NEM and complements the decentralising system. Thirteen distribution companies are covering very different geographies. For example, in Victoria, three distribution companies are covering the city of Melbourne, and two covering the more rural areas. Each distribution company has different priorities, some have a large business customer base, some have city suburbs, while others have many fringe-of-grid customers. The consultative approach that the customer forum allows creates a revenue determination that prioritises the needs of the local customer base. Should this regulation trial be followed in the future, then the role of the national regulator becomes more of a coordination role, which could be used to incentivise priorities for network companies to meet the recommendations for network operation, as set out in the Finkel review.

8.2.4.2 Pricing regulation

As the States joined the NECF, regulation for retail pricing was moved into the national space and the AER took over the role for energy market retail regulation. The exception to this is VIC, who did not join the NECF due to the recent completion of their smart meter roll-out (see section 5.1.3). This allowed the Victorian ESC to create a retailer led energy efficiency scheme as part of the VRET, which has a Victorian Energy Efficiency Target (VEET) as part of its legislation. Victoria also has a legislated minimum requirement for solar FiTs, to be paid by the retailer, which is based on the ESC's calculation for the benefits of DER. Following an amendment to their legislation[13], these benefits now include a requirement to calculate '*the avoided social cost of carbon and the avoided human health costs attributable to a reduction in air pollution*' (ESC, 2017). The ability of the federal government in VIC to set legislation for RETs, for energy efficiency and local FiTs has meant that Victoria can have a more cohesive local energy policy. However, VIC will need to update their retail regulation to match the changes that are currently under review for customer protections in the NECF (see chapter 7, section 7.2.4). The review updates customer protections for household demand response, and other business models and DER related issues.

8.2.4.3 Pricing reform

The uptake of DER in the NEM has meant that the idea around the value of energy is changing. In their report *The Network Value of Distributed Generation* (Essential Services Commission Victoria, 2017), the ESC concluded that the way to fairly charge and pay customers for DER services is to have a distribution level market. The ESC suggested that this market should take account of the time-location-social value of DER services and requirements. The use of a distributed energy market (DEM) has also been recognised by AEMO and the ENA and there are currently four possible options for the operation of the market under consultation (AEMO and ENA, 2019). The use of a market for DER also has the added benefits of reducing the need for network augmentation and in reducing the need for private investment in new generation (ibid.).

Until the distribution market is established, and assuming that DER owners want to engage with a market, there are conversations around how to pay for the networks currently, with time-of-use tariffs and capacity payments being the main considerations. As previously mentioned, it is the value of grid connection that will become an important factor, rather than the value of received energy (see section 7.3.2). The problem for the NEM is that the economic innovations, particularly around regulation and pricing need to happen at the same pace as the current DER uptake. The lack of synergy between this uptake and economic innovation is what may still cause the NEM to undergo a utility death spiral.

[13] Energy Legislation Amendment (Feed-in Tariffs and Improving Safety and Markets) Act 2017 (Vic), assent date 14 February 2017

8.2.5 The importance of vision and coordination

Within the NEM there are political, technical, social and economic innovations occurring at the distributional areas of the system. Innovations at the political level have occurred in the State sphere through State accountability and decentralised government processes that allows the States to set RETs, and, in the case of SA, due to transformative leadership and a stable policy landscape. Technical innovations have been supported nationally, and knowledge shared through the funding from ARENA. The technical and political innovations have promoted social innovation in the form of the rise of the prosumer. Supporting the rise of the prosumer, economic innovations for decentralisation have included the use of VPPs and aggregation, and the use of blockchain technology to buy and sell energy. The rise of the prosumer will need to change how the networks determine their future revenues and how energy is priced.

The recent consultations on the post-2025 market design and the Open Energy Networks distribution market, although welcomed, may still be too late to capture the value from DER that will assist in the affordability, security and reliability of the NEM. The lack of outside participation within the decision-making processes of the NEM institutions means that there is a lack of the transparency and legitimacy needed to create trust with the NEM customers, something which will be essential to encourage DER owners to become engaged prosumers. The DEIP is a welcome move to correct this but is still in its early stages and, at time of writing, has not been initiated.

The current transformation in the NEM is due, in part, to some adaptive governance processes at the State level. State policy has created State RETs, and these policies have created areas of experimentation in the social and technical parameters which have allowed for further experimentation in the economic spheres, so allowing a transformation to occur at the distributed level. What is lacking in the NEM are the other requirements for a fully adaptive governance process that manages transformation i.e. mid-level coordination of the experimentation process to achieve a strategic national priority (Nelson et al., 2008; Westley et al., 2011), which can be attributed to the national government’s support of the traditional industries.

Essentially, the lack of vision and coordination, and a lack of social capital within State government and the NEMs centralised governance structure, has left the NEM in a position where it is reactionary to new events rather than anticipatory, and lacking the trust it needs from its customers. Unless it moves quickly to more adaptive governance principles, something which is recognised within the New Reg process (AER, 2018b), the Open Energy Networks project (AEMO and ENA, 2019) and the DEIP (ARENA, 2019a), then the NEM may well be unable to maintain its function as an affordable, secure and reliable electricity system.

8.3 AN ADAPTIVE GOVERNANCE FRAMEWORK TO ENABLE ENERGY SYSTEM DECENTRALISATION

As discussed, there have been aspects of adaptive governance that have helped to initiate the transformation that is occurring in the NEM. In particular, the ability of the States to set local energy policy. There are also aspects of adaptive governance that are missing i.e. vision, coordination and customer representation and participation (summarised in Table 8-2). The lack of vision and coordination has led to a missed opportunity for the NEM to create an adaptive process that may enable transformation, by coordinating positive innovations to improve system functionality. A lack of customer participation and representation has allowed vested interests and incumbency within the energy system to slow the changes needed to enable decentralisation. Instead, the NEM is currently undergoing an unmanaged, decentralised transformation, causing challenges that are negatively affecting the desired function of the NEM.

Table 8-2 A comparison of the principles of adaptive governance for energy systems from Table 2-1 to the present governance in the NEM (source: author).

Adaptive Governance Principles for energy systems	The NEM
Customers at the centre of the policymaking and regulation process	Trial with AER and Victorian distribution network
Empowered local policy	at State government level
Knowledge sharing	as part of ARENA's funding; new AER sandbox
National vision and target for decarbonisation	not legislated, suggested within the Finkel review
Coordination of innovation	only for technical trials (ARENA)
Coordination of local policy	no
Coordination between the physical and operational elements (distribution, transmission, markets)	under consultation; SA trial of DEM

As discussed in Chapters 1 and 7, DER (which includes the demand side) can provide some of the solutions to decarbonisation and will need to be used in conjunction with centralised RE and system flexibility solutions to meet decarbonisation targets (AEMO and ENA, 2019; CCC, 2019). However, these positive solutions also bring new challenges. The introduction of DER creates an evolved system which adds various distribution-based options (whether supply, demand, storage, system flexibility) to the broadly centralised approach. It also provides the ability for the new distribution-based prosumer to trade their energy whether in the distributed area of the system or with national flexibility programs.

This section aims to create a framework for adaptive governance which may answer some of the challenges introduced by decentralisation and can be applied to similar energy systems, such as GB. This is achieved by using the lessons learnt from the case study of the NEM and adapting the theories for adaptive governance from SET. Transformation in the NEM occurred in the distributed area of the system, and so lessons can be learnt from this case study for managing this type of transformation and the challenges that can occur as a system evolves. The following sections will describe the elements needed within AG for energy systems, to create an adaptive governance structure that may aid energy system decentralisation to help meet national decarbonisation targets.

8.3.1 The customer at the centre of the policymaking and regulation process

Creating a new governance framework to enable decentralisation requires designing governance around the customer, as the customer is now the heart of the system.

