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Barriers and Opportunities for Residential Solar PV and Storage Markets – A Western Australian Case Study

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Solar PV panels coupled with storage systems present an opportunity to move towards a resilient, affordable, flexible and secure electricity network.

Western Australia provides a unique set of conditions (isolated network, high solar radiation, and rising electricity prices), which has contributed to the rapid uptake of solar PV's in the state. Yet, a number of issues are still obstructing the transition to renewables.

Using Western Australia as a case study, this paper investigates the barriers inhibiting the network transformation and explores the role that solar PV and storage can play as a disruptive threat to the incumbent, centralised service model of electricity utilities.

Keywords: *solar; storage; energy; electricity; barriers; network.*

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Dev Tayal [α] & Vanessa Rauland [σ]

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Using Western Australia as a case study, this paper investigates the barriers inhibiting the network transformation and explores the role that solar PV and storage can play as a disruptive threat to the incumbent, centralised service model of electricity utilities.

These barriers are identified and qualified through a series of interviews with several Western Australian energy market participants.

If policy makers intend to enable widespread adoption of solar PV and storage, they will need to address barriers to support these emerging technologies. In parallel, market participants must work with policy makers to drive flexibility in regulatory frameworks and progress the evolution towards innovative and sustainable electricity networks of the future.

Keywords: solar; storage; energy; electricity; barriers; network.

I. Introduction

Western Australia (WA) has inadvertently become a central player in addressing the universal challenges that are inherent in the transition to a renewable, distributed model of electricity networks. The WA Government has traditionally subsidised the centralised model of fossil fuel generation as a political offering to consumers. But this has only artificially reduced prices, and taxpayers ultimately face the impact of non-cost-reflective pricing. As a result, the state is now faced with some of the highest increases to electricity costs in the world, has discovered this subsidy is unsustainable, and is thus seeking to benefit from the some of the best renewable resources available (Nahan, 2015; Bromley, 2015; Sayeef, 2012).

Coupled with these changing economics is the structure of WA's electricity market itself: still highly regulated, dominated by Government-owned entities and currently undergoing a major reform program. Although the WA market is relatively late in considering initiatives such as full retail competition and flexible pricing (Australia's Eastern States implemented similar reforms through the nineties), the industry is now open to consider major structural reforms and market re-design - not just economic improvements to existing models (CSIRO, 2009; Sharma, 1997). For example, WA is now in prime position to consider the impact of increasing penetration of solar PV on the grid and unlock the potential of increasingly cost-competitive battery storage systems. The technology innovations driving battery costs lower will only increase the challenges for utilities and Government, more so for WA's isolated electricity network relative to other states in Australia, or around the world. As such, the authors predict that WA's energy sector and market will become a demonstration site for energy authorities around the world looking for guidance on how to manage the transition (Parkinson, 2015a).

Whilst other markets are also beginning to contend with the pressures of solar disruption (most notably Hawaii, California and Germany), WA has a unique confluence of economic affluence, market reform, network isolation, high solar radiation and consumer demand that has driven enough Government impetus to recognise the urgency in addressing its impacts (Parkinson, 2015; Bromley, 2015).

While change is imminent, there are still a number of barriers. This paper explores what barriers are preventing renewable energy technologies (specifically residential solar PV and battery storage) from transforming the current energy markets of WA to deliver across the priority outcomes of a low cost, low-carbon, and secure energy network.

Through conducting an extensive literature review and analysing a series of interviews with industry stakeholders, key barriers relating to the development and integration of residential solar PV and battery storage in WA are identified. To assist in the

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identification process, this paper classifies these barriers into three groups: institutional, technological and financial.

It is hoped that this research can be used in practice to encourage energy businesses and utilities operating in WA (and those in similar energy markets around the world), to utilise solar PV and storage systems in a strategic fashion, in order to reduce grid congestion, and/or to remove (or at least defer) the need for network investments, thereby creating value for all stakeholders. This research should also provide valuable insights and recommendations to policymakers currently grappling with an electricity service and delivery model in a state of flux. The authors note that ultimately, all electricity grids share a common goal of achieving a safe, secure, sustainable and affordable service of electricity to customers, and in order to achieve this, leveraging and integrating new technologies into existing grid structures and business models will be inevitable.

II. Background

a) *The WA energy transition*

Energy markets are inherently complex structures. They have numerous stakeholders constantly lobbying for industry and regulatory reform. In WA, the complexity is made even more apparent by the state's geographical isolation, preventing any feasible prospect for WA's networks to be connected to neighbouring systems. However, within this challenging environment, WA's unique isolation also presents an opportunity to study the extent to which renewable energy technologies and distributed generation can be utilised to disrupt the conventional, centralised model of our existing systems.

