Impact of the Nature of Energy Management and Responses to Policies Regarding Solar and Wind Pricing: A Qualitative Study of the Australian Electricity Markets

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ABSTRACT

The present study employed various qualitative techniques to investigate the nature and influence of policies and regulations concerning solar and wind pricing on the Australian electricity spot and options markets. The analysis was based on data gathered through interviews conducted with energy managers, chief executive officers and other significant personnel from the Australian electricity industry. The interviewees' responses regarding the solar and wind policies of relevance to the Australian electricity markets were examined, and the thick and in-depth content data derived from the interviews were used to examine how their views and personal politics influenced pricing within the electricity markets. The results suggest that renewable energy policies lower the electricity prices, reduce the risks for investors and also result in larger deployment mechanisms.

Keywords: Electricity Pricing, Renewable Energy, Energy Policies
JEL Classifications: Q13, Q4, Q42

1. INTRODUCTION

The depletion of fossil fuel sources, climate change and pollution have all resulted in governments worldwide being faced with a number of challenges related to energy security (Alsaedi and Tularam, 2020; Ata, 2015). In recent years, various levels of legislation and different types of policies have been promulgated in an effort to encourage the development of the renewable energy sector in Australia. Such development is fundamental when it comes to addressing challenges concerning energy security, as it can help to meet the future energy demand as well as to minimise the risks associated with traditional energy supplies (Wüstenhagen and Menichetti, 2012). According to Solangi et al. (2011), the renewable energy sector in Australia is subject to various regulations, in addition to being influenced fiscally by all three spheres of government, namely the federal, state and local governments. These three spheres of government are coordinated by the Council of Australian Governments (COAG) (Kuwahata and Monroy, 2011).

Australia has undergone a number of policy changes in recent decades with respect to its energy system, including the formulation of the aim of achieving net-zero emissions by 2050 (Office of Environment and Heritage [OEH], 2015) and the introduction of the country's 2030 climate change targets (Commonwealth of Australia, 2019). The overarching aim of these programs is to reduce the electricity price uncertainty faced by renewable generators. Additionally, such efforts underpin the Australian commitment with regard to the Paris Agreement, which established an overall national target of reducing emissions by 26–28% below 2005 levels by 2020 (Csereklyei et al., 2019).

Currently, electricity prices are among the most important policy issues in Australia, and they represent a critical component of the ongoing energy and climate change policy discussions (Alsaedi et al., 2019). Several attempts to move forward with energy and climate change policies have been stymied by concerns about possible electricity price increases (Alsaedi et al., 2020b). With regard to this policy debate in Australia, renewable electricity generation is seen as a fundamental factor in relation to electricity prices. Given the increasing penetration of solar and wind generation in Australia and the simultaneously increasing wholesale and retail electricity prices, it is widely believed that the wholesale electricity price increases are related to the increased penetration of renewables.

A key driver of the debate concerning energy policy in general, as well as the role of renewables in particular, has been the rapidly increasing electricity prices, both wholesale (Figure 1) and contract prices, over the last 10 years. In recent years, the Australian electricity spot and options prices have fluctuated significantly as a result of different regulations, including the Kyoto Protocol, the Paris Agreement and Australia's renewable energy target (RET) (Auer, 2016; Maryniak et al., 2019; Simshauser and Tiernan, 2019; Trujillo-Baute et al., 2018).

The increasing costs associated with electricity generated from renewable energy sources has been suggested to be the main driver of the price increases (Trujillo-Baute et al., 2018). This is illustrated by the closures of two large Australian coal stations between 2016 and 2017, especially given that the closures were announced just 5 months after the Paris Agreement was signed in 2015 (Wiseman et al., 2017). As a result of the closures, and after 20 years of consistent performance, the Australian National Energy Market (ANEM) became unstable during 2016–2017 (Simshauser and Tiernan, 2019). The base-load electricity futures rose above AUD\$100/MWh, which was well above the ANEM's historic average spot price of AUS\$42.50/MWh (Simshauser, 2019b).

The aim of the present study was to examine the nature of energy management practice as well as the responses to policies regarding renewable energy within the Australian electricity markets by means of a qualitative analysis. The study investigated how the federal and state governments develop and manage policies regarding electricity pricing in relation to the use of, for example,

Figure 1: Average annual spot prices in Australia 2009–2019 ($/MWh)
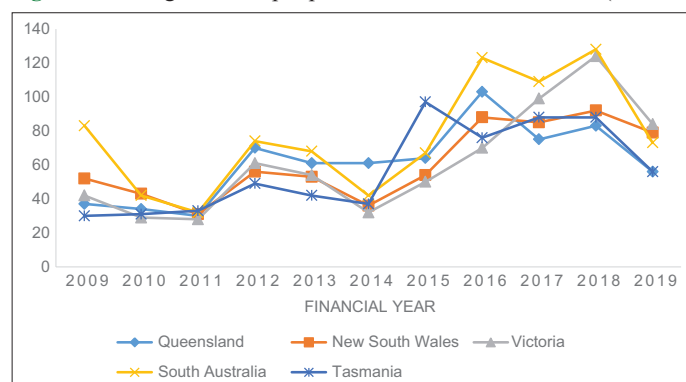
Source: Australian Energy Regulator (2020a)

solar and wind power. A qualitative approach was considered appropriate for this study, as the data were gathered through interviews conducted with selected personnel, managers and chief executive officers (CEOs) from within the Australian electricity industry. The interview questions were specifically developed to elicit (i) how the interviewees perceived the influence of the solar and wind industry within each Australian state, (ii) what they considered the current status of the industry to be and (iii) what future challenges/solutions they perceived in relation to solar and wind energy within the Australian electricity markets.

The study also analysed information obtained from the managements of energy companies in each Australian state so as to compare and contrast their responses regarding the effects of solar and wind pricing on the electricity markets with those given by the interviewees. The interview data were professionally coded, and the author then developed the patterns and themes identified in the responses with regard to the impacts of solar and wind power on the Australian electricity spot and options prices.

The present study makes two important contributions to the literature. First, it is the only study to date to have truly explored the impact of wind and solar power generation on the electricity spot and options markets using a qualitative methodology. Second, the interviews conducted with the CEOs and energy delegates provide a significant amount of useful information that can be subjected to a content analysis, for example, to study the nature of the effects that such people have on the volatility and long-term pricing of the electricity spot and options markets.

The remainder of this paper is organised as follows. Section 2 reviews the relevant literature and also presents an overview of both the available renewable energy sources and the various Australian renewable energy programs. Section 3 sets out the chosen qualitative research design as well as the criteria for selecting the participants, and it also presents the data collection procedures. Section 4 outlines the results of the qualitative analyses. Finally, section 5 concludes the study.

2. LITERATURE REVIEW

This section discusses the prior literature as well as the key concepts regarding the nature of energy management practice and responses to renewable energy policies within the Australian electricity markets. The first subsection presents an overview of the available renewable energy sources, with a focus on solar and wind power in Australia. The second subsection considers Australian programs and policies related to renewable energy. The third subsection then analyses the prior literature concerning the nature of energy management practice and responses to renewable energy policies.

2.1. Renewable Energy in Australia
Similar to the situation in many other countries, the penetration level of renewable generators within the ANEM is growing rapidly (Blakers et al., 2017; Hua et al., 2016; Rai and Nunn, 2020). For example, during 2006–2007, small- and utility-scale wind and solar photovoltaic (PV) power accounted for less than

1% of generation within the ANEM, while it accounted for around 24% during 2018–2019 (Australian Energy Regulator [AER], 2019). Moreover, South Australia has the second highest utility-scale variable renewable energy (VRE) penetration worldwide, with only Denmark exceeding it (International Energy Agency [IEA], 2019).