Enabling DER can reduce costs for all customers by reducing the wholesale price of electricity and reducing network investment. The institutions and industries in the energy system need to recognise that an energy system that includes DER, so becoming more decentralised, only operates efficiently for all customers if the customer is active and engaged. To gain customer trust, customer representation is needed throughout the decision-making processes. Customers need to trust the institutions and industries to encourage them to become a prosumer. This requires transparency and legitimacy in the decision-making processes through increased customer participation and representation in all aspects of system governance, including policy and regulation.

8.3.1.1 Customer protections

Customer protections, such as financial protections and national safety standards, are needed for new technologies and business models. As it is not possible to predict the innovations of the future, broad standards and protections may be required e.g. minimum safety requirements for electrical installations, consumer protections for the selling practices of new business models, retail pricing regulations to allow customers to easily compare retail offers, and follow national and international guidelines. By creating a broader set of standards and protections in this way, innovations to meet challenges would be able to operate under a clear set of guidelines. Following international standards may also open overseas markets for local initiatives, or for innovation to come from elsewhere. To reduce the difficulties of diffusion or scaling up of innovation, it may be prudent to continue to create consumer protections and standards at the national level, and under centralised control.

8.3.2 Empowered local policy

As seen in the NEM, State policy was able to create a stable investment landscape for RE and DER. The uptake of DER then allowed for innovation within the economic, social, technical and political parameters. However, this was only true of the States which had a positive decarbonisation agenda. The lack of an overarching national policy, with targets for the timely delivery of achieving decarbonisation, left those States with vested interests in the political sphere little incentive to promote decarbonisation. The influence of vested interests in the State policymaking process can also be attributed to a lack of participation and representation from outside of government. Increasing outside participation and representation would reduce the power of lobbying from interest groups.

To achieve positive decarbonisation and decentralisation policy, local policy could be created through understanding how local needs and resources - where resources include the environmental resource plus the social resource combined with the technical and economic capabilities of meeting local needs - may help to meet a national vision. It would be recommended that local policy is empowered by local funding so that funding can target the needs and resources of the local area (e.g Victoria's VEET and VRET).

Innovative approaches to challenges associated with energy system decarbonisation and decentralisation could be encouraged by opening participation in decision making. In this case, local energy policy could be decided with representation in the policymaking process from all political parties as well as customers, community groups, advocacy, NGO's, academia, and industry representatives and the institutions of the energy system. Creating local energy policy in this way increases social capital allowing for more diversity and hence innovation, plus the possibility of transformative leadership. Practical examples of AG have shown that creating local policy in this transparent and legitimate way increases the trust of individuals in institutions and industries (Dietz et al., 2003; Engle and Lemos, 2010; Westley et al., 2011) which, as mentioned previously, is essential for DER owners becoming prosumers, thereby benefitting all energy users.

As part of local policy, and in a similar vein to the ISP (AEMO, 2018a), local areas could create a local energy plan which sets out local objectives over the short-, medium, and long-term. Creating a plan in this way allows the institutions and industry to work with the local initiatives set by the plan to achieve a positive industrial, economic and social outcome for decarbonisation and decentralisation.

The local energy plan could become instrumental in how the distribution networks decide on their future revenue determinations. Using a process, such as the New Reg process, this allows the networks to work with a customer forum to show how their investments could enable the outcomes identified within the local area plan.

Creating revenue determinations in this way are more transparent and legitimate and enable the distribution network companies to increase their levels of customer trust. The increased use of customer participation and creating a revenue determination that helps to achieve a local energy plan may, as a result, increase the trust between the networks and the regulator. This may allow the role of the national economic regulator to change as it reduces the need to assess the business plans in terms of benchmarking performance or questioning the revenue determinations. The role of the national economic regulator could then become a coordinating role, to provide output based regulation (see Mitchell, 2016) for the networks, encouraging them to use innovative and cost-effective means to help to meet the national objective through their local collaborations.

8.3.3 Coordination of local policy

As can be seen from the NEM, creating local policy with no overarching vision allows local policy to meet the needs of the local area even if these needs are counter to the decarbonisation goals of climate change mitigation. To meet a national vision, there would need to be coordination of local policy to ensure that local policy objectives are aligned to the strategic national priority.

8.3.4 Coordination of innovation through knowledge sharing

Coordination of innovation may be needed to promote the technical, economic, political and social innovations that come from the local policymaking process. A knowledge-sharing initiative may be used so that innovations can be shared between local regions to be diffused or scaled-up. Knowledge sharing could also include areas of experimentation that have *not* been successful to avoid repetition. The open-access platform of ARENA's Knowledge Bank is an excellent example of knowledge sharing for technical innovation and could be replicated for innovation in other areas. The benefit of this type of coordination of knowledge is that it amplifies the identification of where changes to the national rules and regulations are needed, to allow innovation within any area of the energy system.

8.3.5 Physical and operational coordination

Protecting system functionality as the system evolves to include decentralisation requires both physical and operational coordination. A distribution market operator may be needed and could be created by changing the current network role from a distribution system operator to a distribution system provider or be provided by a new separate entity. The new decentralised markets require coordination between themselves and the wholesale market. This role could be a new, separate, independent market coordinator, or the responsibility of the current market operator (AEMO and ENA, 2019).

The use of a decentralised market changes the flows on both of the supply networks. As well as a two-way flow on the distribution network, decentralisation also changes the flows on the transmission network as DER, through either self-generation or aggregation, in conjunction with other demand-side options, are able to meet local demand. Changes to the way the networks are regulated may need to include coordination of the networks business plans to ensure that future plans recognise these changing flows and are incentivised to meet any future challenges.

8.3.6 Adaptation to the future unknowns

Within this section, I have examined how adaptive governance can be framed to assist in the current energy system decentralisation. As discussed in Chapter 2, the energy system is complex, and disturbances may come from any part of the system. As a complex system, changes within one part of the system will invariably create challenges within another. Adaptive governance increases the flexibility of the system by increasing the innovation capability for solving challenges created through change, whether these changes are positive or negative and foreseen or unforeseen.

It is also not possible to predict how the energy system may need to change or evolve in the future. An adaptive governance framework manages a transformation and then allows the new desired system to be resilient, and have a high adaptive capacity, by adapting to changes through the benefits of increased social capital. Should this desired system be considered undesirable in the future, then adaptive governance can allow for a new system transformation by creating a new desired vision and allowing local regions to adapt their local policy, which is then coordinated to meet the new vision.

8.4 Conclusion

One of the major lessons to be learnt from the NEM is the unpredictability of change and therefore, the need for flexibility and coordination within governance to gain the benefits that this unpredictability may bring. The governance of the NEM needs to facilitate this unexpected change to protect the desired system function. This may be achieved by updating the rules and regulations (AEMC, 2019d), creating new markets (ESB, 2019), and possibly creating new institutions (AEMO and ENA, 2019; Mitchell et al., 2016; Willis et al., 2019a). New methods of regulation are also being discussed which incentivise the utilities to change from a business as usual scenario to one which allows new and innovative products and services to optimise DER in the NEM (ENA, 2017b). The NEM case study shows the importance of coordination, both vertically and horizontally between the physical and operational elements, as DER is able to both cause and answer some of the challenges associated with a decarbonising energy system. Updating the rules and regulations, creating new markets for DER and for flexibility, as well as pricing reforms, may help to answer some of the challenges around the affordability of energy supply while still maintaining the reliable and secure functioning of the system.

For NEM governance to protect the desired function of the system, the principles of adaptive governance suggest that the current transformation in the NEM would need to be managed in a positive way. However, taking lessons learnt from the NEM, for adaptive governance to have this type of positive management, adaptive governance *must* include a national vision for decarbonisation, with coordination of the current local initiatives to meet these national decarbonisation targets and coordination between the physical and operational elements. Unfortunately, due to the national government's support of the coal industry, a national vision for decarbonisation is unlikely, however AEMO's possible introduction of a flexibility market may still enable some of the value of DER to be captured within the NEM.