In WA, the energy sector (retail, distribution and generation of electricity and gas) accounts for around three-quarters of the state's greenhouse-gas emissions, with just over 40 per cent of this attributed to electricity generation (EPA, 2007; ABS 2012). Resource availability, and the associated politics and economics of fossil fuel supply (with an abundance of gas, oil and coal resource in the state), are major factors that will shape energy market reform and policy going forward (Martin, 2015; Commonwealth of Australia, 2012; Tongia, 2015).

The WA Government has remained relatively silent on the issue of climate change, and in particular, its interactions with electricity generation. Meanwhile, the underlying economics of renewable generation have already shifted in favour of the decentralised models of clean technology - as afforded by solar PV and storage, and concerns are already being raised with regards to future industry investment and business decisions for WA energy companies (COAG, 2014; Allen et al., 2009; Grace, 2014).

Recognising the inevitable impact of a changing environment, on 6 March 2014 the Minister for Energy in WA launched a broad based review of the structure, design and regulatory regime of the electricity market in the south west interconnected system (SWIS) of WA. The Minister reflected industry wide-concerns that the electricity market was not functioning as expected and was susceptible to high network costs and the need for significant subsides to maintain downward pressure on costs, contributing to high (and rising) electricity prices (Government of WA, 2014).

These assessments were made against a 'business as usual' view for the government's electricity businesses. However, when considered in the context of the changing landscape – driven by the need for clean energy to address climate change and the surge in distributed generation, particularly in the form of solar PV systems plus storage (Denholm, 2007; Katiraei, 2011; Yip, 2013) – this new wave of technical innovation is set to disrupt WA's electricity utility business models, dramatically affect the availability of capital in the industry, and further intensify the issues with the State's electricity market.

In January 2016, an additional impetus for distributed energy systems was (unfortunately) provided by a destructive fire that damaged or destroyed 873 power poles, 77 transmission poles, 44 transformers and up to 50 kilometres of overhead power lines (Western Power, 2016). In response to criticism of the high expenses involved in restoring the grid, the Minister for Energy in WA outlined that distributed energy options, such as the use of solar and storage micro-grids, were being considered by Western Power (Parkinson, 2016A).

As market dynamics force the hand of electricity utilities globally, changing the business model away from a conventional, grid-based system towards a grid plus distributed solar model across the entire network is forming as a likely solution for WA electricity businesses. Utilities undertaking future business planning and strategy development should be proactively looking to energy efficiency, solar PV and energy storage as growth opportunities rather than an existential threat, and acknowledging that their place in the energy system will only grow (Poudineh &Jamasb, 2014; Klose et al, 2010). The question then remains as to why electricity businesses have not already embraced this change, and what barriers are preventing this transition from occurring.

III. Methodology

a) *Interviews*

A review of existing literature was carried out over six months to gain a broad understanding of barriers to the increased adoption of solar PV and residential storage systems in electricity networks

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around the world. This research helped to inform the design of a series of semi-structured interviews held with several stakeholders in the WA electricity industry, to ascertain the specific barriers, obstacles and potential solutions within the Western Australian context. Semi structured interviews are based on a protocol and were identified as the most relevant method to use to ensure consistency of topic and discussion (Robson, 2002).They involve priming interviewees for responses based on a set of formulated questions (see Table 1), but also provide flexibility for the discussion to involve topics beyond the structured questions.

Table 1: Semi Structured Interview Questions

No.	Question
1	What are your thoughts on the speed of the energy [revolution/evolution] process occurring?
2	Where do you see your businesses' role in the solar PV and/or residential storage market? Are you already/planning/exploring/advising product and service offerings in this space?
3	Energy st orage is often quoted as the most 'disruptive technology', but to what extent is it an opportunity or a challenge for your business? Do these technologies pose any challenges in maintaining the service of traditional electricity networks? (e.g. expectation for 1 in 10 year service interruptions?), and related to this, what do you see as the biggest threats over the next 2 – 5-10 year time horizons?
4	Are you also considering large-scale solar projects? i.e. once base-load coal and gas generation retires? If not, why not? (UBS released a very optimistic report on the growth prospects of large-scale solar projects for Utilities)
5	How else is your business model changing? Would you consider splitting off 'traditional' energy from renewables (e.g. E.ON in Europe?)
6	What are the remaining barriers, if any, for residential solar PV and storage markets and will the rapidly evolving landscape drive potential opportunities specific to WA?
7	How can existing barriers be overcome? Through regulation and policy change? Technological innovation? Capital investment? Business Model adaptation?
8	Any active measures you and your company are employing over the short term to address these barriers?
9	How will the continued uptake of solar PV and storage affect cost and revenues for utilities and what are the likely impacts for consumers?
10	What is your view on the tariff reform needed going forward? Would you support a demand based network tariff being passed through retailers to more accurately reflect the cost of the system? How should technologies such as solar and storage best be rolled out at the consumer level, and what role will tariffs play in helping this?
11	Where do you see WA's energy market relative to the east coast? Other places in the world?
12	What is the best means to transition the grid, as it is now, to one best placed for the future?