Five Australian states comprise the ANEM, namely New South Wales (NSW), Queensland (QLD), South Australia (SA), Victoria (VIC) and Tasmania (TAS). A report by the Clean Energy Council (2020) revealed the leading states with regard to the use of renewable energy to be TAS and SA, followed by VIC (Figure 2). In 2019, based on their individual contributions, the renewable energy sources utilised within the ANEM included wind (35.40%), hydro (25.70%), small-scale solar (22.30%), large-scale solar (22.30%) and biogas (1.4%) (Clean Energy Council, 2020).

In Australia, solar and wind represent the most logical and easily harvested of all the available renewable energy sources for a number of reasons:

1. Solar power is abundant, while advancements in PV technology have significantly enhanced the effectiveness of solar power generation at the same time as reducing the installation costs (Dincer, 2011; Li et al., 2019)
2. The Australian continent has the highest solar radiation per square meter of any continent (Bahadori and Nwaoha, 2013b)
3. The harnessing of wind energy has a long history worldwide, and it is supported by both mature technology and policy incentives (Kaldellis and Zafirakis, 2011; Li et al., 2019)
4. Australia has some of the best wind resources in the world, mainly in the southern parts of the continent, which lie in the path of the westerly wind flow known as the "Roaring Forties" (Bahadori and Nwaoha, 2013a)
5. Improvements in battery efficiency have radically improved the viability of both solar and wind resources as a rapid back-up system for the grid during times of major generation failure (Li et al., 2019).

Other renewable energy resources, such as hydropower and bioenergy, are constrained by land/resource availability, water requirements and material supply/security issues (Blakers et al., 2017). For example, hydropower is unable to keep pace with
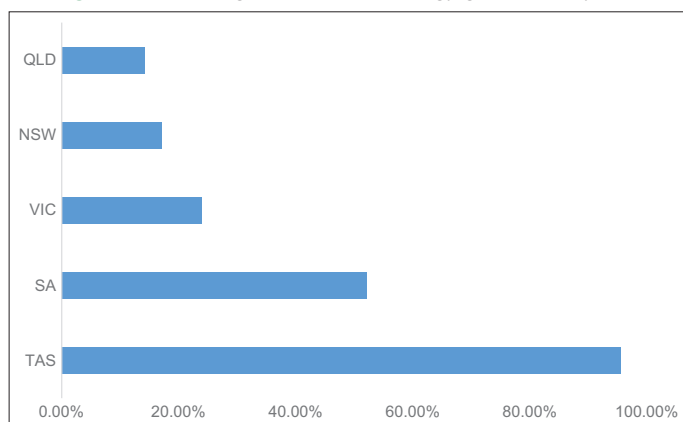
demand due to the fact that there are only a limited number of rivers available to dam, while bioenergy is severely limited by the low availability of sustainable biomass (Cornett, 2008). Further, the use of hydropower is challenged by climate change (due to being an ancient technology) and other environmental concerns (Blakers, 2017). Additionally, hydropower growth is mainly limited to TAS and certain parts of the eastern seaboard, while biomass is at present mainly available in the form of bagasse derived from sugarcane in QLD and Lindell gas from around the country (Oliphant, 2015).

2.2. Overview of Australian Renewable Energy Programs

Over the last two decades, Australian government policies have focused on reducing the cost of renewable energy technologies for consumers as well as on encouraging their uptake (Byrnes et al., 2013; Nelson et al., 2019). As noted above, according to Solangi et al. (2011), the renewable energy sector in Australia is subject to various regulations, in addition to being influenced fiscally (Martin and Rice, 2012) by all three spheres of government, namely the federal, state and local governments. These three spheres of government are coordinated by the COAG (Kuwahata and Monroy, 2011). Among the three spheres, the state governments play a significant role in renewable energy utilisation in Australia.

According to Simshauser and Tiernan (2019), the electricity-related policy options pursued by successive Australian governments in response to international climate change commitments can be divided into four broad streams:

a. RETs imposed on energy retailers (Onifade, 2016; Simshauser and Tiernan, 2019)
b. Carbon pricing or emissions trading schemes (ETSs) imposed on generators (Simshauser, 2018a; Simshauser and Tiernan, 2019)
c. Government-initiated contracts for difference (CfD) funded by taxpayers or electricity consumers (Bell et al., 2017; Simshauser, 2019c)
d. Distributed energy resource (DER) policies, such as feed in tariffs (Poruschi and Ambrey, 2019; Simshauser, 2019c).

Australia's RET is the result of a federal government policy introduced in 2015 with the aim of ensuring that at least 33,000 GWh of the country's electricity is generated from renewable sources by 2020 (Simshauser, 2018a; Simshauser and Tiernan, 2019). In 2001, the Australian government introduced the mandatory renewable energy target (MRET) scheme to encourage investment in renewable energy technologies (Ferrari et al., 2012). According to Kent and Mercer (2006), the MRET scheme set a target of 9500 GWh by 2010 so as to encourage investment in renewable energy through tradable renewable energy certificates (RECs; 1 REC = 1 MWh of electricity). In 2011, the RET was divided into two parts: (i) the large-scale renewable energy target (LRET) and (ii) the small-scale renewable energy target (SRET). This change was intended to create separate incentives for large-scale renewable energy projects and small-scale technologies, with the aim of decreasing competition among renewable energy projects (Great Barrier Reef Marine Park Authority, 2012).

Figure 2: Percentage of renewable energy generation by state

Source: Australian Clean Energy Council (2020)

In July 2012, the Australian federal government introduced a carbon pricing scheme (Bailey et al., 2012; Jotzo, 2012). To a certain extent, this scheme has shifted the balance of competition between renewable energy and fossil fuels due to (a) increasing the cost of fossil fuel generation and (b) rendering renewable energy more viable. Cost represents the major barrier to renewable energy development, which requires much higher up-front capital costs when compared with fossil fuel generators (Han et al., 2019). Additionally, both the cost and risk of fossil fuel electricity have historically been externalised (Elliston et al., 2014), which leads to lower private costs but higher social costs when compared with renewable energy, in addition to decreasing the competitiveness of renewable energy (Byrnes et al., 2013). Carbon pricing in Australia has, therefore, aimed to internalise the environmental costs of fossil fuels due to the associated emissions.

The lack of a post-2020 policy for achieving Australia's long-term carbon emissions targets has seen state and territory governments take unilateral action using CfD. Government-initiated CfD have the effect of diversifying the buy-side forward market liquidity and, thus, bringing about certain short-run benefits (Simshauser, 2019c). As highlighted by Simshauser (2019c), CfD allow the parties to a power purchase agreement (PPA) to set a long-term price and also take into account the ANEM spot market variations. This long-term price is known as the "strike price" and, in CfD, generators pay customers the difference when the spot price is above the strike price. When the spot price is below the strike price, customers pay generators the difference between the prices.

Feed-in tariff (FiT) policies have been used in Australia to promote the uptake of renewable electricity, primarily in the form of rooftop solar PV systems (Poruschi et al., 2018). A FiT is a way of subsidising and encouraging the uptake of renewable energy and, in Australia, such policies have been enacted at the state level, in conjunction with a federal MRET (Nelson et al., 2011). In March 2008, the COAG agreed that solar FiTs would have to have a relatively uniform structure throughout the country (Poruschi et al., 2018). From July 2008, states and territories across Australia started to implement FiT schemes (Nelson et al., 2011). As a result, Australia has the highest uptake of solar power worldwide, with more than 21% of homes having rooftop solar PV (Clean Energy Council, 2020). By 2020, more than 2.53 million rooftop solar power systems had been installed across Australia (Clean Energy Council, 2020).