Following the theory for SET and the lessons learnt from the NEM, this chapter has suggested a general adaptive governance framework for energy systems that could enable decentralisation through a managed transformation and can be applied to similar energy systems elsewhere. This framework would require that:

- Customers are at the centre of the policy and regulation process, thereby creating transparent and legitimate processes which increases customer trust and accessibility;
- Broad national customer protections and standards are created, to allow for innovation under clear guidelines;
- Local areas are empowered, to allow for local policymaking and funding to create areas of experimentation for innovation in the social, technical, economic and political parameters, including a local area plan;
- Local areas will require coordination, this may be achieved through policy coordination, creating a distribution level market, creating a more adaptive regulation process and through knowledge sharing that will help to meet a national vision;
- Further physical and operational coordination is needed between the decentralised and centralised assets/institutions, and that
- coordination will only be effective if there is a national vision and target for decarbonisation.

Application of this framework to other energy systems is then possible to either understand (i) if elements of this framework are currently being used, and if this is helping to enable a system transformation, (ii) if, due to the complexity of the energy system, governance of transforming systems are being pushed towards more adaptive principles as set out in the framework, or (iii) as will be demonstrated in the following chapter, applying the framework to suggest an adaptive governance process to enable the decarbonisation and decentralisation of energy systems.

9. ADAPTIVE GOVERNANCE: A FRAMEWORK FOR DECENTRALISATION IN GREAT BRITAIN

The GB parliament has declared a climate emergency and the government has set a target of net-zero emissions by 2050 (CCC, 2019). As well as the national level, 237 local authorities in GB (ranging from parish councils to devolved national governments) have also declared a climate emergency, with 67% of those setting a more ambitious net-zero target of 2030 (Harvey-Scholes, 2019).

As GB moves towards a decarbonised energy system, system design and operation is expected to become characterised by a combination of centralised and decentralised facets (NIC, 2016; Ofgem, 2017a). By taking the lessons learnt from the NEM, in how a lack of adaptability can affect system function, the purpose of this chapter is to begin a discussion on how an adaptive governance could be framed and applied in a GB context.

In GB, the National Grid ESO has provided possible future energy scenarios (FES) dependent upon the level of societal change happening within the system and how much change will be needed to meet net zero (National Grid ESO, 2020). What the FES show is that in each of the possible scenarios put forward, technological and behavioural changes are needed. Although the changes *needed* are able to be predicted, exactly when and if these will happen is not so simple to predict. For example, in GB it may not be solar PV that causes challenges to the centralised system but electric vehicles (EV) should the cost of EV ownership fall dramatically (as was seen with battery storage in Australia). An increase in EV ownership could cause challenges to maintaining supply for charging and to the security of the system pertaining to frequency and voltage. Similar to PV in the NEM, the uptake of EVs could also bring solutions, such as EV charging/discharging aggregated to provide system services in much the same way as a VPP. What the NEM case study has shown is that an encouraged change may happen at an unexpected pace due to outside influences, and so perhaps approaching the future energy scenarios with the idea of management rather than control, may be needed.

This chapter will build on the framework suggested by the IGov2 project and introduce adaptive governance processes that could enable decentralisation and innovation, which may be able to counter the challenges that arise due to changes within a complex system. This chapter will show how the adaptive governance framework suggested in Chapter 8 could be applied in GB to assist local governments to meet their decarbonisation targets. The Chapter suggests methods that may help to meet decarbonisation targets through the empowerment of all local areas (other than those that currently have access to decentralised funding e.g. devolved governments) and the coordination of all local areas, including the devolved governments, to meet a national vision. This chapter has been written to encourage a conversation around if/how adaptive governance could be practically applied for the inclusion of decentralisation in a centralised system. This chapter brings together separate strands of current research, under the adaptive governance framework suggested in Chapter 8, and suggests changes that could be applied to current GB energy governance (illustrated in Table 9-1) to become more adaptive (Table 9-2, page 191), building on the research undertaken by the IGov project (Willis et al., 2019a).

Table 9-1 Illustration of current GB energy system governance in comparison to the suggested adaptive governance framework from Table 2-1 (source: author).

Adaptive Governance Principles for energy systems	GB
Customers at the centre of the policymaking and regulation process	new customer challenge panel for transmission and distribution
Empowered local policy	no; only devolved governments and administrations
Knowledge sharing	no
National vision and target for decarbonisation	Legislated net-zero target by 2050; Clean Growth strategy
Coordination of innovation	no
Coordination of local policy	no
Coordination between the physical and operational elements (distribution, transmission, markets)	Open Networks Project; National Grid ESO

9.1 IGov2: Getting energy governance right

As mentioned Chapter 1, this thesis was funded as part of the IGov2 project which suggested possible governance changes needed at all levels of the GB energy system to meet future decarbonisation targets. In GB, as in the NEM, the need for a distribution market and for changes to the way the distribution networks operate is being discussed (AEMO and ENA, 2019; ENA, 2017a; Mitchell, 2017). Distribution networks in GB are moving towards a Distribution System Operator (DSO) model, which allows the DNO to become a 'neutral market facilitator' (ENA, 2017a) but with limited changes to how the networks are regulated. IGov suggests further evolving this role to that of a distribution service provider (DSP), with increased performance based regulation with the majority of network revenue being earnt through providing platform services and non-wire demand side and DER services (see Mitchell and Poulter, 2018). IGov has also suggested a new role, an Independent Integrated System Operator (IISO) (Willis et al., 2019a) in GB, similar to the independent market coordinator suggested in Australia (AEMO and ENA, 2019), to allow for coordination between the decentralised and centralised physical elements of the energy system.

Within GB, the importance of local, or sub-national government to meet climate goals has been recognised (see Duggan, 2019; Smith, 2007; Willis et al., 2019). In countries which have complete centralised control over energy governance, there have been difficulties encouraging small-scale projects to enter the energy space (Webb et al., 2016). In comparison, where local policy has been empowered, such as in the NEM, the uptake of DER, encouraged by local policy, has created a transformational decentralisation. The need for local areas to be funded to meet individual targets has been recognised within the IGov project, as has the importance of creating local area plans, to recognise the different resources that each local area can provide to meet whole system outcomes (Willis et al., 2019a). IGov also recognised the need for direction setting (Lockwood, 2018) and coordination (Hoggett, 2018) within the GB energy system and it has been suggested that an Energy Transformation Commission is needed to oversee the direction-setting process and to coordinate the key actors at the national level (Willis et al., 2019a). Figure 9-1 sets out the local and national governance interplays, as suggested by the IGov project.