Interviewee responses helped to identify how important, in practice, these barriers are in the adoption decision and to gain a greater understanding of the challenges that participants in the electricity industry are having to grapple with, particularly during this disruptive period in the energy sector.

Although the interviews were primarily conducted with Western Australians regarding the local barriers faced, it is expected that they could be considered indicative of issues faced globally across energy markets worldwide. It is also noted that under normal circumstances, this information is often difficult to acquire – as business challenges and potential innovations remain in-house and are rarely published in public material. By framing the interviews as a contribution to research, without unduly impacting any competitive advantages the participants and their respective companies may otherwise be protecting, the interviews were able to achieve a rare level of candor to benefit the study.

b) Selection process

Various methods were used to identify candidates. These included online databases (e.g. LinkedIn), industry magazines, conferences, news articles, academic literature, and recommendations. They were contacted via email and in total, 40 people were asked to take part in the interviews, of which 45% accepted.[1]

The open nature of semi-structured interviews also allowed for new topics to be discussed, and the guide was tailored to suit the interviewee's experience and background and adapted 'live', depending on what the interviewees said.

Interviewees were identified on the basis of their knowledge and expertise in this area, primarily within the WA electricity sector. Interviewees were predominantly senior executives and directors and represented an

[1] Homogeneity of interview content, structure and participants, and a high degree of expertise of participants offers comprehensive information from smaller interview samples (Guest et al., 2006).

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eclectic mix of organisations, including: state and local governmental bodies, network generation and retail electricity utilities, private energy companies, energy consulting firms, associations, non-governmental organisations, academics, and several industry professionals from legal, economic and political backgrounds. The importance of a wide ranging selection across public, private and individual viewpoints was identified in order to obtain more of a balanced and objective account of the current challenges related to distributed generation and barriers being faced in residential solar PV and storage markets.

A summary table of interviewees and their affiliation is included below, which also corresponds as a reference to particular comments and views expressed throughout the text that follows.

Table 2: Interview Participant Summary

Interviewees	Affiliation
Participant 1	Senior Manager - Energy Consulting Firm
Participant 2	Managing Director – Independent WA Electricity Retailer
Participant 3	Manager – Network Utility
Participant 4	Manager – Government Electricity Retailer
Participant 5	Director – Government Energy Policy Office
Participant 6 & 7	Directors – WA Local Government
Participant 8	Director – Energy Consulting Firm
Participant 9 & 10	Analysts – Australian Energy Market Operator
Participant 11	Director – Energy Consulting Firm
Participant 12	Director – Non-Government Organisation
Participant 13	Director – Local Electricity Regulatory Authority
Participant 14	Partner – Professional Services Firm
Participant 15	Manager – Metering Firm
Participant 16	Manager – Distribution Network Utility
Participant 17	CEO – Solar Energy Firm
Participant 18	General Manager - Independent WA Electricity Retailer

All interviews were recorded on a phone microphone recording application, with the majority occurring in person. The interviews were largely informal, typically lasting between 45to 60 minutes.

IV. Results

a) *Overview of barriers*

Research on increasing the adoption of solar PV systems has a long heritage, beginning in the 1980s and with research literature continuing today, profiling the advancement of PV technologies from socio technical (Müggenburg et al, 2012; Dewald &Truffer, 2012), economic (Lund, 2011) and political perspectives (Jacobsson & Lauber, 2006).This research shows that the barriers to increased uptake of solar PV typically relates to a similar set of areas including socio technical, management, economic, or policy (Karakaya & Sriwannawit, 2015; Balcombe et al, 2014). Although specific research investigating the barriers from a WA context was not found, barriers are expected to be similar, albeit with varying levels of priority, and encompassing issues including cost, environmental concerns, self-generation, policy uncertainty, inertia and inconvenience and aesthetic impacts (Ratinen, 2014; Strupeit, 2015; Balcombe et al, 201 4; Sandberg & Aarikka-Stenroos, 2014; Suzuki, 2015; Luthra et al, 2014).For ease of classification, barriers have been re-grouped under three main headings: technological, institutional, and financial.