Aside from the federal RET, state and territory governments have adopted policies to increase the sourcing of electricity from variable renewable energy sources and/or adopt a net-zero emissions target (Bhattacharya et al., 2020; Li et al., 2019). For example, in 2014, SA announced the target of sourcing 50% of its electricity from renewable energy sources by 2025 and 100% from renewables before 2030 (Byrom et al., 2020). In addition, the state has set the goal of achieving net-zero emissions by 2050. In 2015, QLD committed to generating 50% of its energy from renewable sources by 2030 as well as to ensuring that one million of its homes had rooftop solar systems by 2020 (Keck et al., 2019). In 2016, the government of VIC committed to renewable energy generation targets of 25% by 2020 and 40% by 2025, in addition

to a net-zero emissions target by 2050 (Reedman et al., 2018). The NSW government has committed to an aspirational objective of net-zero emissions by 2050 (Byrom et al., 2020).

2.3. Related Literature
A number of empirical studies have explored the relationship between renewable energy sources and prices, in addition to their influence on the electricity spot and options markets (Alsaedi et al., 2020a; Csereklyei et al., 2019; Forrest and MacGill, 2013; Worthington and Higgs, 2017). However, there is a noticeable lack of literature concerning in-depth qualitative investigates of such matters (Anderson et al., 2007; Runquist, 2016; Simpson, 2017a).

Anderson et al.'s (2007) study was conducted in the Australian context and, therefore, is relevant to the present investigation. Their study was based on interviews conducted with participants in the ANEM. The aim was to explore the operation of the contracting process in Australia. Further, they analysed risk management practices in the Australian energy-only pool market. Anderson et al. (2007) revealed that there exist significant gaps between the assumptions made in the literature and the actual practices seen in the Australian marketplace.

Simpson (2017a) analysed the social acceptance of renewable energy policy in Australia using a mixed-methods analytical approach, including (i) quantitative survey data, (ii) qualitative interview data and (iii) a content analysis of publicly available secondary sources. This indicates that the interview and content analysis methods have led to significant insights in the present area of interest.

In a similar vein, Simpson (2017b) conducted in-depth interviews to determine the extent to which network operators in Western Australia are perceived to facilitate or block the transition to a distributed and renewable generation system. The results of this exploratory analysis demonstrated that network operators are perceived to "push back" on distributed generation by increasing the complexity, cost and unreliability of connection applications, restricting the further connection of distributed generation to the network and requiring consumers to invest in technology for grid protection. The interviewees suggested that network operators do so for a number of reasons:
1. Distributed generation creates technical issues at the distribution-level of the network
2. Distributed generation can reduce financial revenues for the network operator
3. Due to the lack of strategic direction regarding how network operators should respond to distributed generation
4. Due to a "risk averse" engineering culture that rejects the unknown.

McGreevy et al. (2021) investigated the factors behind SA's successful renewables transition from 2002 to 2018 through empirical interviews conducted with key actors in light of the theories of transition management and planning. The results showed that when renewables establish a critical mass of generation, they produce a path-dependent trajectory that is difficult to alter. The authors concluded that SA's experience demonstrates a means by

which renewable transitions can be expedited by public policy initiatives within a privatised market system.

Of all these qualitative studies, the work of Anderson et al. (2007) is the most relevant to the present investigation due to revealing that there are significant gaps between the assumptions made in the literature and the actual practices in the Australian marketplace. This finding represents the principal motivation for applying a qualitative approach in the present paper. Such an approach will provide useful insights into the Australian energy market. The lack of prior qualitative studies in this regard suggests that more work could be done on the issue of preference in relation to policies and their effects upon electricity pricing, either directly or indirectly, when higher percentages of renewable energy sources are included in the mix.

3. METHODOLOGY

3.1. Selection of Participants

This study applies a qualitative research design with the aim of investigating the nature and influence of solar and wind pricing policies and regulations on the Australian electricity spot and options markets. The data were gathered through interviews conducted with directors or senior executives, primarily from within the Australian electricity industry. More specifically, the study draws on interviews with CEOs and energy delegates that were conducted in English, either in person or via email, between September 2019 and April 2020. Each interview lasted between 45 and 60 minutes, and all the interviews were transcribed verbatim. The interviewees were from the Department of Environment, Land, Water and Planning; the Australian Energy Market Commission (AEMC) and four energy companies. Prospective interview candidates were identified using a variety of methods, including online databases (e.g., LinkedIn), industry magazines, conferences, news articles, academic literature and recommendations. The interviewees were purposively selected so as to represent the relevant perspectives in a balanced manner based on their current and prior professional roles.

The sample sizes for qualitative studies are usually much smaller than those for quantitative studies. Mason (2010) and Ritchie and Spencer (2002) have provided reasons for this. First, qualitative research does not necessarily lead to more information through more data, as just one occurrence of a piece of data is necessary to ensure that it forms part of the analysis framework. Second, qualitative research is extremely labour intensive, while analysing a large sample can be time consuming and, often, impractical. Finally, a large amount of data might become repetitive and superfluous, since the collection of further data does not always shed further light on the issue under investigation (Mason, 2010; Ritchie and Spencer, 2002).

Further, Patton (1990) highlighted that the number of interviewees included in qualitative studies does not matter as long as the researcher is able to capture the essence of the data. In fact, Boyd (2001) suggested that saturation can often be reached after interviewing two to ten participants. In addition, Yin (1994) noted that "saturation" often occurs after six participants have been interviewed. Thus, six seemed to be a sufficient number of interviews to achieve the aim of the present study. In other words, the interviews were of sufficient quality and length to address the research objectives.

3.2. Data Analysis

The basic steps involved in the analysis of qualitative data consist of coding the data, combining the codes into broader categories and themes, and then interpreting the results (Creswell et al., 2007; Sinkovics et al., 2005). A thematic analysis, which involves developing themes by detecting and analysing data (Creswell, 2002), was performed in this study. The interviews were transcribed verbatim in English. Next, a thematic analysis was conducted to develop the themes and allow for a comparison and discussion of the data across all six participants. The six essential stages of a thematic analysis (Braun and Clarke, 2006; Saldaña, 2015) were followed in this study. First, all the data were transcribed and then read and reread to generate ideas for the coding. Second, early codes were produced from the collected data, and all the relevant data were grouped. Third, the possible themes from the codes created in the previous step were linked and explored. Fourth, the themes were reviewed and reread to determine whether or not they were sufficiently supported by the codes and the total data set. Fifth, the themes were described and labelled by defining and refining the meaning of the data so as to identify the essential themes, which were then assigned to the appropriate research phenomenon. Finally, a report was written, which included an analysis and the conclusions that could be drawn from the results (Braun and Clarke, 2006).

4. RESULTS

The findings of this study were derived from a qualitative thematic analysis of the six semi-structured interviews conducted with the self-selected and sufficiently qualified study participants. There are two key approaches to writing up qualitative research results (Burnard et al., 2008). The first is simply to report the main findings related to each major and minor theme or category, using appropriate quotes to exemplify those findings. This should be accompanied by a separate discussion that links the results to those of prior studies. The second approach is somewhat different in that it incorporates the discussion into the results, although it is otherwise the same. Each research question in the present study was used as a thematic category (or basis of analysis) so that it could be adequately addressed later on. Only one appropriate verbatim quote was used to reflect the theme of each question. Figure 3 presents an overview of the analysis process.

