ENGINEERS AUSTRALIA

Modernising Australia's Electricity Grid

Engineers Australia Submission to the House of Representatives Standing Committee inquiry

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1. Executive Summary

Who we are

Engineers Australia is the peak body for the engineering profession in Australia. With 100,000 individual members across Australia, we represent all disciplines and branches of engineering. Engineers Australia is constituted by Royal Charter to advance the science and practice of engineering for the benefit of the community. Engineers Australia's response is guided by our Charter and Code of Ethics which states that engineers act in the interest of community, ahead of sectional or personal interests towards a sustainable future. Engineers are members of the community and share the community's aspirations for Australia's future prosperity.

Engineers Australia appreciates the opportunity to provide a submission to the inquiry into modernising Australia's electricity grid. We believe that the House of Representatives Standing Committee is investigating a critical issue which has far reaching consequences throughout the Australian economy and community. This submission from Engineers Australia will focus on specific questions which will require engineering expertise to navigate optimal outcomes.

Vision

Engineers Australia believes the electricity grid should support an electric energy policy that provides plentiful, affordable, reliable and quality electricity supply to underpin industrial and social objectives, while at the same time reducing emissions to comply with international commitments. The best way to achieve these objectives is through a national transition strategy, which establishes a consistent long term policy framework and associated technical rules which improves the grid, provides a stable environment in which investors can bring forward options of using low or zero emission generation technologies, coupled with a flexible electricity grid which allows optimal connection and transport of this energy.

Background

Australia's electricity system has come under increased scrutiny in recent times. This has been brought about by the recent black out event in South Australia, along with discussions about electricity prices, and the influence of the electricity generation sector on climate change. As a result, there has recently been a number of reviews and inquiries which have looked at the electricity sector. This includes the current Review of the Future Security of the National Electricity Market, which has a final report due this year, which Engineers Australia put forward a submission. It is vital that all reviews and inquiries on this topic look across boundaries and a mechanism needs to be in place so that the proponents of each review and inquiry can readily discuss outcomes.

Power systems and the electricity grid

A power system is defined as all the components which create an electrical network for transmitting and distributing electrical power from the point of generation to the point of supply. These components are usually grouped together and considered as primary systems and secondary systems. Primary systems are the power stations, transformers, poles, wires and cables (the electricity grid) all used to produce consumer mains voltages for the customer. These systems are designed to be safe, secure and reliable. Secondary systems (also part of the electricity grid) are required to support the functionality of the primary system. This keeps the primary systems safe, secure and reliable using protection systems, control systems, metering systems, pilot cables and backup battery systems that provide an alternative power source when mains power is unavailable to operate the secondary system. The modernised grid will add to both these systems to provide optimal performance, keeping electricity prices affordable for customers.

The smart grid

In this submission Engineers Australia will make reference to the smart grid. Smart grids are electric networks that employ advanced monitoring, control, and communication technologies to deliver reliable and secure energy supply, enhance operation efficiency for generators and distributors, and provide flexible choices for prosumers (consumers with embedded generation technology). Smart grids are a combination of complex physical network systems and cyber systems that face many technological challenges[1].

The electricity trilemma

There is no single solution to a secure, reliable, sustainable and affordable electricity supply, and a modern electricity grid will need to accommodate variable energy sources, low emissions power, plug-in electric vehicles, peaking power, decommissioning of aging plants, storage and demand response management. If the future of Australia's electricity supply is to satisfy the trilemma, it will also need to include a diversity of energy generation options, energy efficiency, demand management, connectivity between the states utilising interconnectors and the development of smart grids, integrating with critical infrastructure.

A national transition plan is essential to lead Australia through the coming decades. Power generation in Australia is fast approaching a point where distributed generation is beginning to challenge the traditional model of baseload power. Future loads must be planned for, and cost benefit analysis must be completed to find the right balance. Energy policy makers should avoid unnecessarily increasing vulnerabilities and risks in both the energy sector and other sectors that affect electricity generation. Energy policy is not just about supply-side solutions, but also energy efficiency and demand management.

Any transition plan or changes to energy policy needs to have bi-partisan support for political stability, while at the same time allowing flexibility for whatever arises in the future. Flexibility will allow Australia to quickly adjust to any major advances or changes in new technologies, staying up to date with the most affordable, reliable energy options in a carbon constrained energy sector.