A summary of the barriers under these three classifications (as reported by stakeholders in interviewees and identified in literature) has been included in Figure 1:

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Figure 1: Summary of barriers to solar PV and storage uptake

Each barrier is discussed in more detail below.

b) Technological

i. *Fore casting capability*

Forecasting inaccuracies are infamously known to drive poor decision-making across any industry, but forecasting has become embedded into the centralised model of electricity provision. In WA, actual demand growth has been far below forecasts made at the time the Wholesale Electricity Market in WA was designed. As a result there is now a substantial excess of capacity in the market, imposing a significant cost to electricity consumers as there is a Capacity Market that pays for the capacity of all generators, even if they simply provide back-up services and are rarely if ever called on to generate electricity. In conjunction, the market mechanism designed to reduce this cost over time is not functioning at all – failing to incentivise generators to mothball or retire redundant capacity. Poor forecasting by the Independent Market Operator (as WA's system operator), Government authorities, and the Economic Regulation Authority, has now resulted in a situation where consumers have to pay for the costly errors and un-needed infrastructure investments in the market (Government of WA, 2015; Parkinson, 2015B).

Whilst the impact of additional costs imposed by poor forecasting might provide residents with additional incentive to go 'off-grid' or install solar PV and storage units, at a business level, electricity generators, networks and retailers have a reduced need for additional capacity and can already secure long term power contracts at long-term average costs (Participant 1, 2016).

ii. *Constraints of existing technology*

The transformation of electricity systems requires technological innovation in order to implement services and products to consumers in an affordable and accessible way (Suzuki, 2015).The quality and reliability of solar PV and storage systems is therefore critical for their increased adoption and barriers exist relating to the uncertainty of the technical performance of solar and storage systems (Zahedi, 2011; Luthra et al, 2014). Adoption rates in China provide an example where high levels of dissatisfaction with the low performance of solar home systems (whether caused by improper usage or not) has reportedly prevented other potential adopters from purchasing systems (Karakaya & Sriwannawit, 2015; Yuan et al, 2011). Similarly, studies in the US indicated that consumers were also likely to hesitate from adopting solar PV systems due to the perceived risks of unknown technologies and associated complexities (Drury et al, 2012).

As part of the Government led electricity market reforms in WA, the local network utility responsible for grid connections for the SWIS, Western Power, has begun reviewing its processes and technical standards for distributed generation connection in order to reduce system connection costs (Government of WA, 2015).

WA will also require the adoption of smart meters, sensors and advanced communication networks in order to realise the full benefits of new technology such as solar PV and storage systems. For example, new control systems will have to be developed to deal with the bi-directional power flows inherent in a fully developed distributed market. As existing networks evolve to become 'smart grids', utilities will also need to grapple with the complexities of data ownership, cyber security and data privacy (Luthra et al, 2014).

Market participants and smart-meter provider sinter viewed for this research noted that engaging with incumbent utilities in WA was still a slow and often unsuccessful process, with network utilities (Western Power and Horizon Power) and Government owned retailer (Synergy), still applying existing centralised business models (Participant 15, 2016). Trials being conducted by both companies (e.g. at the Alkimos Beach energy storage trial, a fringe of grid development on the outskirts of Perth)[2], and removal of regulatory barriers may assist in alleviating these technology constraints.

[2] For information on this, see https://www.synergy.net.au/Our-energy/Energy-Storage-Trial-at-Alkimos-Beach

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iii. *Network capacity and access*

Integrating solar PV systems (with or without storage) also raises technical challenges in regards to network stability, reliability and power quality. Western Power is responsible for following technical rules and regulations in order to safeguard and maintain its network assets. Therefore, as the gatekeeper to network access, Western Power is extremely interested in the potential impacts of new connections. While individual residential solar PV customers introducing 1 or 2kW into the system may have only a minor impact, when aggregated across the interconnected system, or when concentrated in areas with existing network constraints or older infrastructure, network impacts may be more pronounced (Participant 3, 2016).

Given the rapid uptake of solar PV that has already occurred across the state, network access barriers appear to have been minimal over the last few years. Going forward may present a different situation, however, particularly as the penetration rates rise from less than 20 per cent of customers on the network to estimates far above 50 per cent in the next decade. The unknown disruptive component in all of this is of course the impact that residential storage systems will play across both supply and demand side management. Although the connection of small-scale residential batteries received a promising start in 2015, when the WA Energy Minister facilitated the removal of regulations prohibiting homes with battery storage from feeding electricity back into the grid (Participant 4, 2016).

c) *Institutional*

i. *Psychological will –increasing motivation to embrace innovation*

A 2013 study of the German energy market by Richter (2013), found that not only were German utilities yet to react to solar, but the majority of managers interviewed saw no future for solar PV within their organisations (at that time). This was driven by the view of solar PV as a relatively small-scale technology, with relatively high costs and therefore a strong reliance on government subsidies to remain competitive (Richter, 2013). This view may be particularly prevalent for companies without established capabilities in solar or storage technologies (most incumbents), who have a greater reluctance to embrace these technologies than comparable companies with some previous experience (Markard & Truffer, 2006; Stenzel & Frenzel, 2008; Luthra et al, 2014).This places most incumbent electricity utilities (particularly the dominant government-owned entities in WA) in a position where they may be inclined to rely more on their beliefs than facts when formulating business strategies and predicting future market outcomes (Henderson & Clark, 1990).Alternatively, as Storbacka et al. (2009) note, companies may just be 'stuck' in their mindset and identify the structures and players of the energy market as being "given and unchangeable".