4.1. Current Status of Solar and Wind Energy in Australia's Electricity Markets

In recent years, the share of solar and wind power has increased worldwide, which has resulted in those renewable energy sources having an increasing impact on electricity system prices and costs. For example, in 2018, renewable sources contributed some 49,339 GWh (19%) to the total electricity generation within the ANEM (Commonwealth of Australia, 2019). Thus, the first research question in this study concerned the current status of solar and wind energy in Australia's electricity markets.
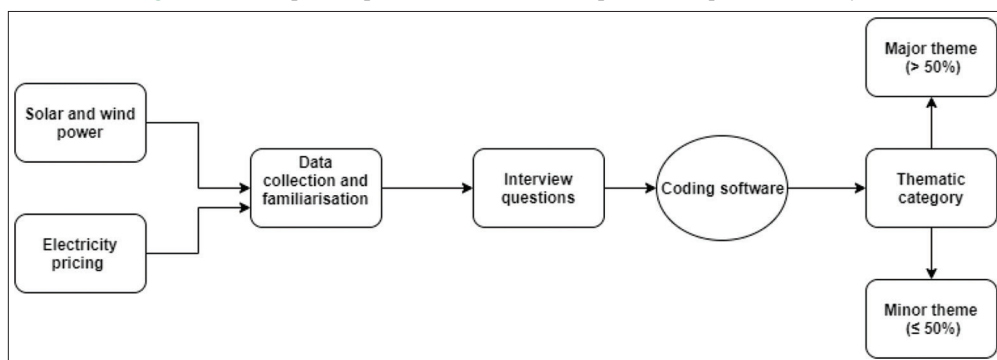
4.1.1. Major theme 1: Solar and wind energy are becoming cheaper and increasingly common

The interviewees believed that the electricity generation capacity based on wind turbines (WT) and solar PV cells has rapidly increased over the last decade in Australia. It is estimated that Australia produced 48,279 GWh of renewable electricity in 2018, which accounted for 21.3% of the total electricity generated. As of July 2018, wind power supplied around 33.5% of Australia's renewable electricity (or 7.1% of the total electricity). Further, solar power accounted for 5.2% (or 11.7 TWh) of Australia's total electrical energy production (227.8 TWh) in 2018. The interviewees discussed the current status of solar and wind energy in Australia's electricity markets.

Wind and solar (both large-scale and rooftop PV) generation are commercially competitive technologies that are widely accepted in the ANEM. In 2018–2019, renewable sources provided over half (52.1%) of SA's electricity generation. Wind energy is the most prevalent form of generation in SA, with 1,929 megawatts of fully installed wind capacity across 21 wind farms. Additionally, there is over 1,240 megawatts of behind-the-meter solar PV across the state. Large-scale solar farms also contribute to the state's overall electricity generation, with three farms now in operation totalling 378 megawatts. With the exception of SA, where wind and solar generation produce about half the state's electricity, wind and solar technologies produce a relatively small share (less than 20%) of electricity generation in each state. These shares are increasing due to new large-scale renewable energy projects under construction across Australia and continued investment in rooftop solar systems by households and small businesses (Interviewee I4, Researcher, 2019).

4.1.2. Minor theme 1: Solar and wind investment entering a period of slowdown in Australia

Interviewee I5 opined that investment in wind and solar plants slowed from mid-2019, as technical issues involving integrating new plants into the system delayed projects. Coordinated planning reforms aim to better integrate renewable plants, rooftop solar PV, demand response and battery storage into the system, with a focus on ensuring the transmission grid can meet transport needs. Additionally, interviewee I5 stated that new investment in large-scale solar, wind and storage projects in Australia continued to slump from mid-2019 as Australia's perennial grid woes and policy uncertainty continued to undermine investor confidence. Difficulties finalising grid connection processes and obtaining

Generator Performance Standards (GPS) delayed a number of large-scale solar and wind projects, undermining their economic viability. This fall in investment reflects the growing risks faced by renewable energy developers. Under current policy, lower levels of renewable energy investment are expected to become the new normal until the retirement of coal-fired generators later in the decade, with renewables investment forecast to become reactive to coal-fired closures (and higher prices), rather than proactive (policy driven) to prepare for expected retirements (Interviewee I5, Researcher, 2020).

4.2. Future Solar and Wind Energy Challenges in Australia's Electricity Markets

The past decade has seen a dramatic increase in the penetration of wind and solar PV power within the ANEM (Blakers et al., 2017; Hua et al., 2016; Rai and Nunn, 2020). Solar and wind power are both weather-dependent technologies, meaning that their electricity production is intermittent. Therefore, their inclusion in an electricity system results in costs associated with guaranteeing the backup capacity and maintaining conventional energy sources in ready-to-use states. Additionally, solar and wind power have negligible marginal costs and insufficient priority of dispatch to satisfy demand, which also poses a challenge for electricity markets (Di Cosmo and Valeri, 2018). Thus, the second research question concerned the likely future challenges that the Australian electricity markets will face due to the influence of solar and wind energy.

4.2.1. Major theme 2: Lack of a credible emissions trajectory and policy poses a challenge

Overall, there were five occurrences of this theme, indicating that it was identified in 80% of the interviews. Interviewee I2 explained how Australia's energy policy and regulatory framework should be structured to ensure the security of supply, an area that has become mired in controversy. The issue of the security of supply within the ANEM in the face of the increasing penetration of solar and wind power also highlights the need to re-consider the question of whether wholesale electricity markets are inherently prone to market failure, meaning that government intervention in the form of the imposition of capacity payments or strategic reserves is justified.

At a high level, ensuring that Australia's transition from predominantly fossil fuel-based electricity generation to predominantly renewable electricity generation occurs in an

orderly fashion is a key challenge facing the ANEM over the coming years. At a more technical level, energy market rule makers will need to monitor whether the ANEM's current market design continues to be appropriate as the share of wind and solar generation increases and a greater proportion of the ANEM's supply is bid into the market at very low or zero prices (Interviewee I2, Researcher, 2019).

4.2.2. Minor theme 2: Solar and wind sources create instabilities for the centralised electricity grid

This minor theme emerged in 20% of the interviews. Interviewee I3 noted that system strength has emerged as a prominent challenge to the integration of renewables into the ANEM. This challenge must be overcome to ensure system security and reliability. Yet, despite continuous warnings, not much has been done to strengthen the grid and pave the way for new renewable energy projects to join the market. Instead, the situation in some parts of the grid has rapidly deteriorated, thereby putting a growing number of projects at risk.

As we continue to see an increasing shift toward non-traditional generators and the increasing take up of household rooftop PV, we are encountering new challenges associated with managing voltage, system strength and inertia. Partly as a result of the rapidly increasing renewable energy generation capacity, the AEMO has been intervening in the market more frequently to maintain system security. For example, some renewable energy generators have had their output constrained due to insufficient grid capacity. In addition, some generators located in weak areas of the grid have faced significant reductions in marginal loss factors, reducing the revenue earned for electricity produced. Tighter technical standards concerning connecting to the grid have also led to connection delays and higher costs for new projects (Interviewee I3, Researcher, 2019).

4.3. Solutions to Future Solar and Wind Energy Challenges in Australia's Electricity Markets

The transformation of the power system from a reliance on fossil fuels to a focus on renewable energy involves new challenges that must be addressed in the ANEM (Byrnes et al., 2013). These challenges have come about due to the changing mix of generation, which has been driven by policy (Simshauser and Gilmore, 2020). Since Australia is a world leader in terms of its increasing reliance on wind and solar power, it is incumbent upon practitioners and policymakers to understand the challenges and put appropriate solutions in place. Thus, the third research question concerned the solutions that could be applied to address the future challenges facing the Australian electricity sector due to the influence of solar and wind energy.

4.3.1. Major theme 3: Developing and coordinating renewable energy policy and regulation

Four interviewees made reference to this theme. For instance, interviewee I2 indicated that Australia stands to become an energy superpower if it can manage the transition to a cleaner energy future well, although that will take very close cooperation between government, industry, regulatory bodies and research institutions. Furthermore, interviewee I2 identified a number of solutions that

could assist in achieving an orderly electricity sector transition in Australia, including:

- Governments must provide clear and credible signals to the market regarding the future pace of the electricity market transition
- Large fossil fuel generators must provide the market with sufficient notice of their closure dates
- New transmission interconnections between (and within) regions must be developed in sufficient time to support this transition
- Market participants must be sufficiently incentivised to invest in dispatchable capacity and any system strength remediation measures required in their areas (while governments and market bodies must undertake any necessary actions and reforms to enable this to occur) (Interviewee I2, Researcher, 2019).