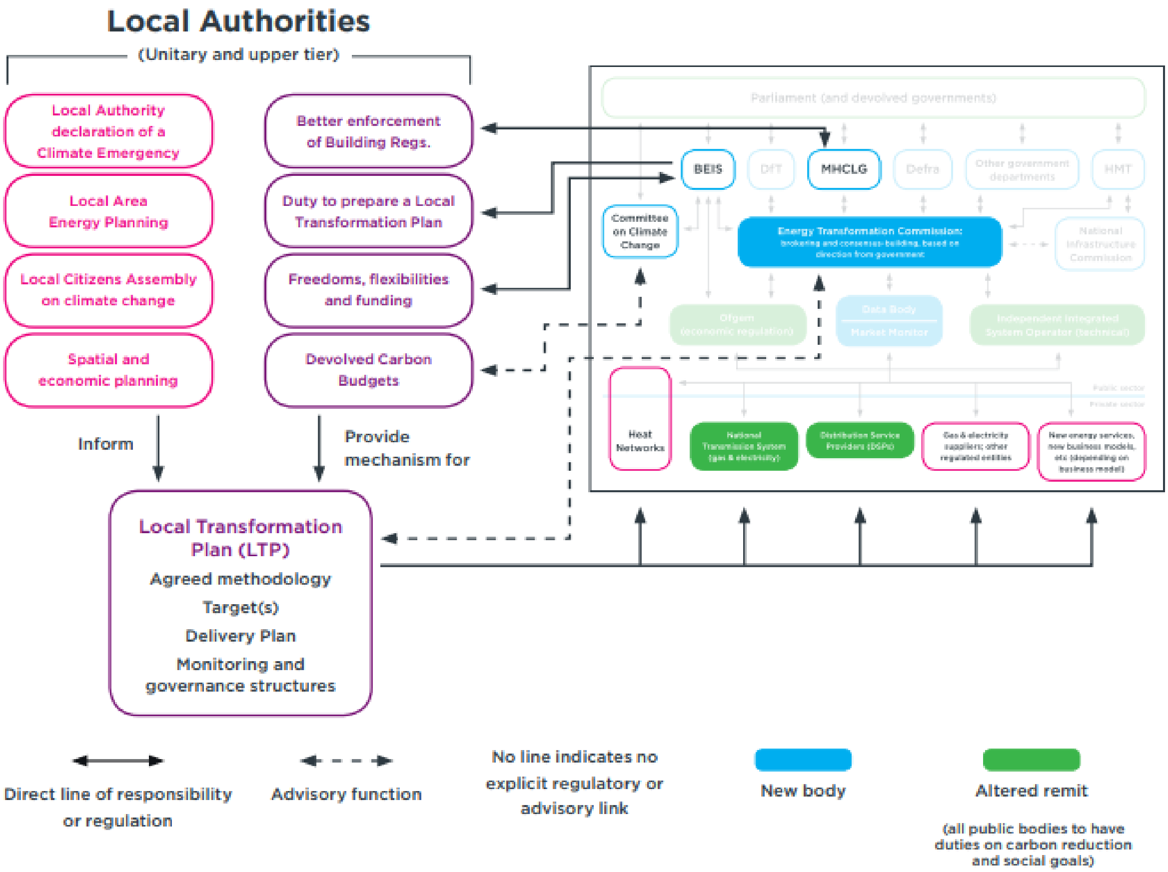


Figure 9-1 IGov proposals for local and national governance

The thesis suggests that the adaptive governance framework complements the research above by creating adaptive governance for decentralisation by empowering local government and then coordinating the local initiatives to align with the direction and targets as set by the national government. The following sections of this chapter suggest how adaptive governance in the GB context could be implemented from the principles as set out in Table 9-1 and by building on the IGov proposals, other relevant research and current energy policy.

9.2 A NATIONAL VISION AND TARGET FOR DECARBONISATION

In Chapter 8, an adaptive governance framework was suggested. It stated that for the framework to be effective, and to ensure that local policy would not be open to vested interests, it would need to work towards a national vision and target for decarbonisation. Currently, in the UK, the government has declared a climate emergency and has legislated a target for net-zero emissions by 2050 (CCC, 2019). In 2017, the UK Government issued a white paper on an Industrial Strategy (HM Government, 2017) for the UK. The Industrial Strategy set out a vision for the future productivity of the UK, which included four grand challenges to make the UK a leader in future industries. One of the challenges was for British industry to benefit from clean growth. Alongside the Industrial Strategy, the government released the Clean Growth Strategy (BEIS, 2017). Within the Clean Growth Strategy, the government set out how it planned to meet the forthcoming carbon budgets, with the majority of investment given to decarbonising transport and power (58%). However, within the Clean Growth Strategy, and the current government's election manifesto (The Conservative and Unionist Party, 2019), there is little mention of the benefits of DER and the majority of innovation funding is targeted at large-scale RE innovation, such as offshore wind or the use of carbon capture and storage.

The Clean Growth Strategy may be a missed opportunity for the government to allow for more adaptive processes and to create a true decarbonisation agenda by setting sector targets i.e. electricity, heat and transport, to meet the carbon budgets that will allow the UK to achieve Net Zero by 2050. Targets such as these have been recommended within a recent report by the National Infrastructure Commission (NIC, 2019) which suggested that sector targets are needed to provide long term strategies to support investment and that these should be set through a Strategic Policy Statement (SPS) (see also Mitchell, 2018). This would then enable the local areas to plan how they could meet these targets (see section 9.3), with regional and national coordination to ensure that local area plans are operating within the direction set by the national government (see section 9.6).

The use of an overarching vision has been used for the New York Reforming the Energy Vision program (NY REV) (New York State, 2014) (see also Willis et al., 2019). The NY REV has created a process for energy system transformation that sets out a clear vision and then coordinates this vision to meet targets. It does this by acknowledging that implementing the NY REV creates wider system change and so coordination includes the recognition of themes through various workstreams, such as the changing role of the customer, new metering models and new regulatory processes. Regulation has moved to more output-based regulation, incentivising the networks to meet the REV goals. This has also required the DNO's to change their operations to include a platform that allows trade between DER owners and also between DER and the wholesale market (see Mitchell, 2016). The NY REV recognised that change is needed throughout energy system governance to meet the decarbonisation agenda.

Broad decarbonisation targets could be set, perhaps based on the GB carbon budgets, to provide a clear direction for business, industry and other initiatives. The targets could be set by Strategic Policy Statements, as suggested by the NIC report (2019) and implemented by the new Energy Transformation Commission (ETC), as suggested by Willis *et al* (2019a). The role of the new ETC could be to coordinate the regional and local areas through direction setting to meet the government targets. This could be achieved i) by providing strategic oversight of the system goals as set by the SPS; (ii) through an engagement function to encourage wider engagement from new and established players, as well as from the wider public; and (iii) provide input of decarbonisation goals that require consensus-building and forward planning at a national level. Setting a direction in this way (Lockwood, 2018) could give the local areas of GB a defined end-point of where their local initiatives could help to achieve the wider decarbonisation objectives, without being too prescriptive, allowing more flexibility for local policy goals.

9.3 EMPOWERED LOCAL POLICY

Following the setting of the broad decarbonisation targets, policy could be created at a local level which feeds into the national targets, as set by the SPS. For example in GB, local could be defined as county level, as there are distinct differences between each of GB's counties e.g. urban, rural, semi-rural, with each geographical type located in different areas of GB. Each county then has different capacities, dependent on physical geography, resource, demographic and economy, on how they would be able to help achieve a national overall RE target (Roelich, 2018; Smith, 2007).

Authors have suggested that this type of local governance for energy would benefit from empowerment through access to funding, enabling local councils to act on locally significant energy policies (Britton, 2018; Smith, 2007). The benefits of local policy and having the available capital to invest in these policies can be seen in those countries that operate a federal system. In both Australia and the USA, states such as South Australia, Victoria, California and New York State, have achieved positive decarbonisation agendas, and in the case of California, has allowed the State a voice in the COP negotiations (Duggan, 2019).

An example of targeted funding is the use of DER to create system benefits while helping to alleviate social difficulties, as was demonstrated by the South Australian VPP project (Government of South Australia, 2017). The state-funded project targeted 1000 social housing homes to install solar and batteries, so reducing the cost burden of electricity supply to low income and vulnerable households, with the system benefit of demand response, and frequency and voltage regulation via the VPP. A targeted approach, rather than a blanket subsidy or FiT scheme, has the advantages of (i) allowing those who would not normally be eligible for FiT or subsidy schemes access to DER e.g. renters, low-income families, and (ii) to fund the optimum solution to the decarbonisation challenge for a particular area.

This type of targeted local funding may also be very applicable in the decarbonisation of heat e.g. electrification or biomass may be the best method of decarbonising heat for rural households, whereas, for urban areas, heat networks may be the more appropriate decarbonisation method. Where the broader approach has been used in GB, through the Renewable Heat Incentive, difficulties arose when urban households installed biomass technologies creating air pollution problems (Air Quality Expert Group, 2017). It is these types of considerations that would be highlighted within a Local Area Plan (see section 9.3.1). This then allows local government to create policy, and most importantly, be able to target their funding to achieve the policy objectives using the optimum decarbonisation solutions for their region.