In contrast, and three years on, all WA stakeholders interviewed now see solar PV as a 'disruptive innovation' given its potential (particularly in combination with residential storage systems) to challenge the entrenched, centralised models of electricity generation and the opportunities it presents to the electricity market going forward (Participant 1-18, 2016).

Further, the growth potential in the expanding solar market and building new customer relationships would be additional opportunities for utilities; and long-term contracts for solar PV provided by the utility would also facilitate customer retention. Within this new perspective, solar PV could then be viewed as a stepping stone into promoting other 'green energy' initiatives, such as energy efficiency and battery system offerings (Richter, 2013). In the WA context, many stakeholders agreed with the vast opportunities that 'new energy' offerings provide, but various views were expressed on the timing of when these opportunities would be pursued (Participant 1-18, 2016).

ii. *Organisational management - is listening to customers a bad thing?*

Interviewees also cited a general belief that lack of management expertise has acted as a central barrier to increasing adoption of solar PV and storage systems in WA. Unlike the conventional type of value chains in the centralised energy industry (i.e. generators wholesale to distributors and retailers), in the distributed generation model, participants need to develop different types of business models that cooperates across multiple fronts with multiple actors (Karakaya & Sriwannawit, 2015; Participant 1-18, 2016). The question then becomes how these new models will be developed.

Research on disruptive technology's impacts on existing markets has highlighted the inability for incumbent firms to recognise the true nature of threats to existing business models (Christensen, 1997). A study by Christensen and Raynor (2013) found that the primary reason incumbent firms are resistant to innovating product sis because of an over-reliance on listening to what customers are asking for. According to the study, the average customer is blind to any potential benefits from new and innovative products prior to their commercialisation, and therefore rather than driving any form of radical innovation, customer preferences simply lead businesses to make gradual improvements on existing products and services (Christensen and Raynor, 2013).

Apajalahti et al. (2015) identified a further institutional barrier; the inherent complexity faced by utilities attempting to unbundle and split their business units along service offering lines.

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Two interviewees also raised the important issue of culture for utility businesses (Participants 8 and 14, 2016),and suggested that whilst in Government hands, WA utilities such as Horizon Power and Western Power would be more resistant to embrace innovation and would inhibit any form of lasting institutional change. One interviewee argued that unless Government-owned enterprises continued to provide secure and stable returns via traditional business models, they would be acting outside their mandate as they could then be seen as first movers and take on the risks of unproven technologies(Participant 14, 2016).

iii. *Government led decision making*

Another challenge for WA's state-owned electricity companies cited by market participants is overcoming inhibitions to adapt to changing market conditions and surmounting the barriers inherent in bureaucratic decision making processes. As government-owned entities, Synergy, Western Power and Horizon Power have a requirement to obtain not just Board approval, but Ministerial sign-off for all major strategic initiatives. This can be a slow and cumbersome process. Should these businesses remain as public corporations going forward, these restrictive remits will need to be flexible enough to adapt the company's functions and objectives to encourage innovation and repositioning, not hinder it(Participants1, 4,18, 2016).

Levi-Faur (2003), argues that this relationship with policy makers is so pervasive, that even following privatisation, bundling of interests and ties between government and utilities continues to permeate through all levels of the policy-making process. These ties slow down both the ability for utilities to change their business models, and the innovations occurring across the sector as a whole (Levi-Faur, 2003).

Indeed, utilities across Australia have been primarily interested on protecting their traditional sources of revenue, and several have gone so far as to publicly announce proposals for higher fixed tariffs, specific solar 'charges', and attempt to introduce market rules and regulations to prevent the sale of generation from battery storage connected households – all efforts to dampen the attractiveness of new technologies for customers (Parkinson, 2016B).

Further, the dominant government-owned electricity utilities of WA have previously sought to slow renewable energy development and influence state energy policies (through politically driven point scoring or otherwise), and have taken limited or lagging actions to address or benefit from its increasing relevance to energy markets and networks (Bromley, 2015; Mitchell, 2000; Pehle, 1997; Participants 1, 4, 12, 18, 2016).

Ultimately, these incumbent entities will have to adapt and compete with new services and products entering the market, or face increasing redundancy in an increasingly competitive energy market.