Impediments to achieving a modern network

Historically power flowed via power transformers from high voltage to low voltage. We are now at a point where we are adapting this grid to accommodate two-way energy flows which

[1] Yu, X and Xue, Y, 2016, *Smart Grids: A Cyber-Physical Systems Perspective*. Proceedings of the IEEE, Vol 104, Issue 5, http://ieeexplore.ieee.org/document/7433937/

can be done with sections of low voltage, but the original grid was not designed to operate this way.

Some technologies are already having significant impact on the electricity grid, such as solar photovoltaic systems (solar PV), and although it may still be decades before the role of other new technologies is fully realised, energy policy strategies planning for the short to long-term need to be implemented. There needs to be a more holistic approach to the role of new technologies. Not only will new technologies for distribution and transmission play a key role in modernising the grid, but also new generation technologies will change the system. Technologies need to be viewed together from generation to transmission, distribution and the end user and coupled with smart technology for optimal grid use.

The concerns of consumers must be at the forefront in establishing policy for modernising Australia's electricity grid. It is noted that much of the significant price increases of the past decade can be attributed to the network sector, where in some jurisdictions network charges comprise half the customer's end bill. Furthermore, distortions in market pricing through manipulation of pricing and gaming by participants in the National Electricity Market (NEM) need to be structurally addressed.

How Australia compares internationally

There are some similarities and differences between Australia and other comparable countries overseas. Like many other countries Australia utilises extra high voltage transmission and also has a national consumer voltage standard. Additionally, Australian consumers expect high reliability and mass power outages are not accepted by the general public.

However, the Australian grid is different to many other comparable countries as our grid is long and thin and predominantly made up of overhead power lines. Other large countries and regions such as the United States and Europe have greater reliability due to greater interconnections. A long thin grid with exposed power lines makes Australia particularly susceptible to extreme weather events such as bushfires, storms and floods, as well as interference from vegetation and animals where interconnection are inadequate.

There has been lots of discussion in Australia for some time about the advancement of smart grids, looking to forge a path as a world leader, but there has so far been very little action by governments to back this up. Australia still lacks a comprehensive long term plan in the development and implementation of grid modernisation.

Engineering workforce

Engineers Australia believes that a transition to a successful modern electricity grid will be dependent on a strong engineering workforce. Engineers are essential in the development of energy efficiency measures and emerging technology options, helping to provide reliable energy to Australian consumers while at the same time helping to meet Australia's emission reduction targets. Many of the issues the industry is presently facing are due to the fact that there has been a substantial de-engineering of the organisations driving the electricity industry.

It is critical to have sufficient technical expertise at all levels of organisations which play a part in the electricity network. Having engineers with the technical knowledge in these organisations including at the executive levels helps to promote a better understanding of how the system works, and how it can be improved. This needs to be addressed in the short-term.

Workforce planning is always required to maintain a stable and healthy economy. As the workforce evolves over the coming decades, new jobs will emerge as technology advances. Engineers will help drive Australia's technological advances, as engineers are problem solvers, critical thinkers and innovators. Implementing Chief Engineers within the executive of energy organisations and utilities should be considered as these positions provide independent advice on engineering intensive policies and projects, including in the modernisation of the electricity grid.

Australia's ambition is to become an innovative, technically progressive and globally progressive nation. This success will be critically dependent on the nation's engineering profession. Australia needs a larger engineering capability and the Australian government needs to look at policies which look to produce more engineers in areas such as electricity transmission, distribution and generation, coupled with smart grid technologies.

Key messages

Engineers Australia recently released a report on the future of electricity generation, calling for a national transition strategy. Engineers Australia believes that this should also incorporate the electricity grid and that a transition to a modern grid must:

1. Outline the optimal way for the grid to modernise and to assist in providing secure, affordable, reliable electricity supply which meets international emission reduction requirements.

2. Aim for bi-partisan support for the benefit of the nation providing for community expectations and reducing politicisation.

3. Be flexible to incorporate new technologies, while also noting the concerns of consumers.

4. Look to incorporate the benefits of overseas models, while also realising that Australia is geographically different from many regions and will require further research into its own system.

5. Promote the development and capability of the engineering workforce who will be critical to this transition, including the implementation of engineers in energy organisations and positions of independent advice, while also promoting best practice collaboration between universities and industry.

2. Terms of Reference Questions 1

1. The means by which a modern electricity transmission and distribution network can be expected to ensure a secure and sustainable supply of electricity at the lowest possible cost.

• How are the objectives of security, reliability, sustainability, and affordability interrelated?

