Independent Review into the Future Security of the National Electricity Market

3 March 2017

About the Warren Centre for Advanced Engineering

The Warren Centre brings industry, government, and academia together to create thought leadership in engineering, technology, and innovation. We constantly challenge economic, legal, environmental, social, and political paradigms to open possibilities for innovation and technology to build a better future.

The Warren Centre advocates for the importance of science, technology and innovation. Our 30 years' experience of leading the conversation through projects, promotion, and independent advice drives Australian entrepreneurship and economic growth.

This document forms the response of the Warren Centre to the Independent Review into the Future Security of the National Electricity Market. We thank the Chief Scientist for the opportunity to respond.

Executive Summary

Australia needs affordable, reliable, diverse and sustainable energy. For a variety of reasons, the trend towards greater variable renewable electricity generation is inevitable. Decentralised generation and growing ancillary assets will become increasingly important in the future network. Australia needs an increasing emphasis on adopting innovative solutions. Policy makers and operators must acknowledge the structural technology changes to avoid harmfully disruptive effects to power security. How Australia manages the transition towards the decentralised energy network will dictate the affordability, reliability and efficiency of the NEM for decades to come, and these aspects of the network will underpin the resilience and productivity of our economy.

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The best solutions lie within demand side management, ancillary services, examination of global best practices, and ongoing forward view of incoming technology trends that can positively or negatively affect system stability.

Introduction

Australia's largest electricity system is undergoing its single greatest upheaval since the National Electricity Market (NEM) was first implemented in 1998. The NEM has relied on abundant and easily accessible fossil-fuel resources along Australia's eastern seaboard. In the past, coal-fired generation was significantly cheaper than other electricity sources, but with global solar PV costs falling 58%[1] in the past decade and predicted to fall another 60% by 2025[2], and onshore wind energy already estimated by many as the lowest levelised cost generator[3] [4] [5], coal is no longer the default technology option for cost effective electricity generation. Further, the electricity sector continues to respond to Renewable Energy Targets (RETs), international commitments on emissions reductions and to changing consumer preferences. We agree that these developments in generation technology and finance, along with the evolving priorities of the market are testing existing arrangements and the viability of Australia's current energy infrastructure.

Transitioning the electricity system to cope with new demands requires urgent action and a combination of market pull and technology push driven by diligent, sustainable policy. The Warren Centre strongly advocates for a long-term, sustainable, bipartisan policy platform with input from State and Commonwealth levels. We also advocate for technology-neutral policies that do not hinder the ability of the market to engage with unique consumer-side technologies.

This paper specifically answers questions 1.1, 1.2, 1.3 and 7.6 under the headline innovation and the global context; questions 2.3 and 6.2 under the headline issues facing consumers and grid adaptability; and questions 4.1 and 4.4 under the headline grid pricing and resilience.

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1 http://www.irena.org/DocumentDownloads/Publications/IRENA_REthinking_Energy_2017.pdf
2 ibid
3 https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf
4 http://www.smh.com.au/federal-politics/political-news/clean-coal-would-push-up-power-bills-more-than-wind-solar-or-gas-analysts-20170203-gu4ow5.html
5 https://cleantechnica.com/2017/02/07/new-coal-build-expensive-energy-option-australia-bnef/

Innovation and Global Context (1.1, 1.2, 1.3, 7.6)

1.1 How do we anticipate the impacts, influences and limitations of new technologies on system operations, and address these ahead of time?

Forecasting the potential impacts of new technologies and changing consumer behaviour patterns is essential to maintaining a flexible yet resilient electricity market. Novel technologies such as smart meters and the Internet of Things provide massive opportunities to reduce peak demand, but technology must be validated to avoid potential increased cyber vulnerability and jeopardised grid security.[6] Other technology trends must be considered: decentralised residential and commercial site generation, integration of consumer-owned energy storage systems (ESS), electric vehicles (EV), and peer-to-peer energy trading within micro-grids. Whilst all of these technologies may pose problems for the function of the NEM today, they simultaneously present great opportunities to increase system resilience and decrease costs.