4.3.2. Minor theme 3: Better planning through the integrated system plan (ISP) process

Interviewee I5 commented on how the AEMO's ISP has shown that, in many situations, a centralised approach to managing system strength would prove more economical than developing individual solutions for each wind and solar farm. The ISP is a whole-of-system plan that provides an integrated roadmap for the efficient development of the ANEM over the next 20 years and beyond. Interviewee I5 noted that the objective of the ISP is to: Maximise value for end consumers by designing the lowest cost, secure and reliable energy system capable of meeting any emissions trajectory determined by policymakers at an acceptable level of risk. It fully utilises the opportunities provided by existing technologies and anticipated innovations in DER, large-scale generation, networks and coupled sectors such as gas and transport. Without an ISP, we would see more and more situations – such as those we are working through in some weaker parts of the network in eastern states – where even the best engineering analysis and effort cannot keep pace with market demand, creating adverse consequences for investors and consumers (Interviewee I5, Researcher, 2020).

4.3.3. Minor theme 4: Careful network augmentation to avoid the Averch–Johnson effect

Interviewee I6 reflected on how the ANEM is the longest network in the world and, in a network its size, how it is fair and reasonable to assume that there would be limitations to the existing grid. Significant network augmentation will ultimately be required if the system is to continue the transition toward renewable energy adoption. However, an increase in network costs will lead to allegations of excessive investment in the networks, which is known as "gold plating". The gold plating effect, that is, the risk that rate-of-return regulation will lead to inefficient levels of investment and high prices, is also known as the Averch–Johnson effect (Averch and Johnson, 1962).

The Averch–Johnson effect concerns the unintended consequences of fair rate-of-return regulation. Such regulation may cause a firm to select excessively capital-intensive technologies and so to not produce its output at minimum social cost. Specifically, the main Averch–Johnson result is that the capital–labour ratio selected by a profit-maximising, regulated firm will be greater than is consistent

with a cost-minimising one for any output it chooses to produce. If the fair rate of return is greater than the cost of capital, a firm will have an incentive to invest as much as it can consistent with its production possibilities, as the difference between the allowed rate and its actual cost of capital is pure profit (Interviewee I6, Researcher, 2020).

## 4.4. Effects of Solar Generation Pricing on Australia's Electricity Markets

Australia has some of the best solar resources in the world, in addition to some of the highest electricity prices (Poulter, 2020). It also has the highest per capita level of domestic solar PV installations worldwide, standing at almost 25% of households (Heidari et al., 2020). The direct effect of solar power on the electricity spot and options markets is typically adverse, since solar power allows for the generation of electricity at very low or even zero marginal cost and, thus, displaces more costly means of generation (Alsaedi et al., 2020a). Moreover, solar power can indirectly decrease the electricity spot and options prices by lowering the power of the market in systems in which generators bid strategically (Alsaedi et al., 2020a). Therefore, the fourth research question concerned the experts' attitudes toward the effects of solar generation pricing on Australia's electricity spot and options markets.

4.4.1. Major theme 4: Solar generation pricing decreases the spot and options electricity prices

Most experts recognise that solar generation (through the so-called "duck curve") has the effect of reducing the residual grid demand during the peak sunlight hours in the middle of the day, which tends to reduce the wholesale electricity prices at those times. These price reductions flow through to the price of baseload options.

People are putting thousands of megawatts of solar PV on their roofs, which is dropping demand during the middle of the day in what was historically the peak period. Electricity users consume power in a very typical manner. Demand begins to pick up in the morning and, traditionally, remains constant throughout the day before hitting its peak at sundown and tapering off during the night. This creates a situation where the spot prices during the day are low, although they skyrocket as soon as the sun sets as the grid tries to cope with the massive spike in demand. This is known as the duck curve (Figure 4), as a duck's belly curves downwards, and SA, with its high penetration of solar PV, has a world-leading duck curve in relation to minimum demand (Interviewee I1, Researcher, 2019).

Figure 4: Effect of growing rooftop solar power
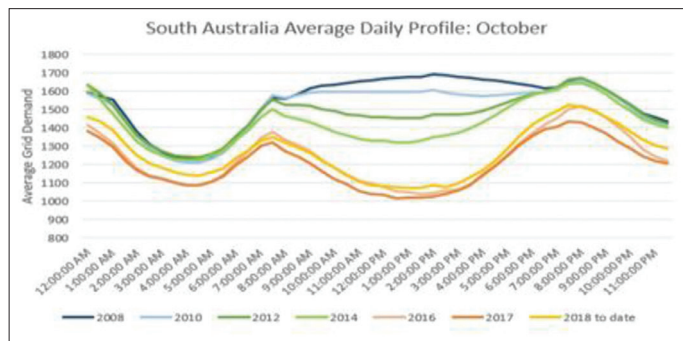
Source: AEMO (2018)

4.4.2. Minor theme 5: Solar generation pricing leads to price extremes

The experts agree that solar generation can cause large daily swings in the spot prices. However, they differ as to what is fair value for PPAs and other contracts because pricing depends on assumptions such as a shadow carbon price, the uptake of even more solar generation and network congestion.

The adoption of solar power is having profound consequences for electricity prices. Solar generation in Australia's electricity markets has resulted in contrasting effects on the daily price volatility. For example, when the solar output is low, the (short-run) aggregate supply curve shifts back to the left and, when combined with fluctuating demand, can be expected to intensify price volatility – producing distinctly elevated prices (Figure 5 for an illustration of this) (Interviewee I6, Researcher, 2020).

4.5. Effects of Wind Generation Pricing on Australia's Electricity Markets

As a low-carbon technology, wind power plays an important role in addressing climate change (Shen et al., 2020). The installed capacity of wind power has increased significantly in recent years. For example, in Australia, the cumulative installed capacity of wind energy increased from 1840.1 MW in 2010 to 6279.4 MW in 2019 (Clean Energy Australia Report, 2019). To compare the costs of different types of generation technologies, a levelised cost of electricity (LCOE) is defined, which is commonly accepted as the metric for the economic analysis of power generation systems (Tran and Smith, 2018). This method estimates the average total cost of constructing and operating an electricity generation asset over its entire lifetime divided by the total power output of the asset over that lifetime. Today, the cheapest form of new generation technology on an LCOE basis in Australia is wind (Rai and Nunn, 2020). Thus, the fifth research question concerned the experts' attitudes toward the effects of wind generation and pricing on Australia's electricity spot and options markets.

4.5.1. Major theme 5: Experts recognise that wind generation pricing results in lower prices

The experts agree that wind power (through the "merit order" effect) plays a role in reducing the wholesale electricity prices when generators bid into the market at low, zero or negative prices to ensure it is dispatched. These low bid prices stem from the very low marginal costs faced by wind generators. Such bids effectively reduce the amount of grid demand that must be met through higher priced bids, thereby reducing dispatch prices at those times.