Currently, there is no single solution to a secure, reliable, sustainable and affordable electricity supply. The electricity grid will need to accommodate increasing variable and intermittent renewable energy, but will also need some low emissions power, peaking power, storage and demand response management. Secure, sustainable, low-emissions, lowest cost electricity will come from the best mix of these technologies.

The Australian Energy Market Commission (AMEC) outlines the National Electricity Objective (NEO), is to promote investment, and operation of electricity services for the long-term interests of consumers with respect to price, safety, reliability and security of supply. The NEO makes no mention of any requirements for sustainability. The recent Review into the Future Security of the National Electricity Market, refers to a trilemma of affordability, reliability and sustainability, and the NEO needs to be updated to reflect this trilemma of energy requirements.

Energy Security

Australia's economic prosperity is underpinned by the need for reliable supply to ensure that key industrial and commercial processes are not disrupted by poor energy supply. Discussions about energy security in Australia after the blackout event in South Australia have predominantly focused on the lack of a traditional baseload power production, without looking at the issue from a holistic approach. Too often the discussion about energy security in the context of electricity generation is too narrow and can miss the broader issues. Managing and planning for the sudden failure of energy infrastructure is the biggest challenge to energy reliability and security.

While renewable energy sources are a good source of sustainable, low carbon emissions, they cannot currently be completely relied on to provide energy security to ensure that electricity capacity is available to meet the system demand at any instant of time. Strategies must be put in place to ensure that demand can be met when required. A balance of distributed generation types is likely to provide the most reliability and further add to grid resistance.

Diversity of energy options and strategies

A secure energy future will be reliant on a diversity of energy options including renewable energy production, connectivity between state borders and the development of smart-grids to help strengthen resilience (storage and demand response). Baseload power that is currently being supplied by fossil fuelled power stations needs to transition to a mix of energy options that, combined, are capable of providing the equivalent of the demand profile and the modification of the frequency support required. This will require research which is specific to Australia's grid.

The engineering profession plays a lead role in the successful adaptation and implementation of technical solutions that can help minimise major disruptions to power supply, apply synchronous condensers, synthetic inertia, demand response and power storage conversion systems. It is important that Australia participates in the development of international standards for the successful adoption and implementation of new technologies. If the market operator is to alter the way that electricity is managed in an extreme weather event, there needs to be a mechanism in the market outlining how this can be achieved. Smart grid solutions can be considered in compilation with load shedding, generation and grid options to provide sufficient reliability to an acceptable level as expected by the community.

Interconnectors

Interconnectors are high capacity electric transmission lines that connect different regions, and they do currently play a role in the NEM. Interconnectors are vital because they can:

- Improve economic efficiency of electricity production (noting there are some losses in grid transmission which can be reduced by improved design), allowing lower cost electricity generation to be produced in one area and consumed in another area.
- Improve the reliability of the power system making it maintain the voltage and power in the area needing support.
- Share reserve generating plant between regions across the interconnector. Power systems need to have some spare generating capacity, that can be brought into service to immediately replace generators that suddenly break down.

Interconnectors are important security measures especially if renewable generation is to become more prevalent in the system. Often the best renewable energy resources are located long distances from the load centres (Wind in South Australia, Solar in Queensland) and interconnectors are needed to transmit this generation. However, a new remote generator seeking to connect with a major grid (E.g. Victorian La Trobe Valley Grid) cannot be expected to build a major interconnector in between regions.

It is essential that a national perspective be taken in the development of the electricity grid. The transmission infrastructure and development of interconnectors is a vital element of the national infrastructure for the facilitating the efficient transport of electric energy between regions. Whilst the benefits of interconnection between systems in terms of security and reliability are self-evident, it can be difficult to demonstrate the economic benefits as benefits are dependent on generation availability and cost. The Regulatory Investment Test for Transmission (RIT-T) process needs to be modified in respect to interconnectors so that the benefits to all possible options might be realised.

Cyber security

Cyber security strategies will be essential to mitigate the risks of damage, unauthorised use and exploitation of data[2]. Although the physical vulnerability of an electricity grid has been known

[2] Energy Networks Australia, CSIRO, 2016, *Electricity Network Transformation Roadmap: Key concepts report 2017-27*

for a long time, the cyber vulnerability of a grid is a much more recent occurrence. Cyber security is an ever evolving commitment that requires on-going vigilance[3].