9.3.1 Local area plans

As discussed in previous chapters, creating local policy allows for greater diversity in the decision-making process, allowing for new and alternative ideas, processes and technical solutions, and the opportunity for transformative leadership (Folke et al., 2005; Nelson et al., 2007; Westley et al., 2011). Those areas that have similarities within their geographies would then be able to share and discuss their approaches. This could be achieved through collaboration and coordination of a local energy plan

(Tingey et al., 2017), or Local Transformation Plan (LTP) (Britton, 2019; Willis et al., 2019a). Before creating local policy, each local area would need to create an energy plan for system transformation (which for this chapter is to be known as the Plan). The Plan would include how the local resources - where resources would include the environmental resource, plus the social resource, combined with the technical and economic capabilities of meeting local needs – would help to meet the national targets. Before creating local policy from the Plan, the separate Plans could be coordinated at a regional level, which may be DNO areas or the areas currently covered by the newly created regional Energy Hubs (Johnson, 2019), to achieve a national objective and to highlight economic and technical considerations that cannot be captured at a local level (coordination will be discussed further in section 9.6). Following refinement of the Plan, local government could design local energy policy.

9.4 CUSTOMERS AT THE CENTRE OF THE POLICYMAKING PROCESS

Following lessons from empirical studies of adaptive governance, creating policy that is accepted and trusted by the local community, needs to involve the community within the initial planning process (Engle and Lemos, 2010; Firestone et al., 2020; Schultz et al., 2015). Within the central government, a Citizens Assembly (CA) was used to discuss the future of Adult Social Care (UK Parliament, 2018). This Assembly included representation from a mixed demographic of UK citizens, advised by expert leads from academia and NGOs who had impartial expertise in the subject area. Although deemed as a successful collaboration, there has yet to be any finalised report from the UK government, and therefore if any of the recommendations from the CA have been acted upon (OPSI, 2019). A similar assembly is also currently being established for climate change mitigation (UK Parliament, 2019). A similarly structured advisory group could be created to ensure transparent and legitimate policymaking process (Folke et al., 2005; Mitchell et al., 2016; Nelson et al., 2007; Shove and Walker, 2007) for local policy. The CA, through their varied expertise, could make recommendations for the final policy briefing that enables the Plan, and that also gives wider societal and economic benefits to the local area.

9.5 CUSTOMERS AT THE CENTRE OF THE REGULATION PROCESS

It is anticipated that meeting national targets for decarbonisation needs both centralised and decentralised electricity generation (National Grid, 2018; NIC, 2016). Electrification of heating and vehicles is also expected to increase as a method of reducing sector emissions (National Grid, 2019). The use of other demand-side initiatives to decrease energy use and meet increased demand also needs to be encouraged. This changes the use of the electricity distribution networks, and the role of the network operator, and will require networks to work closely with the local policymakers to enable local decarbonisation plans. As has happened in New York as part of the REV process, and also recommended in the recent National Infrastructure Commission (NIC) report (NIC, 2019), and within the IGov project (Willis et al., 2019b), meeting a net-zero target requires a review of how electricity distribution networks are regulated.

In Chapter 8, it was suggested that for networks to be more adaptive a new approach would be needed to assess future revenue determinations. Section 8.3.4 recommended a process similar to that being trialled in Victoria (AER, 2018b), where network business plans are constructed through a rigorous customer focussed process using a customer forum, such as the Citizens Assembly, as recommended in the previous section. Also, in the previous section, it was discussed that a local Plan would need to be formulated that would include short-, medium- and long-term propositions for reducing emissions.

Currently, in GB, the DNOs price control periods are set over eight years. However, for the next distribution price control (RIIO2 ED2), which begins in 2023, the price control period is reduced to 5 years. If the local Plan was set over the same five-year periods i.e. what can be achieved now and in the next five years, out to ten years and then fifteen, this would allow policy and regulation to be aligned. Aligning area Plans and network price controls could enable the DNOs to structure current and future investments in conjunction with the local area plans, while advising on how local plans are able to fit within the current regulations and codes (this also highlights which aspects of regulation and the electricity codes may need to be reviewed to enable a positive innovation, which could be part of the regional coordinator's remit (see section 9.8)). It would then be possible for the network business plans to show the investments needed to meet the local requirements. The network business plan would be focussed on the needs of the local customer and able to show future investment possibilities for relevant businesses, whilst having undergone pre-determination scrutiny through the local advisory group.

The NIC report – Strategic Investment and Public Confidence (NIC, 2019), highlighted areas within Ofgem's duties they felt needed to change to meet the 2050 net-zero target. These included:

1. Ensuring decisions are consistent with, and promote, the net-zero target.
2. Regulators take regard of devolved administrations strategic vision, and that advisory committees should be put in place to ensure this.
3. Regulators should require companies to demonstrate that they have taken regard of the strategic visions set out by the metro mayors and local governments.
4. Legislation should be introduced to remove barriers to the use of competition to provide network enhancements, and that regulators should be able to carry out competitive tenders.

Creating a business plan and price control process, in conjunction with local government Plans and policy and under the direction of a local advisory group, may allow coordination of network investment to meet the net-zero target. As networks would have worked closely with local government and independent customer advisory groups, it could be assumed that network business plans have taken into account points 1-3. As networks would also be involved in short-, mid- and long-term planning, their investment strategies would highlight areas for present and future investment. This then ties in to point 4, as each local area would have highlighted the network enhancements needed to meet local area decarbonisation objectives, so these could be put to tender in a timely manner should the relevant legislation be introduced.

Currently, customer input to network business plans is incentivised through a small incentive as part of the Broad Measure of Customer Satisfaction (BMCS) (Ofgem, 2017b; Poulter, 2017). An incentive of a maximum of 0.5% of the DNO base revenue may be given should the regulator consider that the DNO has shown increased engagement with their customers during the business plan process. However, there is no risk of penalty if the DNO chooses not to engage. Although this does somewhat incentivise the networks to engage more with their customers, as there are no penalties for those networks who choose not to engage, the approach seems more of a box-ticking exercise rather than a formal planning approach as recommended above.

In the RIIO2 ED2 price control, to start in 2023, the use of a customer challenge panel has been agreed (Ofgem, 2019a). The panel is to be set up by the DNO, with the DNO having the choice of the panel representing its license area or by region. Rather than the panel having oversight of the entire business plan process, and coordinating between local areas and the networks as suggested above, the panel in RIIO2 is only used as a pre-assessment panel of the business plans once they are nearing completion (Ofgem, 2019b). Although this is an improvement on current price controls, it still does not actively seek meaningful customer input during the entire business plan process. In this case, rather than the RIIO2 customer challenge panel, the use of a local advisory group and the networks working in conjunction with local government and county Plans would be prudent, providing more customer focussed business plans, and introducing increased transparency and legitimacy to the business plan process.

Using a local advisory group could also reduce the burden on both the customer challenge panel and the regulator to have complete oversight of points 1-4 as these points should have been addressed through the business plan process. The role of the regulator could then be to coordinate the networks to meet outcomes based on the national vision, as set by the ETC, with the outcomes set over the same short-, medium- and long-term timeframes as the local Plans and network price controls. Regulation could then become more ‘outcome’ based, similar to that as recommended by the NY REV (Mitchell, 2020), with the networks incentivised to use innovative measures to meet the outcomes as set by the regulator. The regulator sets an endpoint, and it is then up to the networks to arrive at this endpoint through the most efficient and innovative means, operating within the boundaries set by the regulator and within the electricity codes, while meeting the needs of the local Plans and national vision. This type of regulation could increase the adaptiveness of the networks through less prescriptive regulatory controls, and the adaptiveness of regulation itself as outcomes can be managed should there be unexpected events, such as rapid technological advancements or the need to intensify the decarbonisation agenda.

As recommended by IGov ((Willis et al., 2019b), Ofgem's role could change to that of purely economic regulation of the networks, with its code management role being taken by the new IISO (see section 9.8.2). Ofgem's new role as economic regulator would be to ensure that network business plans work to the outcomes set within the price controls, with the outcomes based upon the strategy set by the ETC from the government's Strategic Policy Statement.