Figure 5: Solar price impression effect in Queensland, August 2019
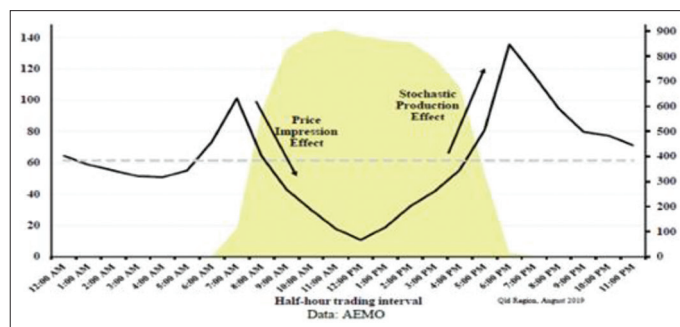
Source: Simshauser (2020)

Csereklyei et al. (2019) revealed that an extra GW of dispatched wind capacity decreases the wholesale electricity price by 11 AUD/MWh at the time of generation. They also noted the existence of a wind merit order effect, meaning that additional wind generation resulted in reductions in wholesale electricity prices. This indicates that under a counterfactual of a lower penetration of wind power than was actually seen, the wholesale electricity prices in Australia would have been higher than they actually were (Interviewee I4, Researcher, 2019).

4.5.2. Minor theme 6: Electricity prices become more volatile

Some experts asserted that the issue with wind generation is not just that the output is variable, as it is also poorly correlated with demand. This is especially true of the wind output in SA, which is typically negatively correlated with demand. Hence, supply becomes harder to equilibrate with demand, which is manifested via higher price volatility as the penetration of wind power increases. Interviewee I5 explained that more extreme spot prices could increase in the future under high wind generation. For example, if the correlation between wind resources across the ANEM increases due to a lack of sufficient geographic and technological diversification and/or increased coincident weather patterns, the potential for greater interconnection to dampen volatility may diminish as demand and supply become more correlated across regions (Interviewee I5, Researcher, 2019).

4.6. Implementation of Australian State Governments' Renewable Energy Policies

The rising levels of VRE within the ANEM have been driven by the desire to reach the 20% renewable energy target by 2020 (Simshauser, 2019c). This certificated renewable portfolio standard has successfully driven new investment, allocated risk amongst buy- and sell-side market participants and met overall policy objectives (Simshauser, 2019c). However, a policy vacuum when it comes to achieving long-term CO_2 emission targets post-2020 has led to sub-national and, potentially, national governments initiating CfD to further drive investment activity in new plants—with virtually no coordination between the jurisdictions (Simshauser, 2019c). Thus, the sixth research question concerned how renewable energy policies have been implemented at the state level in Australia.

4.6.1. Major theme 6: FiT schemes and CfD are the two main policy instruments currently driving increases in renewable energy

This major theme was mentioned by four interviewees. Interviewee I6 commented that FIT schemes and CfD are a way of subsidising and encouraging the uptake of renewable energy and, in Australia, have been enacted at the state level in conjunction with a federal MRET. Interviewee I6 also noted that the RET is an Australian government scheme designed to reduce emissions of greenhouse gases in the electricity sector and encourage the additional generation of electricity from sustainable and renewable sources. The RET scheme imposes a target than can be met at the lowest cost. A FiT scheme sets a firm price for renewable energy and allows the market to decide how much capacity will be added. Every Australian state or territory has offered some form of FiT for renewable energy. Most are aimed at household systems, such as rooftop solar panels. Under such a scheme, the household is guaranteed connection and receives a set rate for the electricity fed into the grid. Moreover, as a policy mechanism, CfD represent a means by which the winning (lowest) bids in $/MWh of electricity for renewable electricity generators are guaranteed by the government. If the wholesale price of electricity received by the winning owners is less than the guaranteed contract price, the government pays the difference; but if the reverse is true, the owners pay the difference to the government, which benefits consumers (Interviewee I6, Researcher, 2020).

4.6.2. Minor theme 7: State governments have announced the establishment of ambitious renewable energy targets

Two interviewees reflected on this theme. Interviewee I2 stated that several state and territory governments have set renewable energy targets that are more ambitious than the national scheme. Programs encouraging new renewable entry typically support such targets. Interviewee I2 indicated that, while government policies have helped to drive the surge in renewable energy, the declining costs of renewable plants (at both the commercial and small-scale levels) have accelerated the shift. Improvements in plant technologies and the scale benefits of an expanding market are also significant drivers of these cost improvements.

Over the past few years, VIC has played a very active role in implementing state-wide renewable energy policy. At a high level, VIC's renewable energy policy has been implemented through a combination of legislation (such as renewable energy targets and reforms to the state's planning laws) and direct action (through renewable energy auctions and government support for renewable energy projects) (Interviewee I2, Researcher, 2019).

4.7. Policy Instruments for Renewable Energy in Australian States

The Australian federal and state governments' renewable energy targets form comprehensive economic and industry development strategies aimed at accelerating the growth of Australia's renewable energy sector (Nelson et al., 2015). The targets are broad in scope and include a raft of initiatives intended to address areas of market failure, drive regulatory reform, streamline planning processes, remove non-economic barriers and facilitate technological innovation (Simshauser, 2019c). Such measures position the state as the driver of the national renewable energy plan while detailing mechanisms to attract maximum investment under the expanded national renewable energy targets (Byrom et al., 2020). The primary objective is to increase the deployment of renewable energy infrastructure in Australia. This means providing the right incentives to encourage industry to move beyond business as usual and look for new opportunities. Thus, the seventh research question concerned the policy instruments used to implement renewable energy policies at the state level.

4.7.1. Major theme 7: State governments have adopted comprehensive policy frameworks to support renewable energy

Most interviewees commented that state governments have taken proactive steps to encourage the uptake of renewable energy. They now have strong renewable energy targets or net-zero emissions targets in place. The targets are broadly consistent with the level of

renewable energy required across Australia by 2030. Interviewee I3 noted that, in the past few years, enormous progress has been made by Australian states and territories, with most increasing their commitments. Interviewee I3 added that, in the absence of federal government mechanisms driving more investment in renewable energy beyond 2020, the approaches adopted by states and territories are the primary mechanisms for increasing renewable energy generation. Moreover, interviewee I2 explained how VIC has implemented renewable energy policies through a number of policy instruments, including

- Legislating Victorian RETs (VRETs) for 2020 (25% renewable generation), 2025 (40% renewable generation) and 2030 (50% renewable generation)
- Holding the 2017 VRET reverse auction and supporting 928 MW of new renewable energy capacity
- Using the government's energy purchasing power to contract with new Victorian renewable energy projects to provide the renewable energy certificates associated with the government's electricity consumption
- Introducing the Solar Homes program to provide rebates and low-cost finance to eligible Victorian households that install rooftop solar systems
- Reforming the state's planning laws as they apply to renewable energy projects (Interviewee I2, Researcher, 2019).

4.7.2. Minor theme 8: Central auction CfD are a viable policy option

Interviewee I6 stated that CfD have been used by state governments to drive investment in renewable energy. CfD have been undertaken unilaterally by sub-national governments—first by the Australian Capital Territory (wind, 2015), then QLD (solar PV, 2016), SA (semi-CfD for battery storage, 2017) and VIC (wind and solar PV, 2018). These targeted and centrally planned CfD auctions have proved successful at meeting their policy objectives. Additionally, CfD facilitate state/regional economic development, while adding new renewable supply can reduce the spot and options electricity prices.

In the ANEM, CfD have been used selectively and effectively by state governments to "prime" emerging markets and navigate Commonwealth government policy discontinuity, with material on market transactions following. The Australian Capital Territory government's CfD pioneered nominal price transactions, the QLD government's CfD led to more than 1900 MW of follow on solar PV projects and the SA government's semi-CfD for battery storage has resulted in more than a dozen battery projects. From a project execution perspective, the effectiveness of government-initiated CfD is unquestionable (Interviewee I6, Researcher, 2020).