Protecting an electricity grid from a cyber-attack can be difficult as the grid is made up of a range of physical elements, coupled with integrated computerised technology, connecting a range of buildings, substations and transmission infrastructure. The grid must also continue to operate in real time, supplying the right amount of electricity to the right areas. While computer and smart-grid technology is updated every few years, it may take major electricity grid systems over a decade to follow suit.

The growing size of this issue will require techniques to manage and reduce the number of vulnerable points the grid has[4]. There needs to be further research to create a best practice for Australia to help to identify and mitigate these risks.

Reliability

Resilience and reducing vulnerability

A key goal of the energy security agenda should be to reduce vulnerability and improve resilience of energy supply systems by constantly improving these systems and ensuring integration with critical infrastructure[5]. The current grid's overreliance on aging twentieth-century architecture could create future systemic vulnerabilities.

The big cities get their power primarily from large clustered power producers located away from urban centres and electricity is transmitted over long, high voltage infrastructure. The transmission network plays a critical role by providing a highly reliable energy balance in a wide range of operating conditions and will play a key role in ensuring that power system security can be retained[6]. The potential of smart grid technologies with emerging energy storage systems can increase generation and distribution resilience.

Renewable distributed generation has become more popular as it provides greenhouse emission reduction, can handle grid vulnerability, curbs unnecessary infrastructure investments and enhances grid efficiency. However, it is a complex area and not enough practical experimental and simulation studies have been engaged to delve into the operational and policy conditions. Without further investigation in this area, we could see implementation of sub-optimal renewable generation practice and policies not being able to cope with increasing demand loads. As a result, stakeholder engagements for leveraging artificial intelligence and big data approaches need to be sought for digitalising and optimising renewable participated distributed generation, in particular with storage (including batteries and hot water), on which engineering and policy decisions should be based.

Australia's population growth is not forecast to become more widely spread; rather, it shall continue to be sparsely populated with only a concentrated number of energy intensive

[3] Energy Networks Australia, *Cyber Security and Energy Networks Fact Sheet*
[4] Govindarasu. M and Hahn, A. 2017, *Cybersecurity of the power grid: A growing Challenge.* The Conversation. www.theconversation.com
[5] Yates, A, and Greet, N, 2014, Engineers Australia, *Energy security for Australia: Crafting a comprehensive energy security policy.*
[6] Energy Networks Australia, CSIRO, 2016, *Electricity Network Transformation Roadmap: Key concepts report 2017-27*.

locations such as cities, mines, smelters, and steelworks. This is conducive to a long skinny overhead transmission network, a structure which typically is of high vulnerability to extreme weather events, and interference from vegetation and animals.

Focusing on the strength of energy intensive locations, local network meshing can advance the security of a network with distributed energy resources via distribution and sub-transmission interconnectors or bus-coupling utilising new technologies such as fault current limiting (FCL) ceramic high temperature superconductor (HTS) cable technologies. These interconnectors and bus-couplers do not increase the fault level (an issue usually created with more available sources of generation energising a busbar) but increases the security by reducing the vulnerability (e.g. one FCL HTS interconnector will increase the security of a N-1 substation to N-2). This is an enabling technology, providing a distributed energy resource topology not possible otherwise. The topology created by the distributed interconnectors would enhance interconnectivity (making the power system more secure) while featuring the ability to cope with an increased number of smaller sized distributed energy resources that can supply states internally. Moreover, this opens up distributed energy resources to competition, providing both investors and customers a real choice of installation projects and supplies not possible otherwise.

If local network meshing options are to be considered, then true network vulnerability analysis will be required for future network planning accommodating distributed energy resources while reducing network vulnerability. This analysis would include determining where distributed interconnectors could best be located and installed, optimising the spend on the network while providing enhanced network security.

Sustainability

Transition to lower emission technologies

Using a combination of existing and emerging technologies in a structured policy environment is consistent with achieving energy security, reliability, affordability and emissions reductions targets. It is important that any transition plan or change to energy policy receive bi-partisan support for political stability, while at the same time allowing flexibility in the future. This will encourage new technologies to enter the market as they become more economically viable or allow existing technologies to improve.

Driving renewal of the plant and asset of the electricity grid is vital to a sustainable network. The renewing plant needs to be properly justified, and only when the business case supports it. This means business cases need to have mechanisms in place to realise customer expectations, manage risk as well as meet sustainability targets (non-network solutions).

Distributed generation is going to play a more prominent role in Australia's electricity supply, most notably in rural and regional areas. There is the possibility that a large enough increase in distributed generation could encourage the shutdown of traditional baseload power distribution in these areas as consumers on the fringe look to go off-grid. This needs to be considered and planned for, to reduce disruption and to see where the most ideal benefit for network investment in infrastructure and new technology would be utilised.