To anticipate international and domestic technology trends and maximise their potential benefit for the NEM, frequent consultation is needed with the broad community of stakeholders, with a particular emphasis on research institutions, industry bodies, professional organisations and not-for-profit, independent institutions. Utilising the comprehensive forecasting, simulation and analytical capabilities of Australia's leading universities and research groups will be essential in helping Australia anticipate and adapt to the numerous technological developments set to disrupt the existing energy paradigm.

The capacity to anticipate disruptive future technologies lies within institutions with a mandate and the resources to give honest, non-commercial, but business-savvy advice. The Warren Centre aspires to fulfil such a role as a government advisor for public good with strong input from academia and industry.

1.2 How can innovation in electricity generation, distribution and consumption improve services and reduce costs?

The transition to a grid which effectively manages the energy 'trilemma' necessitates the integration of both established and nascent technologies. Equally important,

[6] http://www.ijcaonline.org/research/volume133/number8/rastogi-2016-ijca-907903.pdf

however, is the flexibility of grid regulators, operators and consumers to adopt further energy innovations.

The dependable monotony of rising consumer energy bills is coupled with decreasing grid reliability and accentuated by seemingly more frequent system black events. This undermines Australia's economic development and attractiveness to international investment.

Partly in response to these trends, Australia is experiencing a growing uptake in residential solar PV systems, currently at the highest global per-capita installation rate[7] and forecast to nearly double in the next decade.[8] Investment in these systems will become increasingly attractive as unit prices continue to fall and supporting technologies such as residential ESS increase market penetration.[9]

Decentralisation of energy generation, although not without associated risks, provides a massive opportunity to reduce reliance on existing transmission infrastructure and, if appropriately managed, associated network costs. The anticipation and coordination of decentralised generation coupled with the use of ESS will provide great potential to increase reliability in the grid and lessen peak load demands through the development of peer-connected virtual power stations.[10] Inadequately preparing for the impacts of consumer-driven change in the network will only hinder the final outcome for all market participants. Market regulators and operators will likely benefit more through embracing the impending shift toward decentralised generation, rather than resisting change with dogmatic favour for incumbent technologies. Ultimately it will be most advantageous to position the market where its participants stand to receive the greatest possible benefits during this period of transition.

At the commercial and utility scale, state-of-the-art generators such as Gen IV nuclear small modular reactors (SMRs) may eventually provide unmatched potential for synchronous, zero-emission generation capacity with relatively less waste product compared to conventional nuclear generators. The potential of these generators to further decentralise generation with safe, reliable, synchronous capacity provides a potentially great opportunity to reduce dependence on existing transmission infrastructure and, if aptly managed, reduce associated network costs. Furthermore, SMRs provide an effective method for high-usage consumers to secure their energy

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[7] http://theconversation.com/factcheck-qanda-is-australia-the-world-leader-in-household-solar-power-56670

[8] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEFR/2016/Projections-of-uptake-of-smallscale-systems.pdf

[9] http://www.irena.org/DocumentDownloads/Publications/IRENA_REthinking_Energy_2017.pdf

[10] https://www.csiro.au/en/Research/EF/Areas/Electricity-grids-and-systems/Intelligent-systems/Virtual-power-station

supply during periods of system instability. We acknowledge that presently SMR technology is not proven, and we acknowledge that Australia does not have a base of public education, awareness and community consent to allow even minimal government dialogue on the topic. Australia should stay closely aligned to international Gen IV developments so that if the technology is required domestically to achieve zero carbon emissions, the transition will not be critically painful due to delay in acknowledging international technology trends.