4.8. Impact of Renewable Energy Policies on the Australian Solar, Wind, Spot and Options Electricity Prices

While government policies on renewable energy have helped to drive the surge in solar and wind energy, the declining costs of solar and wind plants have accelerated the shift (de Atholia et al., 2020). Improvements in plant technologies and the scale benefits of an expanding market have also proved significant. The literature on renewable energy sources has revealed that an increase in intermittent wind and solar generation significantly affects the distribution of electricity prices (Csereklyei et al., 2019). The eighth research question concerned how policies and regulations influence wind and solar pricing and, consequently, the Australian electricity spot and options markets.

4.8.1. Major theme 8: State governments' policies and regulations reduce the spot, options, solar and wind electricity prices

Most interviewees emphasised that state governments' regulations have increased the output of wind and solar generation and supported investment in a number of wind and solar projects currently under construction. Interviewee I2 stated that the increase in solar and wind generation in VIC has reduced the Victorian wholesale electricity prices below what they would otherwise have been. Moreover, Interviewee I1 explained that the government is delivering policies that drive down solar and wind electricity prices as well as electricity spot and options prices.

The costs of solar and wind generation technology have decreased markedly in Australia in recent years. While it is difficult to compare the cost of electricity generation from different sources, one common approach is to use the LCOE measure, which represents the present value of the cost of building and operating a power plant over its assumed life. While renewable power plants have quite high fixed costs, their operating costs are very low owing to the zero cost of fuel. The LCOE for new solar and wind power plants has fallen significantly over the past decade and is estimated to be between 40% and 60% of the cost of a new fossil fuel plant. The share of electricity generation from solar and wind sources is expected to continue increasing as projects that are currently under construction or have recently been completed begin generating output. This increase in solar and wind generation has decreased the spot and options electricity prices for many Australian states (Interviewee I1, Researcher, 2019).

4.8.2. Minor theme 9: CfD shift risk from investors to taxpayers and electricity spot, options, solar and wind prices lower as a result

CfD play a role in reducing solar and wind electricity prices as well as spot and options prices. Interviewee I5 added that CfD facilitate state/regional economic development, while adding new solar and wind supply can reduce wholesale electricity prices.

The policy objective of government-initiated CfD is to introduce generation plants that energy markets are failing to deliver. In this sense, CfD have the effect of bringing forward future power projects to today, with the benefits, costs and risks of doing so being allocated to electricity consumers, taxpayers and incumbent rivals. In addition, government-initiated CfD reorientate policy and the credit risk away from buy-side energy market participants and toward taxpayers… so prices lower as a result. However, they are lower because taxpayers absorb the risk (Interviewee I6, Researcher, 2020).

4.9. Responses to the Implementation of Renewable Energy Policies in Australian States

The renewable energy targets and policy mechanisms of several Australian states have proven effective (Chatfield and Reddick,

2018). States' renewable energy policies have been favourably received by investors and households alike. For example, at the end of 2019, 11,000 MW of new generation was under construction or financially committed, representing $20.4 billion in investment and more than 14,500 jobs (Clean Energy Council, 2019). In addition, Australia has the highest uptake of solar power worldwide, with more than 21% of homes having rooftop solar PV systems (Lan et al., 2020). As of 31 August 2020, more than 2.53 million rooftop solar power systems had been installed across Australia (AER, 2020b). The ninth research question concerned the responses to the implementation of renewable energy policies by the states.

4.9.1. Major theme 9: Lots of eager investors willing to execute renewable energy projects

All six interviewees revealed that state governments' policies have encouraged investment in renewable generation. Interviewee I3 noted that investment in large-scale solar and wind energy projects increased significantly between 2016 and 2019. This investment stemmed almost entirely from the private sector. Interviewee I3 added that households have been the main driver of small-scale solar investment, with around 25% of dwellings now having rooftop solar panels. This has been incentivised by government policies, including the national government's small-scale technology certificate scheme and state-based FiTs. Moreover, Interviewee I2 explained how investment in renewable energy generation has increased markedly in VIC in recent years, driven by government policy incentives.

VIC's renewable energy policies have generally been favourably received by industry and households. The response of industry to VIC's renewable energy policy is illustrated by the 2017 VRET reverse auction, which sought 650 MW of new renewable energy capacity but attracted over 3000 MW of project bids from industry. The bids were of sufficient quality for 928 MW of projects to be successful in receiving support contracts. The response of households is illustrated by the Solar Homes program, which received such positive interest from households that the government released an extra 23,000 rebates for 2019–2020, leading to a total of 65,000 solar PV rebates over 2019–2020 (Interviewee I2, Researcher, 2019).

4.9.2. Minor theme 10: The corporate PPA market in Australia has grown considerably due to the RET

Interviewee I1 stated that there had been increased interest in corporate renewable PPAs due to government energy policies. The strong uptake of corporate renewable PPAs over the last few years has led to records being broken for both the amount of new capacity secured under off-take contracts and the total amount of deliverable electricity generation contracted.

Long-term PPAs assist developers in obtaining finance by providing revenue surety. Historically, developers typically entered into PPAs with electricity retailers, who had obligations to purchase electricity from renewable sources under the RET. Over the past few years, however, projects have been increasingly supported by PPAs with other corporate entities. Corporate PPAs can take many forms but often involve the corporate entity entering into an electricity supply contract directly with the generator. Corporates are entering into PPAs to reduce their electricity costs and exposure to price volatility as well as to meet environmental commitments (Interviewee I1, Researcher, 2019).

4.9.3. Minor theme 11: Increased vertical integration of energy companies

Interviewee I3 stated that there has been a noticeable trend toward increased vertical integration between retailers and generators due to renewable energy policies. The major Australian electricity generators tend to be vertically integrated into electricity retail as a means of managing spot market risks.

Vertical integration is considered a key means of managing the energy-only market risk and, based on market share, the vast majority of ANEM retailers primarily manage risk this way under the RET (Interviewee I3, Researcher, 2019).

4.10. Main Barriers to Implementing Renewable Energy in Australian States

Despite strong investment in solar and wind projects in Australia, significant legal disputes have arisen due to problems with the physical infrastructure of the electricity grid (Li et al., 2020). The principal barriers to the rapid growth of renewable energy result from the emerging constraints in those parts of the electricity grid with strong renewable energy resources. Renewable energy power plants tend to be geographically dispersed based on the availability of wind and solar resources (de Atholia et al., 2020). In some cases, they are built in areas of the grid with insufficient transmission capacity. Further, investment in renewable energy power has fallen since the national target of 23% of electricity coming from clean energy sources was reached in September 2019 (Clean Energy Council, 2020). The tenth research question concerned the main barriers to implementing renewable energy in the states.

4.10.1. Major theme 10: Challenges to integrating renewable energy sources into the electricity grid

The interviewees expressed concern regarding technical system integration (i.e., frequency stability, inertia, system strength). Interviewee I2 shared how renewable energy affects the grid as well as the implications for the grid of a high penetration of renewables in the future.

There is uncertainty about future national renewable energy policy and emerging constraints in some parts of the electricity grid with strong renewable energy resources but weaker transmission capacities. The emerging grid constraints in weaker parts of the electricity grid are seeing the output of some renewable generators in those areas constrained to preserve system strength. In addition to reducing the output of those generators, this grid congestion is reducing the expected future prices received by generators in those areas through the effect on marginal loss factors. Uncertainty about future revenues makes it difficult for renewable energy project developers to invest in new projects and for governments to identify how much support, if any, new renewable energy projects will require (Interviewee I2, Researcher, 2019).

4.10.2. Minor theme 12: Lack of united energy and climate change policy architecture at the national level

Interviewee I1 opined that after the RET was fulfilled, thoughts inevitably begun to turn to the next step. While there does not appear to be any end in sight to the federal political impasse, the good news is that the states and territories and Australia's energy regulators are stepping in to fill the void.