9.6 Coordination of Local policy

A British government policy brief recently noted that '*Subnational government bodies, financial institutions, NGOs and multinational firms all possess influence over energy policy, and their own objectives and agendas may not necessarily align with one another or with central governments.*' (POST, 2019 pp.36). In the Paris Climate Conference in 2015, the Talanoa Dialogue recognised that a broader range of actors was required, but methods would be needed to answer the complex challenges that would arise from including this broader range of viewpoints (Duggan, 2019). What both of these statements suggest, and what can be seen from the NEM case study, is that empowerment of local actors and governments can be beneficial to decarbonisation, but without coordination leaves the policy process open to influence from vested interests, and may also create a 'messy' pool of innovation that lacks commonalities, or indeed works against each other, rather than being coordinated to meet a desired end goal (Krog and Sperling, 2019; Sperling et al., 2011). Ensuring that local empowerment does not become 'out of control', or open to excessive influence from the wrong direction, the coordination element will be vital to ensure that local policy continues to follow the direction set from the national government.

Section 9.1 discussed that national coordination was needed to set energy system targets and that this could be the remit of the ETC as suggested by Willis *et al* (2019a). In section 9.3, the need for a local area plan to create policy objectives was discussed and it was suggested that the local plan would need to be coordinated at a regional level to meet a national agenda. Recently in England, regional Energy Hubs have been established. These Hubs cover the Midlands, North East, Yorkshire and Humber, North West, South East and South West regions of England. Energy for Scotland, Wales and Northern Ireland is the responsibility of the devolved administrations. The remit for the Energy Hubs is to provide funding for large projects that deliver a public good, e.g. decarbonisation, wellbeing, and that will be profitable and can be replicated in other Hub areas. Projects are expected to complement the areas identified within the Clean Growth Strategy and Industrial Strategy and to support the local authority strategies. Omitted from the Energy Hub's remit is a coordinating role around these local authority strategies (Johnson, 2019).

The need for coordination has been recognised in research relating to the practical applications of local government RE strategies (Beermann and Tews, 2017; Krog and Sperling, 2019; Sperling et al., 2011). In Krog and Sperling (2019) and Sperling (2011), a lack of coordination between Denmark's municipalities was seen as suboptimal and led to stakeholders working independently, and sometimes against each other, rather than towards a common goal. A need for regional coordination was also recognised in Germany, where local initiatives overlapped between federal districts (Beermann and Tews, 2017) causing conflict within the social and environmental parameters. A lack of coordination between the supply and demand requirements of the regional areas also caused a lack of optimisation of the physical energy system structure (ibid.). The research undertaken in the NEM case study also showed that a lack of coordination led to vested interests in some of the NEM States influencing State government's decarbonisation targets and RE Policy (see section 6.5).

Research suggests that locally-based institutions may be in a better position to recognise the resources available and required at a local level (Roelich, 2018; Smith, 2007), but coordination of these resources will be needed to ensure that these initiatives do not lead to '*inefficient policy outcomes*' (POST, 2019 pp.36). In countries such as Denmark and Germany, and also from the results of the State RETs in the NEM, research suggests that regional coordination would need to take into account environmental, political, social and technical and economic considerations when organising local initiatives to meet a common goal.

This section argues that regional coordination of local plans is needed and that this could be the responsibility of the Energy Hubs. Energy Hubs are currently being used to identify and fund large local energy projects. In section 9.3, it is suggested that funding of local energy projects – of whatever size - could be the responsibility of local government. A preferred use of the Energy Hubs would be to act as regional coordinators of the empowered local governments. Regional coordination would consist of (i) assessment of local Plans to ensure that they meet national decarbonisation criteria and as an interface between the regional areas to identify challenges, such as possible overlaps/conflicts between local areas, and (ii) as a Knowledge Hub, where initiatives from the local Plans could be stored in an open access database.

9.7 COORDINATION OF INNOVATION AND KNOWLEDGE

For governance to be adaptive, SET authors recognised the need for policy to be treated as a hypothesis, with the initiatives coming from the policy to be thought of as experimentation, thereby increasing learning (Folke et al., 2005; Nelson et al., 2008; Pahl-Wostl et al., 2007). Within public policy literature, knowledge sharing has also been acknowledged as critical in moving to a decarbonised energy system (Kuzemko and Britton, 2020). In the NEM, ARENA's Knowledge Hub was able to bring together a portfolio of separate trials, or 'experiments', aimed at improving the reliability and affordability of rural householders and communities. The results of the fringe of grid (FOG) projects improved the reliability and affordability of electricity in remote areas by using renewable electricity and storage technologies (Ekistica, 2018). Creating a portfolio of separate trials enabled the faster identification of the rule changes needed to replicate the projects as part of standard operating procedures (AEMC, 2019f).

It would be recommended that the regional coordinators operate a central, open-access knowledge hub, similar to that of ARENAs. During the Plan assessment, the knowledge hub would allow all the regions and counties to share the initiatives from their regions, and like the FOG project, enable faster identification of where possible changes to rules or regulations may be needed. Following the finalisation of the Plans and policy enactment, it would then be possible to share completed trials and policy initiatives, including recommendations for improvements. The knowledge hub could include the intention, outcome, and learning from the initiatives, allowing other similar regions to replicate successful initiatives, or to avoid repetition of mistakes, so creating an area to assimilate 'experimentation'.

9.8 Coordination of the Physical and Operational Elements

Including decentralisation into a system that has been optimised for centralisation will require coordination between the decentralised and centralised assets to ensure that the entire energy system remains secure and reliable. This requires assessments of expected changes to the current energy flows on the networks and new methods of coordinating between distributed and wholesale generation.

9.8.1 Networks

In section 9.5, a method of adaptive regulation was discussed. It was suggested that as a requirement for the RIIO price control, the DNOs could work with the county councils to identify physical infrastructure requirements of meeting the plans. The DNOs have oversight of the counties within their licence areas, which could enable coordination of the physical system plans between counties, highlighting wider infrastructure considerations due to the expected changes to energy flows on the distribution networks.

Increased use of the distribution networks, through an increase of DER installation and other electrification proposals, would invariably lead to changes to the flows on the transmission network, as is currently happening in South Australia. It could be expected that transmission may have periods of zero or negative flows on their networks. In this case, there would need to be continued coordination between the two networks to ensure reliability and security, which would be the role of the national regulator. As each of the local authorities has made a 5-, 10- and 15-year plan, so the DNOs could also make complementary plans. This would allow the regulator to assess the current and future changes expected within the distributed area, and so be able to design distribution and transmission regulatory outcomes and incentives based upon these projections.

9.8.2 Markets

Research, and the case study of the NEM, has shown that for decentralisation to benefit all customers, a distribution level market is needed, and requiring the changing role of the consumer to a prosumer (AEMO and ENA, 2019; Mitchell et al., 2016). There are currently discussions on the role of the DNO changing to that of a Distribution Service Provider (DSP) (ENA, 2017a; Willis et al., 2019a). The DSP could act a market facilitator by coordinating local supply and demand through balancing services, such as flexibility markets and demand response.

This would also require coordination between the distribution level markets and the current wholesale market. The IGov project suggests that this role should be taken by a new institution, an Integrated Independent System Operator (IISO) (Willis et al., 2019a). The IISO could coordinate the wholesale and distributed markets to act in accordance with the direction as set by the new ETC, ensuring compliance with decarbonisation objectives.

9.9 Policy as an iterative process

Following the recommendations as set out in this chapter, and the new institutions and new roles for existing institutions as recommended by IGov (Willis et al., 2019b), iteration is achieved at the national level by the ETC acting as a conduit between the national and local governance institutions. The national targets, as set by the government's SPS, are advised by the ETC. The ETC gains information on how targets are being met, and the challenges that have arisen, through communication with the Energy Hubs. The ETC is then able to advise the relevant centralised institutions to evolving situations, such as changes required to the codes or consumer protections, or if local funding may need to be increased or can be reduced. The information received from the ETC could then inform the future SPS. The ETC could also receive and inform market direction through the IISO, and for energy supply through Ofgem.