The recent shutdown of the Tomago smelter, the massive losses incurred by the BHP Olympic Dam facility during the SA system black event, and the initiative of Sun Metals to build an independent solar generator facility in response to large energy price surges all highlight the need for reliable, cost-predictable and low emission energy supply to Australia's heavy industry.[11] [12] [13]

With respect to cost-saving and reliability-enhancing operation mechanisms for consumers, investigation into modern iterations of tried and proven management techniques, such as demand side management (DSM), should be conducted in earnest. The notion that all consumers should have uninterrupted access to energy regardless of capacity limitations or importance of use is largely outdated, and contributes to prevailing inefficient and expensive system design.

Incorporation of innovative technologies and management techniques at all levels of grid operation is fundamental to developing a modern grid for Australia which provides the best possible resolution of the energy 'trilemma'. The inability of the current system to adapt to changes in the market and to incorporate innovative developments is in no small way responsible for the myriad of issues regarding the security, reliability and cost problems facing the NEM and its participants. It is the utilisation of these innovations from a policy neutral, cost-centric and environmentally considerate perspective which will shape the grid of the future and ensure the foundation for Australia's continued economic security and growth.

7.2 What lessons can be drawn from governance and regulation of other markets that would help inform the review?

[11] http://www.townsvillebulletin.com.au/business/sun-metals-achieves-financial-close-on-182m-solar-farm-at-townsville/news-story/8f886e3fe331353ab1657dc25ec6a278

[12] http://www.theaustralian.com.au/national-affairs/state-politics/bhp-steps-up-warnings-over-sa-olympic-dam-power-blackouts/news-story/162d46e37189c21c8bbc47bb760a4b13

[13] http://www.smh.com.au/nsw/tomago-aluminium-smelter-on-the-verge-of-disaster-as-electricity-cut-off-20170210-guabaw.html

The nature of the problems afflicting Australia's energy sector are not globally unique. Though moulded to the Australian context, issues surrounding integration of renewable generators, evolving market operation, new consumer and operator behaviour patterns, rapid technological advancement and administration of ageing infrastructure have all been managed, with varying degrees of success, by foreign nations in the development of their respective energy sectors.

Germany's *Energiewende* programme has experienced many of the difficulties of a renewable-heavy grid, including balancing the variability associated with increased intermittent generators along with a reduction in the baseload generator capacity of traditional lignite, coal, gas and nuclear generators. Recent regulation which only allows for the sale of electricity as it is simultaneously fed into the grid aims to hold energy traders to account by limiting market distortion through artificially inflated bidding practices and hence ensure security of supply.[14] [15] In addition, a series of policy adjustments have been implemented, focussing around improving transparency in pricing and supply systems, reducing and more fairly distributing the costs of grid expansion and maintenance, and the establishment of a capacity reserve outside of the electricity market which functions as a failsafe mechanism in the face of adverse system events.[16] [17]

Closer to our shores, China has recently made many bold moves in a concerted effort to curb emissions-related pollution problems in its major cities, whilst increasing capacity of renewable generation to meet COP 21 commitments. The recent dedication of 2.5 trillion Yuan ($493m AUD) to renewable infrastructure by 2020 comes as the most recent addition to a series of financial and policy moves towards the modernisation of what will likely become one of the most complicated, expensive and geographically challenging grids on Earth.[18]

Although a great many country-specific insights into creating and managing the grids of the future can be found in the international experience, there are many consistent themes in the effective development of the modern electricity sector. These internationally pervasive concepts include:

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[14] http://www.bmwi.de/Redaktion/EN/Dossier/electricity-market-of-the-future.html;jsessionid=9BA2D8920BFC942FB7363043EF5EB124

[15] https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&jumpTo=bgbl116s1786.pdf#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl116s1786.pdf%27%5D__1488437175503

[16] http://www.bmwi.de/Redaktion/EN/Artikel/Energy/strommarkt-2-0.html;jsessionid=9BA2D8920BFC942FB7363043EF5EB124

[17] http://www.dw.com/en/what-exactly-is-germanys-energiewende/a-16540762

[18] https://www.nytimes.com/2017/01/05/world/asia/china-renewable-energy-investment.html?_r=0

- focussed and uniform policy direction with coordinated action from all invested parties;[19] [20] [21] [22] [23]
- creating an open and transparent market, which efficiently restricts the activities of traders, consumers and operators in order to provide the best outcome for all participants;[24] [25]
- anticipation of incoming disruptive technologies and preparation for their integration in order to maximise their benefits to the system;[26] [27]
- greater incorporation of modern operation procedures, such as increased and higher quality forecasting, demand side management and consumer-end behavioural limitations[28] [29] [30] [31]; and
- increased use of data, research and analysis to guide the operation and management of the grid.[32] [33]

Australia will benefit greatly from the serious consideration of these concepts in the future design of a modernised domestic energy network and market.