The continued absence of a policy to replace the RET leaves clean energy, and the energy industry as a whole, in a state of uncertainty at a time when investment in new generation should be increasing to replace the ageing fleet of coal-fired power stations and meet emissions reductions commitments. The states are attempting to fill the federal policy gap. Several have their own renewable energy support schemes and all states in the east coast's market have committed to net-zero emissions by 2050. The energy regulators have also begun planning for a future in which renewables are the dominant form of generation through new pricing models and transmission investment plans (Interviewee I1, Researcher, 2019).

5. DISCUSSION AND CONCLUSION

This study sought to explore the influence of policies and regulations concerning solar and wind power on Australia's electricity spot and options markets. A qualitative approach was used to accomplish this, as the data were gathered through interviews conducted with selected personnel, managers and CEOs from within the Australian electricity industry. The semi-structured, in-depth interviews were conducted between September 2019 and April 2020. A total of six interviews were conducted, ranging in duration from 45 to 60 min.

The first aim of the present study was to investigate the current situation and future challenges/solutions related to solar and wind energy within Australia's electricity markets. The qualitative analysis showed that solar and wind generation represent commercially competitive technologies that are widely accepted within the ANEM. In others words, solar PV and wind are two mainstream forms of variable renewable energy generation in Australia. As noted by Rai and Nunn (2020), the surge in solar and wind penetration in Australia has been driven by a combination of the declining costs of solar PV and wind generation and policies aimed at reducing the emissions intensity of electricity generation.

Further, the transition from fossil fuels to renewable energy, network connection problems and system strength issues represent ongoing challenges concerning solar and wind generation within the ANEM. The ANEM is the longest network in the world, and in a network its size, it is fair and reasonable to assume that there would be limitations to the existing grid. In addition, the weak system strength in some remote parts of the electricity network has rendered it challenging to connect and integrate solar and wind generation sources, leading to significant delays in grid connections.

These findings are in accordance with those of certain prior studies (de Atholia et al., 2020; Simshauser, 2019a). For example, Simshauser (2019a) argued that network policy, network regulation and overall network performance are amongst the most contentious aspects of Australia's energy market reform. Moreover, de Atholia et al. (2020) highlighted how solar and wind projects across much of Australia's eastern regions have been impacted by system strength issues, with the lack of ability to control grid frequency and voltage causing several projects to either cut their output or fail to connect to the grid.

Developing and coordinating renewable energy policies and regulations, better planning through the ISP process and network augmentation represent the main solutions for addressing future solar and wind energy challenges facing the Australian electricity sector. It is clear that identifying technological solutions to grid strength issues will become more crucial as the penetration of solar and wind power increases, which should help to reduce the risks and costs faced by project developers. In addition, the fundamental purpose of an ISP is to identify investment choices and actions that can optimise consumer benefits. The ISP maps least-cost pathways for replacing the ANEM's ageing coal fleet, which is consistent with government policies.

These findings corroborate the ideas of Rai and Nelson (2020), who suggested lowering network prices by adopting more dynamic network pricing, especially at the distribution network level, so that the prices reflect the costs of supplying electricity at different times of the day. Such reforms are targeted at maximising network capacity utilisation, thereby lowering prices. Moreover, reforms to the ways in which generators access both transmission and distribution networks should enable new solar and wind generation at a lowest cost to consumers.

The second aim of this study was to investigate experts' attitudes toward the effects of solar and wind generation pricing on the Australian electricity spot and options markets. The qualitative analysis showed that the solar and wind electricity prices within the ANEM reduce the spot and options electricity market prices. In addition, the interviews provided evidence that the solar and wind electricity prices lead to more extreme spot prices, resulting in increased instances of both very high and very low prices within the ANEM.

This finding is in line with the findings of certain other studies (Alsaedi et al., 2020a; Csereklyei et al., 2019; Simshauser, 2018b). For example, Simshauser (2018b) determined that the increasing penetration of low short-run marginal-cost VRE generation pushes down spot prices and requires incumbent generators to adjust their output so as to complement the variability of VRE generation. Both these effects reduce the profitability of incumbent generators, especially relatively inflexible plants such as coal-fired plants. This "merit order effect" results in the sudden exit of such generators, leading to a subsequent rapid increase in wholesale prices.

The third aim of this study was to examine how renewable energy policy has been implemented as well as what policy instruments have been used to implement renewable energy policies in the different states. The qualitative analysis showed that FiT policies and CfD represent ways of subsidising and encouraging the uptake of renewable energy and, in Australia, have been enacted at the

state level in conjunction with a federal MRET. Additionally, the analysis revealed that reverse auctions (where renewable energy projects bid for power supply contracts from the state government), state-based renewable energy targets and other commitments have been the main policy instruments used to implement renewable energy policies.

These findings are consistent with the findings of other studies (Nelson et al., 2011; Simshauser, 2019c). Simshauser (2019c) argued that CfD have been selectively and effectively used in Australia by state governments to "prime" emerging markets and navigate Commonwealth policy discontinuity, with material on-market transactions following. Nelson et al. (2011) noted that PFiTs have been extensively used in Australia to drive investment in residential solar PV. In some states, around a quarter of detached residences now operate their own embedded solar PV system due to both the use of PFiTs and the significant reduction in the cost of solar PV.

The fourth aim of this study was to investigate how policies and regulations have influenced the Australian electricity solar, wind, spot and options prices as well as what the responses have been to the implementation of renewable energy policies. The qualitative analysis showed that government policies and regulations concerning renewable energy have helped to drive the surge in solar and wind power. As a result, the cost of solar and wind technologies has fallen dramatically, which has led to a decrease in the electricity spot and options prices. In addition, the analysis indicated that the government's renewable energy policies have encouraged investment in solar and wind electricity generation and also increased the vertical integration of energy companies.

These findings support those of recent studies (Bell et al., 2017; Nelson et al., 2019). For example, Bell et al. (2017) found that increasing wind power penetration through mechanisms such as the LRET can lower wholesale spot prices. Nelson et al. (2019) stated that a consequence of introducing production subsidies through Australian climate change policy has been the increased adoption of renewable PPAs and the increased vertical integration of energy companies.

The final aim of this study was to examine the main barriers to the implantation of renewable energy generation in the different states. The qualitative analysis showed that uncertainty about future national renewable energy policies and emerging constraints in some parts of the electricity grid with strong renewable energy resources represent the principal barriers to the rapid growth of renewable generation. As noted by de Atholia et al. (2020), investment in renewable energy generation in Australia is expected to be moderate in the near term as some recent drivers unwind and challenges associated with integrating renewable energy sources into the electricity grid persist. However, in the longer term, the transition to renewable energy generation is expected to continue as ageing coal-powered stations are retired and the decarbonisation process continues.

The results of this study are limited due to its preliminary nature. The study was deliberately limited to the specific empirical and geographical context of Australia's electricity markets. The findings, therefore, may not be meaningfully generalised to other country contexts, although they do provide context-specific insights for the Australian electricity markets. In terms of future research, this study only examined the impacts of solar and wind pricing policies and regulations on the Australian electricity spot and options markets. Future studies could examine the impact of government policies on renewable energy investment as well as the challenges faced by renewable energy developers within the ANEM.

In March 2020, the World Health Organization (2020) declared COVID-19 to be a global pandemic. The virus has since infected millions of people and resulted in hundreds of thousands of deaths worldwide. As a result, economic growth in many countries has slowed as major financial and industrial markets experienced significant decline, international supply chains broke down, borders were closed and tourism was paused. Future studies could examine the effects of COVID-19 on ongoing renewable energy projects as well as the implications of COVID-19 for the politics of sustainable energy transitions.

6. ETHICS

This research received ethics approval from the Griffith University Human Research Ethics Committee. Ethics application number 2018/267.

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