At a local level, the mid- and long-term strategies of the Plan should be open to modification to allow for future changes, such as changes to national targets through the SPS or unexpected events. The channels of communication in the local areas, established in the creation of the Plan and from the CA, could be continued, allowing for continual feedback of the local policy outcomes, with changes to be made to local policy as required. Should local policy not have the desired outcome, lessons can be learnt and shared through the regional Knowledge Hub. Sharing of knowledge in this way may allow solutions to policy problems to be suggested, with local policy then altered to achieve the desired outcome. As policy is enacted in smaller areas, this iterative approach may enable policy to be nimbler in reacting to expected and unexpected outcomes and change. Iteration at this local level could also reduce the risks associated with policy failure as economic and political damage would be limited.

Iterative policy could be achieved by combining top-down and bottom-up processes through coordination of the local, regional and national levels, by using regional and national institutions to achieve this coordination. Iteration may be achieved through national targets setting the local policy direction, which allows for experimentation at the local level, with the results from the local policy experiments helping to inform future strategies.

9.10 Conclusion

This chapter has suggested how a framework for adaptive governance could be applied within the GB energy system. The framework is designed to allow for the inclusion of decentralisation while protecting the functionality of the system, based on lessons learnt from the NEM case study. Should GB wish to move to a system that incorporates both centralised and decentralised facets, then to enable decentralisation, adaptive governance could be considered. To manage the transformational change that decentralisation requires, the adaptive governance processes suggested in this thesis need an institution, such as the ETC, to coordinate the various government departments to meet the decarbonisation targets (see Willis et al., 2019b) as set by the vision laid out in the Governments Strategic Policy Statements (SPS). Local authorities could create a Plan on how local areas could help to meet these targets and be empowered to create and enact local policy, allowing for local experimentation. The Plans could be assessed and coordinated by the Regional Energy Hubs, with initiatives from the Plans shared through the use of a Knowledge Hub. The information collated at the Energy Hubs could advise the ETC on possible future strategies, which could, in turn, inform the SPS (These changes are summarised in Table 9-2).

Table 9-2 Summary of the changes to GB governance to create more adaptive processes which may aid in energy system decentralisation (source: author).

Adaptive Governance Principles for Energy Systems	Current GB Governance	GB Adaptive Governance
Customers at the centre of the policymaking and regulation process	new customer challenge panel for transmission and distribution (only at end of business plan process)	Parish, local government and CA create local energy policy and a local energy plan; customers and distribution networks create buisness plan to meet local energy plan needs
Empowered local policy	no; only devolved governments and administrations	local energy fund
Knowledge sharing	no	through regional coordinator - open access knowledge bank
National vision and target for decarbonisation	Legislated net-zero target by 2050; Clean Growth strategy	Legislated net-zero target to include broad national decarbonisation strategy Strategic policy statements
Coordination of innovation	no	regional coordinator to include knowldege sharing
Coordination of local policy	no	regional coordinator to include knowledge sharing
Coordination between the physical and operational elements (distribution, transmission, markets)	Open Networks Project; National Grid ESO	IISO; DSP

10. CONCLUSIONS

This thesis has suggested how an adaptive governance framework for energy system decentralisation, through a case study of the National Electricity Market in Australia, could be practically applied in Great Britain. Although SET theory for energy has been considered as a promising avenue for further research (Goldthau, 2014), this has been limited and there has been no case study analysis of its use for energy. This thesis builds on the current SET theory and its practical application for water and food systems by suggesting that the principles of SET could also be applied to enable energy system decentralisation.

An adaptive governance framework from SET theory was chosen due to the similarities in the behaviours of social-ecological systems and the current energy system. Comparable to the current energy system, social-ecological systems, such as water and agriculture, are essential and complex systems, and solutions to issues for their sustainability can be solved through the use of local resources. SET theory acknowledges the complexities of these systems and recognises the need for a system to transform should the current system be resilient to a desirable change, through lack of adaptability or 'lock-in'. SET theory, perhaps more than STT, recognises the complex interactions between the social, ecological, technical, political and economic parameters and the importance of coordination between these parameters to meet a particular vision. SET also recognises the value of local resource and of time as a limiting factor. SET proposes principles for the application of adaptive governance:

- an increase in social capital
- to use policy as hypothesis
- have transformative leadership and empowerment of social actors, and
- to create an institutional infrastructure for the coordination of research, social capital and multilevel rules across all levels of governance.

To assess if NEM governance was adaptive, or applied any of the principles above, research questions were designed to investigate the rapid uptake of DER, the history and present governance of the NEM, and the challenges associated with the rapid transformation that was currently taking place. Results from the research questions were achieved, through primary and secondary research, by assessing how the disturbance of DER was received, and managed, by the incumbent industry and institutions within NEM governance. The results of the case study were then used to provide recommendations for an adaptive governance framework, based on SET theory, for transformation of the electricity system and applications for the GB electricity system.

The NEM was chosen as a case study due to the rapid increase in DER. In 2008, the NEM States initiated a FiT policy that hoped to see 15MW of solar PV installed. However, a combination of unexpected synergistic events meant that the adoption rates were far higher than anticipated, and by 2019 over 25% of all Australian households had installed a PV system, with a growing percentage of these also including battery storage. Owning a PV and storage system in the NEM has now reached grid parity in some States. Although this can be seen as a success, in that the NEM far surpassed the original intention of their policies for small-scale PV, the unexpected rapid uptake within the distributed area has caused challenges within the technical, economic, social and political parameters within the NEM.

A review of the history of Australia's energy system and the reforms that have happened within the NEM, showed that energy systems are in a state of constant evolution and so the governance surrounding the system needs to reflect this. The research highlighted that the current transformation in the NEM, to a more decentralised system, is happening more rapidly than previous transitions and suggested that an adaptive governance approach may be more applicable to allow for this rapid change.

Following an unexpected climatic event, which caused a blackout of the SA electricity grid, the Finkel review was initiated. The results of the review recognised the benefits of decentralisation and made recommendations to the future energy security and reliability of the NEM. However, although 49 out the 50 recommendations were approved, the CET was refused and currently, Australia has no national emissions or RE policy past 2020. This lack of national RE policy has limited the power of the Finkel recommendations, as now the recommendations may be initiated at any time. Although the Finkel review contains a vision for decarbonisation and decentralisation, there is a lack of urgency as to when this vision should be implemented.

The reluctance of the federal government to introduce an emissions target can be understood due to Australia's relationship with the coal industry. Coal has played an important role at both the national and State level in the growth of Australia's economy. Yet, environmental concerns, the changing resources for electricity generation, and the climate and energy policies of Australia's export markets, has created an uncertain future for coal in Australia. This uncertainty has created disagreement between the right and centrist political parties regarding their support of the coal industry, and the need to reduce Australia's emissions. However, despite the vested and incumbent interests of the coal industry in the energy system and its governance, the federal system of government has allowed some States to create renewable energy targets, counter to the national government's position. The ability to create, and fund, state RE policy has assisted in the rapid growth of DER in some States, starting a rapid, customer-led, transformation of the NEM.

The use of a singular case study allowed an in depth analysis of adaptive governance principles in an area where transformative change was happening. What the results of the NEM case study have shown is the unpredictability of energy system change. The customer-led transformation, caused by the economics of falling technology costs, combined with high prices and a distrust of the energy industry, led to system governance having to be increasingly reactive to the unexpected challenges that occurred. The case study also highlighted the need for coordination between both the decentralised and centralised physical and operational system and also between State and national policy, which may have alleviated some of the challenges that have, and are, occurring. Maintaining the functionality of a rapidly changing energy system requires governance to keep pace with the transformation that is taking place, by creating governance that is flexible, or adaptive, to enable decentralisation.