The Warren Centre recognises the features specific to the Australian continent, such as high-density coastal population, sparse rural population distribution, unique geography and abundant fossil fuel resources, which have shaped the development of the NEM to this point in time. We should not, however, resist new technology entrants developed from global, interconnected grid systems purely on the basis of their unfamiliarity.

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[19] S. Urquhart, *Electricity Market Reform,* International Energy Law Review, 2012
[20] J. E. Gardner, R. L. Lehr, *Enabling the Widespread Adoption of Wind Energy in the Western United States: The Case for Transmission, Operations and Market Reforms,* Journal of Energy & Natural Resources Law, August 2013
[21] Sweet & Maxwell and contributors, *Transforming Europe's energy system: Commission's summer energy package,* EU Focus, 2015
[22] M. Valiante, *A Greener Grid? Canadian Policies for Renewable Power and Prospects for a National Sustainable Electricity Strategy,* Journal of Environmental Law and Practice, 2013
[23] http://www.bca.com.au/media/no-room-for-partisan-politics-in-energy
[24] http://www.bmwi.de/Redaktion/EN/Artikel/Energy/strommarkt-2-0.html;jsessionid=9BA2D8920BFC942FB7363043EF5EB124
[25] K. Saks, *GREAT LAKES, GREAT POTENTIAL: EXAMINING THE REGULATORY FRAMEWORK FOR WIND FARMS IN THE GREAT LAKES,* Canada-United States Law Journal, 2011
[26] P. G. Neilan, *Solar Power and the Spanish Lesson,* International Energy Law Review, 2014
[27] E. Stoppani, *Smart charging and energy storage: bridging the gap between electromobility and electricity systems,* International Energy Law Review, 2017
[28] Gardner, Lehr, *Enabling the Widespread Adoption of Wind Energy,* 2013
[29] A. Butenko, *Sharing Energy; Dealing with Regulatory Disconnection in Dutch Energy Law*, European Journal of Risk Regulation, 2016
[30] C. Clement-Davies, *Electricity Market Reform: A New Paradigm?*, International Energy Law Review. 2012
[31] E. Stoppani, *Smart Charging,* 2017
[32] Gardner, Lehr, *Enabling the Widespread Adoption of Wind Energy,* 2013
[33] https://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf

Issues facing consumers and grid adaptability (2.3, 6.2)

2.3 How do we ensure the needs of large-scale industrial consumers are met?

The need for widespread reform of the existing energy market is made more apparent with every news cycle. Erratic costs, unreliable supply and policy uncertainty regarding emissions mechanisms all work to undermine economic confidence and exacerbate risk for industrial consumers. These issues have become detrimental to the point where some consumers, such as Sun Metals in North Queensland, have begun to minimise their dependency on the grid through development of private generation facilities.[34] Other consumers, such as BHP's Olympic Dam operation in South Australia and the Tomago aluminium smelter facility in NSW, have incurred massive costs from the inadequacies of the NEM to withstand system events and consistently meet demand. [35] [36]

To secure the productivity of industrial consumers, the operation of the NEM must be safeguarded against susceptibility to extreme systems conditions. The use of DSM to protect the interests of high reliability consumers (hospitals, industrial assets) whilst using incentivised curtailment of supply to less essential assets (household appliances, commercial air-conditioning, escalators, etc.) would reduce general economic harm, whilst providing financial or other incentives to consumers and help minimise necessary peak design capacity of the existing system.