Business cases should be used to determine the best way to continue providing electricity, especially to rural customers. Using distribution to supply rural customers may often be inefficient, and off-grid options for rural and regional customers may prove to be more economically efficient. In some cases, bushfire assessment may be required for public safety reasons, including the progressive replacement of single-wire earth returns to reduce bushfire risk.

Business cases for future costings must also include the full cost of greenhouse gas emissions to create a level playing field when determining the best options. Examples of remote and regional areas already using large scale renewable energy and storage projects exist, including large scale solar in Karratha in Western Australia and grid support systems to rural consumers in regional Queensland.

No state generation curtailment

The 28 September 2016 black system event in South Australia has brought the issue of energy security to the top of the energy policy discussion in Australia. Much of these discussions are on energy security in Australia and have predominantly focused on the lack of a traditional baseload power production. Although renewable distributed energy has complexities, this does not warrant curtailing this form of electricity generation in each region. Instead, these complexities should be resolved in the transition plan we advocate.

The deployment of other low-emission technologies other than wind, such as solar PV in Queensland and New South Wales assisted in reducing the risk of outages when the system was put under pressure in those jurisdictions. Further practical experimental and simulation studies are warranted for optimal integration of distributed generation, and these should be based on sound engineering and policy decisions. There should be some caution about how additional renewable energy is implemented in the future, but this is why a transition plan is essential.

Affordability

Market reform and policies for investment

To allow the market to respond appropriately and flexibly to an increase in different generation options, ongoing market reforms along with assistance mechanisms may be required. For emerging technologies, policies to create initial markets must run alongside research and development programmes, far ahead of widespread deployment of the technologies, and draw on competitive market forces where possible. Many of the large banks, which generally invest in large energy projects, have turned away from fossil fuel investment which may stifle any proposals of retrofitting of existing coal power plants or building of new coal power plants.

Government policies need to promote investment in established and emerging technologies that can provide reliable and affordable electricity supply, but also reduce emissions. For investors of new zero and low emission technologies, governments can initiate change by creating sustainable markets by filling funding gaps, and creating enabling infrastructure for new technology.

Planning for future community energy needs

A comprehensive view of energy security is important because electricity does not sit isolated from other energy considerations in Australia. The looming disruption of transport by electric and autonomous vehicles will shift the reliance from liquid fuels to a decentralised grid. Regulators and Government must plan for this disruption now or risk not being able to meet future demand. Australia cannot wait to be shocked by future events without a plan for a reformed energy grid.

A national energy policy is essential and all states and Territories should participate in a bi-partisan cooperative manner to align with the national policy. Energy policy makers should avoid unnecessarily increasing vulnerabilities and risks in both the energy sector and other sectors that affect electricity generation.

There needs to be further engagement with the consumer, and there is now an opportunity to look at the needs of the prosumer. It is estimated that consumers, and not utilities, will determine over $200 billion in system expenditure by 2050[7]. Consumer behaviours are going to change the way the grid operates, and there has already been evidence of this with the strong uptake of solar PV to remove reliance on the grid. If this is realised on a large scale there is the opportunity for exchanges of energy between different parties, which could also reduce the anticipated investments required for distributed network service providers. Additionally, if the uptake of rooftop solar and storage continues, the supply and demand fluctuations may require additional management on the electricity grid. This customer demand is then hidden from the market as it is behind the meter, which can cause planning issues. A strategy needs to be devised that addresses this unseen demand, including how this information is collected, and what body collects it, and who administers it.

- *What should be the highest priority objectives of a modern grid in Australia?*

The highest priority objectives of a modern grid in Australia is the development of a transition plan for the sector, as well as a long-term bi-partisan strategy to provide stability.

Transition Plan

Engineers Australia believes that the timescale for the transformation of the Australian power system to low to near zero carbon dioxide emissions will be over several decades and during this time there will continue to be major developments.

Without a national transition plan for electricity generation and a modernised electricity grid, Australia puts its energy security and reliability at risk while also facing uncertainties in energy affordability and emission reductions. A transition plan must include an outline for a modern electricity grid which will outline key problems, and provide solutions.

[7] Energy Networks Australia, CSIRO, 2016, *Electricity Network Transformation Roadmap: Key concepts report 2017-27*.