This thesis has presented an adaptive governance framework that may enable decarbonisation while reducing the negative effects of challenges caused by the complex interactions that are part of energy system transformation. As the majority of change is expected at the electricity distribution level, the framework suggested supports the decentralisation of the electricity system by suggesting the need for complementary decentralised energy policy processes, regulation and decision making. The recommended adaptive governance framework works with the governance framework suggested by the IGov project (Willis et al., 2019a), and shows how the framework would interact with the new national institutions as recommended by IGov.

Following the theory for SET and the lessons learnt from the NEM, this suggests that to enable decentralisation through a managed transformation process, adaptive governance for energy decentralisation should:

- Follow a national vision and target for decarbonisation
- Ensure that customers are at the centre of the policy and regulation process, thereby creating transparent and legitimate processes which increase customer trust and accessibility;
- Create broad national customer protections and standards, to allow for innovation under clear guidelines;
- Empower local areas, to allow for local policymaking and funding to create areas of experimentation for innovation in the social, technical, economic and political parameters, including a local area plan;
- Coordinate the local areas, through policy coordination, creating a distribution level market, and through new methods of regulation and knowledge sharing, that will help to meet a national vision
- Coordinate the physical and operational elements of decentralised and centralised facets

Applying this framework to GB energy governance, and incorporating the recommendations from the IGov project, creating adaptive governance to assist GB in meeting the net-zero target, then:

- an institution, such as the ETC, could coordinate targets as set by the government's Strategic Policy Statements (SPS)
- local government should be empowered to create and enact local policy
- local government could create a Plan on how local areas would help to meet national targets
- distribution networks could work with the local governments to enable the Plans, through a new adaptive regulation process

- the Plans could be assessed and coordinated by the Regional Energy Hubs, with initiatives from the Plans shared through the use of a Knowledge Hub
- the information collated at the Energy Hubs could advise the ETC on possible future strategies, which could, in turn, inform the SPS.

Creating an adaptive governance framework in this way could enable flexibility within energy system governance, to react to the challenges of decarbonisation, wherever they may occur. This is achieved by increasing innovation capability through an increase in social capital, which is coordinated to meet a national vision.

For governance to be adaptive the case study also highlights how *all* aspects of the proposed framework are equally important. For example, having empowered local policy can cause challenges if not complemented by a national vision and coordination, suggesting that it may be difficult to achieve adaptive governance in areas that are seeing an increase in DER but where national government do not support decarbonisation. Equally, where there is positive decarbonisation policy from national government but not empowered local policy and no coordination of DER, it may be that system decarbonisation may not be as equitable as it could be or that uncoordinated decentralised projects cause challenges to the centralised grid.

This need for *all* aspects of adaptive governance to be in place suggests that achieving functional adaptive governance may be difficult. Acknowledging the limitations of a singular case study, to further assess the suggested practical application, and to understand the significance of social capital, vision and coordination to achieve a fully adaptive governance process, it is recommended that further empirical research is undertaken to apply the adaptive governance framework to other transforming energy systems. This would enable further understanding of how adaptive governance principles may be framed in an energy context and the benefit of this to rapid system transformation.

11. APPENDIX I

INFORMED CONSENT FORM

ADAPTIVE GOVERNANCE FOR ENERGY SYSTEM DECENTRALISATION: A CASE STUDY OF THE NATIONAL ELECTRICITY MARKET IN EASTERN AUSTRALIA

Please initial each box

If you are happy to participate in the research, please initial each box as appropriate (leave blank any box for which you prefer not to give consent) and then sign this form at the end:

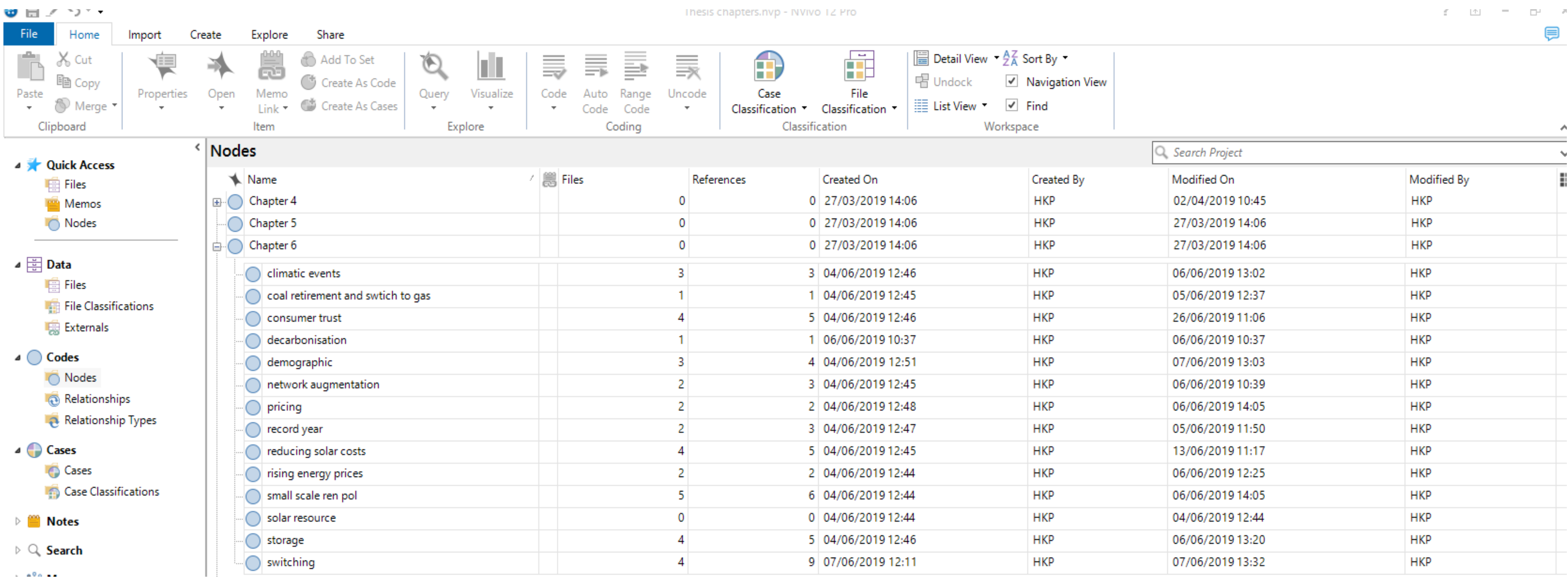
1.	The researcher has given me my own copy of the Participant Information Sheet, and I have had the opportunity to read and consider the information.	☐
2.	I have been given the opportunity to ask any further questions and have had these questions answered to my satisfaction.	☐
3.	I understand that participating in the research involves a one hour interview	☐
4.	I understand that the interview will be anonymous and that any reference to my questions will be given a code e.g. NGO	☐
5.	I understand that my words may be quoted in academic publications, articles, books, reports, web sites, related to the research project.	☐

7.	I understand that the researcher will be audio recording the interview and I give my consent for these transcripts to be reproduced for educational and/or non-commercial purposes, in academic publications, reports, presentations, websites and exhibitions connected to the thesis	☐
8.	I agree that members of the project team can re-contact me at a future date should they wish to follow up on this research.	☐
9.	I agree that other researchers can contact me at a future date should they wish to follow up on this research.	☐
10.	I understand that my taking part is voluntary; I can withdraw from the project later, and I do not have to give any reasons for why I no longer want to take part *(and this will be without any impact on any related services I am using).*	☐
11.	I understand I can ask for specific quotes or statements not to be used (or to be redacted from the data) if I wish.	☐
13.	I understand that if I want to withdraw from the project, I can contact Helen Poulter, who will discuss with me how existing data will be managed.	☐

I agree to take part in this research project

Name of research participant	Date	Signature
Name of researcher recording consent	Date	Signature

12. APPENDIX II



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