The implementation of decentralised generation and large scale ESS also provides effective options for industrial consumers to safeguard energy supply. This is a model which has been used effectively by many industrial consumers around the world for decades, though one which presents its own integration problems around redistribution of network costs as traditional revenue streams are weakened.[37] [38]

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[34] http://www.townsvillebulletin.com.au/business/sun-metals-achieves-financial-close-on-182m-solar-farm-at-townsville/news-story/8f886e3fe331353ab1657dc25ec6a278

[35] http://www.theaustralian.com.au/national-affairs/state-politics/bhp-steps-up-warnings-over-sa-olympic-dam-power-blackouts/news-story/162d46e37189c21c8bbc47bb760a4b13

[36] http://www.smh.com.au/nsw/tomago-aluminium-smelter-on-the-verge-of-disaster-as-electricity-cut-off-20170210-guabaw.html

[37] https://www.ceic.unsw.edu.au/centers/vrb/about-us/history-of-vanadium-redox-battery.html

[38] https://www.environment.gov.au/system/files/resources/97a4f50c-24ac-4fe5-b3e5-5f93066543a4/files/independent-review-national-elec-market-prelim.pdf, Chapter 2

6.2 What are the alternatives to building network infrastructure to service peak demand?

Design of the NEM has historically been based upon the provision of an uninterrupted energy supply capable of meeting peak demand forecasts. This design directive has created a network with considerable oversupply of generation capacity, yet which is, paradoxically, incapable of meeting the present demands of consumers in the NEM at periods of high system stress.[39] [40] [41] The failure of this excess 'base-load' capacity to effectively meet the recent periods of peak demand has highlighted the need for thorough investigation of the current market function, and warrants a comprehensive revision of existing infrastructure and management policy.

The inadequacy of the existing system becomes increasingly relevant as consumers are asked to meet the maintenance costs of peak demand generators, which continually fail to achieve their stated purchase, whilst suffering the increasingly frequent threat of unforseen service curtailment.[42] The technologies which will help resolve the present energy supply reliability issues and mitigate the intensity of peak demand are within the areas of demand side management and system ancillary services.

As discussed previously in this submission, DSM has great potential to allay the intensity of peak demand. DSM is a proven method for reducing the peak load on generators and allowing for a lower design capacity for the system.[43] [44] [45] Implementation of DSM into the modern grid becomes increasingly attractive when considered in conjunction with rising technologies such as smart metering and device interconnectivity through the Internet of Things (IoT). These innovations enable automatic distribution of load and curtailing of specific appliances or services based on digital signals from energy distributors. Techniques such as these will become increasingly palatable to consumers if actual cost savings can be realised in energy bills and if an incentive scheme is connected to any demand management programme.

It will be important for policy makers and regulators to support and possibly lead the investigation and adoption of any DSM procedures in order to coordinate demand

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39 http://thenewdaily.com.au/weather/2017/02/10/nsw-power-blackouts/
40 http://theconversation.com/factcheck-does-australia-have-too-much-electricity-31505
41 http://www.smh.com.au/nsw/tomago-aluminium-smelter-on-the-verge-of-disaster-as-electricity-cut-off-20170210-guabaw.html
42 http://theconversation.com/why-did-energy-regulators-deliberately-turn-out-the-lights-in-south-australia-72729
43 https://eaei.lbl.gov/sites/all/files/Providing_Reliability_Services_through_Demand_Response__A_Preliminary_Evaluation_of_the_Demand_Response_Capabilities_of_Alcoa_Inc..pdf
44 http://www.ontarioenergyboard.ca/oeb/_Documents/EB-2010-0215/THESL_CDM_Strategy_20101022.pdf
45 https://www.iea.org/media/training/bangkoknov13/Session_12b_IEA_Saving_Electricity_in_a_Hurry.pdf

management with a whole-of-system perspective, and to minimise potential issues with system security in an increasingly reactive grid.