A renewable energy expert and active advocate in WA summarised it as follows:

> *"As long as government retains ownership of those facilities, we will not see innovative suppliers or price competition at market. As a consumer…I had no choice of another retailer to go to who might have offered me a new product, a different product. That is an example of where the lack of the competitive market and the lack of consumer choice means that I am stuck with the decision that one retailer makes."*

(Participant 12, 2016)

iv. *Government policy and reform*

The Government is often the vilified target for impeding change, and according to energy market participants interviewed, this is arguably justified in the case of policy for renewable energy technologies. The feed-in-tariff policy controversy, whereby the WA Government attempted to remove payments to solar PV customers for surplus electricity exported back to the grid, is a prime example of political uncertainty. It also led to a great deal of scepticism and added to the perception of Government introducing barriers to the adoption of solar PV (Balcombe et al, 2014; Participant 1-18, 2016).

At the federal level, confusing and complicated legislative frameworks and a lack of long term policy certainty is acting as a barrier to renewable energy investment and introducing unnecessary regulatory 'red tape' (Karakaya & Sriwannawit, 2015). Australia has had significant volumes of legislation, regulations, policies and commitments that apply to renewable energy – large and small scale renewable energy targets; renewable energy certificates, carbon pricing schemes, direct action mechanisms – all while enduring competitive pressures of relatively cheap, thermal coal plants (Martin, 2015).

The need to overcome barriers to the adoption of new technologies through the development of "clear and consistent frameworks" was also noted at the meeting of the Council of Australian Governments Energy Council (COAG, 2015).

Removing regulatory barriers was the most consistent theme and highest priority barrier identified by interviewees. As it stands in WA, there is still no reference in the overarching market objectives to any environment effects of energy supply. The WA Government has also remained notably silent on proposing any tariff reform to specifically encourage innovation and consumer investment in renewable or 'clean' technology such as solar PV– citing a preference only to remove market distortions such as eliminating subsidies given to the Government owned electricity retailer, Synergy (WA Government, 2015; Participant 3-5, 2016).

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Of course, the issue then becomes how you regulate an evolving area with several unknowns. Comments from an experienced representative of the regulatory environment in Australia hypothesised that unknowns are not necessarily a barrier: "regulations are an iterative process" (Participant 13, 2016). The interviewee used the case of existing electricity market regulations, highlighting that at their early stages, the frameworks were short and concise documents, and as issues were raised, evolved in their level of detail and complexity. A similar evolution is likely already underway for regulatory flexibility to incorporate distributed generation on the WA networks.

Tariff reform was also a central theme that interviewees suggested underpinned the transformation of electricity markets (Participant 9-10, 2016). The current flat-rate electricity tariffs do not incentivise consumers to reduce demand for electricity at peak times, nor do they accurately reflect the true cost of service. Once tariff structures can leverage the capabilities of smart meters and reflect dynamic pricing structures, then the full value of solar PV and battery storage will be unlocked ((Participant 9-10, 2016).

v. *Consumer inertia and information blocks*

Related to government involvement is insufficient consumer information contributing to consumer inertia in adopting solar PV and storage systems. UK studies even highlighted a lack of trust for micro-generation system suppliers and installers due to the sharing of previous poor experiences online, or as a result of aggressive marketing and sales promotions (Taylor, 2013).

Other consumer related barriers include uncertainty and information gaps with regards to access requirements and regulations to use and connect solar and storage into the grid. This has prevented many customers from undertaking the required efforts associated with installation of these systems (Strupeit, 2015). Coupled with these uncertainties for consumers is the growing confusion surrounding local council treatment of building aesthetics (i.e. visual impact of panels), strata issues and shading complications resulting from roof-top solar PV panels being effected by neighbouring buildings and trees. These individual issues combined are likely to provide an overall threshold of inconvenience for potential adopters. While interviews with local council planners (Participant 6-7, 2016)re-enforced that there are no local council obstacles in installing the vast majority of residential solar PV or storage systems (as long as they can be considered part of the dwelling structure), the media dramatisation of the rare cases that cause problems can still feed consumer perception (Participant 6-7, 2016).

Arguably, these constraints are less evident in the WA market, where high solar resource and rising electricity prices are driving consumers through any initial or historic inertia and motivating adopters to face the risks, complexities or uncertainties anyway. Further, the expansion of solar PV providers has risen dramatically in WA over recent years, assisting with consumer education regarding price, visual impacts, maintenance requirements, PV reliability and simplifying the installation process (Faiers and Neame, 2006).

d) Financial

i. *Sunk network costs- network design inertia*

Sunk costs in existing network infrastructure are a significant hurdle that is central to the transformation of centralised grids towards more sustainable, distributed platforms for energy trading. A Commonwealth of Australia Governmental led investigation, the Senate's Select Committee on Electricity Prices (Select Committee, 2012), found that network design, connection and cost barriers were the main impediments to increasing embedded generation in Australia's electricity grids.

As per the current design model, customers pay for the sunk costs of electricity poles and wires (whether they want to use them or not) based on levels of spending pre-approved by economic regulators (in Western Power's case, this has been the Economic Regulation Authority). This model has provided very limited incentive to shift these electricity utilities away from their reliance on the regulated asset base (which allows for a more certain revenue stream). In effect, this model propagates old, centralised electricity service business models which are framed to see residential solar and storage generation units as a threat, rather than as an opportunity for new business (Parkinson, 2015B).

One interviewee suggested the immediate focus should be on:

> *"Applications where it already makes more economic sense to have solar and storage technologies, particularly when considering any large capital heavy projects on the electricity network - such as fringe of grid, new developments, undergrounding power lines, or replacing damaged power lines (e.g. following bushfires)*."

(Participant 1, 2016)

Indeed, for the WA context, this appears to be the approach now being followed by the Government and government-owned utilities. The aforementioned trial in Alkimosbeach, combines community scale battery energy storage, high penetration solar PV and energy management, and will test the feasibility of new energy retail models (ARENA, 2016).

ii. Upfront system costs

The high cost of solar PV systems is usually cited as the most common (and largest) economic barrier to increased adoption – specifically the high

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initial capital costs, high repair costs, and long payback period (Zhang et al, 2012; Balcombe et al, 2014; Allen et al, 2008; Ravindranath and Balachandra, 2009). It should also be noted that it is important to consider this cost in relation to the cost of substitutable energy sources available (Karakaya & Sriwannawit, 2015; Sarzynski et al, 2012).

However, significantly cheaper levelised cost of energy[3] for solar and storage systems will not automatically result in strong increases in the uptake for solar PV and storage systems (even if this cost falls below the level of the retail price of electricity), as other cost barriers are likely to continue to impinge on the attractiveness of the investment (Elliston, 2010). These barriers include, for example, investment uncertainty and risk, high rates of return, or a lack of access to debt or equity financing, which can all inhibit "an economically rational decision to install PV once prices provide agood rate of return" (Elliston, 2010: pg 8).

This view was confirmed in research by Mountain (2014), who looked at applying traditional project finance analysis to investigate the value that recent renewable energy policies (feed-in tariff payments and renewable energy target certificates) has had on the uptake of solar in Australia from 2010 to 2012. Combining these government incentives with retailer payments and avoided energy purchases, Mountain's (2014) findings suggested that, on average, households that invested in rooftop PV over the period achieved similar returns to what a utility could have reasonably expected for the same investment. In other words, without these Government incentives in the form of feed-in tariffs and renewable energy certificates, returns would have been strongly negative (Mountain, 2014). Of course, as residential solar and storage technologies continue down the cost curve, these findings will continue to be challenged.

V. Discussion

In all interviews undertaken with stakeholders, it was implicit that whilst barriers were often discussed in isolation, it is in fact their interaction and combined impact, which has the most significant effect on the deployment and uptake of solar PV and storage systems in Western Australia (Participant 1-18, 2016).

Further, some of the barriers identified do not fit neatly into just one category and feed into multiple themes. For example, one interviewee provided a unique insight into a potential barrier that straddles both financial and technological classifications, relating to Australia's relatively small size in the global markets. In their view, since Australia offers a significantly smaller market than those found in Asia, North America and Europe, Australian consumers with strong preferences for solar and storage products will likely be left waiting in line behind the larger markets(Participant 2, 2016). This is likely to be more noticeable in relation to storage products, which have limited supply chains.

Of course, as these products become commoditised (like our mobile phones), then this limiting factor will no longer be an issue for Australian consumers. This 'maturity' of markets is already seen for solar PV systems, which have all but eroded their high capital costs through mass production and technological improvements.

This research highlighteda common occurrence of attributing general market frustrations on a particular entity - a need to blame someone for a lack of progress, regardless of whether the barriersare actual impediments or simply perceived. In the case of impediments to solar PV and storage uptake in WA, the scapegoat appears to be Government and regulators. A common theme that emerged throughout all interviews was the importance of "flexible and forward looking regulatory frameworks". The example of 'uber' and the taxi industry was often cited as a likely and comparable scenario for the energy industry, whereby customers override regulators and established regulatory frameworks once presented with an affordable, efficient and favourable alternative to the status quo.