The technologies of decentralised generation, primarily in the form of residential solar PV and ancillary technologies such as residential ESS also provide great potential for expanding the capacity and resilience of the grid without investment in additional peak-load infrastructure. As discussed in the CSIRO/ENA report *Electricity Network Transformation Roadmap 2017*, optimisation of an increased uptake in residential solar PV and ESS, along with a corresponding reconfiguration of existing networks, could achieve network savings of up to 30% on 2016 rates and a total $101bn AUD saving on network infrastructure expenditure by 2050.[46] These financial benefits, along with a corresponding increase in system resilience, are made additionally appealing when considering the environmental forecast of net-zero emissions by 2050 under this scenario.

Grid pricing and resilience (4.1, 4.4)

4.1 What immediate actions could be taken to reduce the emerging risks around grid security with respect to frequency control, reduced system strength, or distributed energy resources?

Although the establishment and maintenance of a resilient energy network which can effectively address the energy 'trilemma' is a continual process that will likely take many years of research, planning and execution, there are many actions which can be taken in the short term to increase grid reliability and to minimise the many risks jeopardising system security.

It is the opinion of the Warren Centre that much of the vulnerability present in the current NEM could be abated through reforming and modernising the market with proper accounting for new entrants into network function and the effective management of ancillary services. There is a strong role for adopting the lessons of the international experience and recognised best practices, as applied to the unique Australian context. Incorporating the lessons learned from the past operation of the NEM, and in-depth and ongoing consultation with industry, research institutions, universities and various other stakeholders and advisory parties is crucial to the future grid. Existing technology can be optimised. Lack of system inertia from renewable generators, whilst not an insurmountable obstacle for a low-emission, reliable grid, must be predicted and accounted for in systems design and administration.

[46] http://www.energynetworks.com.au/sites/default/files/key_concepts_report_2016.pdf

International experience in Germany[47], the southwest USA[48] and Spain[49], amongst others, illuminates the potential pitfalls of an intermittent-heavy generator profile, whilst also demonstrating how many of these issues may be overcome.

4.4 What role can new technologies located on consumers' premises have in improving energy security and reliability outcomes?

As previously discussed, residential generation, ESS, and EVs might be interconnected through a peer to peer network. Technologies such as blockchain trading and micro-grid connections provide great potential for cost effective generation and transmission with the added advantage of the potential for coordination of these resources into virtual power station-type systems. These systems could supply considerable quantities of stored energy to the grid at periods of peak demand or under supply, ultimately contributing to system reliability and lowering network operating costs. It is essential for policy makers and regulators to anticipate and incorporate the impending move towards combined rooftop PV/ESS systems and to establish methods for maximising the benefits of these systems to both the grid and the consumers, lest they risk loss in revenue from consumers which would ultimately result in a downward spiral of redistributing network costs onto fewer remaining consumers and operators.

4.4.1 How can the regulatory framework best enable and incentivise the efficient orchestration of distributed energy resources?

Consultation with industry stakeholders is needed at all levels of policy development. A regulatory framework which is dynamic, concise and transparent will help to not only ensure the best possible market is developed in the near future, but to allow the market to stay effective and efficient in the long term. Optimisation of distributed systems should be continually monitored. Policy stability is needed, but in the current period of rapid technology change, a degree of technical adjustment is likely.

[47] http://www.bmwi.de/Redaktion/EN/Dossier/electricity-market-of-the-future.html;jsessionid=9BA2D8920BFC942FB7363043EF5EB124
[48] J. E. Gardner, R. L. Lehr, *Enabling the Widespread Adoption of Wind Energy in the Western United States: The Case for Transmission, Operations and Market Reforms,* Journal of Energy & Natural Resources Law, August 2013
[49] P. G. Neilan, *Solar Power and the Spanish Lesson,* International Energy Law Review, 2014

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About the Warren Centre for Advanced Engineering

The Warren Centre constantly challenges the economic, legal, environmental, social and political issues raised by innovation. We collaborate with industry, government and academia to achieve globally significant outcomes.
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