On the other hand, despite these barriers, there are still enough commercial incentives for new and existing market participants to take risks and conduct trials. The opportunitiesin WA have already been identified by global technology and energy service companies (e.g. storage providers: Enphase, Tesla and Red flow), who are working with local governments and electricity businesses to pilot projects such as battery technology trials, innovative pricing structures, demand side management studies and long-term capacity planning methodologies. As the diffusion of these technology innovations grows in the WA energy market, new opportunities will continue to arise for both existing and emerging businesses, and importantly consumers are in line to benefit.

Lastly, the timing uncertainties and the speed at which the energy (r) evolution may occur was a topical theme brought up by most interviewees. The full spectrum of rates of change were voiced across the interviewees, from "yesterday" to "decades away", with the common understanding that forecasting the speed of innovation is an inherently complex task. Although in relation to timing, one respondent (Participant 1, 2016) highlighted the interesting dynamic of late-movers to storage systems potentially benefiting substantially, arguing that once electric vehicle uptake is at a reasonable level (e.g. in 2030), the secondary market for the vehicle's batteries to be used as conventional, stationary batteries in residential applications will likely

[3]Levelised cost of energy is a common summary measure of the overall competitiveness of a particular technology and includes capital and fuel costs, operating and maintenance costs, and financing costs, as well as the assumed rate of utilisation.

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be over supplied and lead to significant downward pressure on battery prices (Participant 1, 2016).

It is outside the scope of this paper to examine in depth the solutions needed to overcome the myriad of barriers inhibiting greater uptake of solar and batteries in the market. Nevertheless, based on the barriers identified in this paper, some potential solutions, which will require further research, may include:

- Improved regulatory frameworks that remove economic and political barriers at the same time as promoting necessary capital investment;
- Customer involvement and education;
- Development of infrastructure – e.g. upgrade to smart grids and bi-directional communication systems;
- Changes to licensing requirements (to allow power purchase agreements) and revision of customer protection frameworks;
- Increased transparency, introduction of performance reporting, and lower cost connection requirements for distributed generation; and
- Exploration of new utility *business models* (e.g. partnership with technology providers and third-party ownership products to shift financial and performance risks away from customers).

VI. Conclusions & Policy Implications

This paper focused on the existing barriers to increased penetration of residential solar PV and storage in WA. Three broad groups of barriers were identified and discussed: technological, institutional and financial. A range of issues were identified under each of these groups, both from existing literature, as well as from interviews with key stakeholders working within the WA energy market.

The main barriers identified within the technological barrier include: forecasting capability; constraints of existing technology; and network capacity and access. Institutional barriers include: psychological will of people and the reluctance to embrace the new; organisational management and issues associated with listening too closely to customers; the need for Government lobbying and policy reform; and consumer inertia& information blocks. The main financial barriers discussed include: how to deal with sunk network costs; as well as inertia around network design and how to cover the upfront system costs of solar PV and batteries. A collective view of the discussions suggests that the adoption of solar PV and storage systems is still a challenging process and one that requires all stakeholders in the sector – whether they are industry stakeholders, policy makers, local communities or consumers – to participate in the transition towards a more innovative and sustainable electricity networks of the future. Results also suggest that regulatory and policy reform is what will underpin the removal of other financial, institutional and technological barriers. Without cohesive collaboration and dedicated support for this regulatory and policy reform, the barriers to wider adoption of technology innovations will not be easily overcome.

While many countries worldwide are yet to fully embrace or acknowledge the forthcoming disruption to global electricity markets by solar PV and battery storage technology, the WA stakeholders interviewed clearly recognise these as a disruptive innovation that is already having a significant impact on the WA energy network and market.

The unique set of conditions within WA (i.e. economic affluence, imminent market reform, network isolation and increased consumer demand for solar and, increasingly, batteries) has created a situation and issue which the WA Government can no longer ignore. For this reason, it is expected that WA's isolated electricity network and energy market will become a demonstration site for energy authorities around the world looking for guidance on how to manage the transition and adapt their own regulatory frameworks for the future.

Given the technological and political uncertainty that remains, this paper highlights the importance of firstly creating regulatory transparency to empower a robust, yet flexible policy design, that can then be used to underpin the energy markets that are essential to the sector. Over the long-term, it is the efficiency of markets that will drive competition, rather than regulators. For example, removing barriers to entry for solar PV and storage will facilitate uptake, which will in turn drive innovation and customer choice across retail, network and wholesale markets. Policy makers must recognise the importance of not only identifying and removing any existing regulatory barriers, but creating adaptable and flexible frameworks so that any future barriers can be easily identified, navigated, or mitigated.

Further research is needed to examine the specific solutions that WA may require to address and minimise the negative impact on the network and the market.

Highlights:

- Several barriers to residential solar PV and storage remain in Western Australia
- Barriers are qualified through a series of interviews with Western Australian energy market participants
- Common scapegoat appears to be Government and regulators
- Flexible and adaptable regulatory frameworks are important for innovation

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