Long-term bi-partisan strategy and stability

Most importantly, any transition plan or changes to energy policy needs to have bi-partisan support for political stability, while at the same time allowing flexibility for whatever arises in the future. In this process, agreement should be reached on what represents critical infrastructure. Although this can be difficult as governments, political parties and policies change, there needs to be an agreed strategy which aims to satisfy the entire community.

The transition from the present energy profile to a different profile will involve changes to the existing pattern of production, transformation, transport and utilisation across all sectors of the economy – that is changes to the 'fleet' of current infrastructure and investments. Investments in energy infrastructure are capital intensive with many assets having long payback periods and asset lives. This means that the strategy needs to be seen in terms of decades rather than years, and that the energy strategy must be linked with long-term industry and social strategies.

- *What are appropriate standards for the security and reliability of the electricity system?*

The appropriate standards for the security and reliability of the electricity system will need to be balanced with community expectations. As a society, we cannot abandon reliability in pursuit of the lowest cost electricity, however Australia has abundant renewable sources of energy and the community wants to utilise these environmentally friendly energy sources.

The existing standards for transmission and distribution are reasonable as Australia's system needs to service a dispersed, low density, mainly overhead network. It is acknowledged that different System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) targets may be assigned for networks with different topologies. Maintaining these levels is challenge enough, with increasing population, aging assets and the impacts of climate change. If there is community expectation to make electricity networks more resilient to extreme weather events, this may require re-visiting some standards and rules such as AS/NZS 7000[8] and the National Electricity Rules (NER).

The current NER specified to network service providers already requires that high security standards must be upheld by those providers. This requirement is to maintain the same performance and functionality they maintained in the 12 months prior to 13 December 1998. By maintaining this rule, a high standard of security will be preserved. A set standard would only be desired if further rules were guaranteed to further advance security and functionality of the system.

Operating protocols may also need to be revisited, such as 'backing off' interconnectors in anticipation of major storm events, rather than relying on traditional generator spinning reserve. Many of the energy and system technologies which will play a significant role in the future energy sector structure are at research and development or pre-commercial stages. Fast acting network support such as battery storage could also form part of contingency planning along with demand response mechanisms.

[8] AS NZS 7000-2010 Overhead line design – Detailed procedures

The engineering profession can play a lead role in the successful adaptation and implementation of technical solutions that can help minimise major disruptions to power supply, apply synchronous condensers, synthetic inertia and power conversion systems. It is important that work on Australian Standards for new technology be implemented early, so that these solutions are ready for real world application as soon as required. If the market operator is to alter the way that electricity is managed in an extreme weather event, there needs to be a mechanism in the market outlining how this can be achieved.

It must be noted that behind the meter user technologies need to be accommodated just as grid and grid support technologies. As new technologies develop and become more popular, the manufacturing supply chain can change, requiring standards to be robust so that consumers know what they are paying for. If there are issues with parts which are used in wide distribution, this risks large disruptions over large areas.

Critical infrastructure will need special attention if the appropriate standards of grid reliability security is to be realised. Future NEM region separations may need to support increased reliability of supply to critical infrastructure.

3. Terms of Reference Questions 2

2. The current technological, economic, community, and regulatory impediments and opportunities to achieving a modern electricity transmission and distribution network across all of Australia, and how these might be addressed and explored.

• What are the costs associated with an 'outdated' grid?

There are a number of costs that are associated with an 'outdated' grid. The existing grid was designed as a 'one way' network with energy flowing from centralised coal generators to power points. We are now adapting this grid to accommodate two-way energy flows, with energy being injected at both low voltage (prosumer) and medium voltage (solar farms, land fill gas). This results in associated costs for:

- New investment in voltage control and protection systems to accommodate bi-directional energy flows.
- Augmentation costs of sections of the network that are not local to the new generation connection, which can be difficult to sell to new generators.
- Planned maintenance and unplanned maintenance of the system as fault response is increased.
- Increasing the useful life of the current aged infrastructure to accommodate any transition plan. Capital investment in existing infrastructure would need to have a transition target in sight before committing to future investment.
- The cost of cables and conductors, including the protection and maintenance.

• What might be the role of new technologies in improving system security, reliability, sustainability, and affordability? What is the potential for new technologies to alter the inter-relationships between these objectives?

Role of new technologies

The transition to an energy mix which can fulfil the trilemma may take a number of decades to implement. Not only will a wide mix of different energy options need to be considered, but energy policy strategies planning for the short-term should also be implemented. Energy security, reliability, and affordability issues must be front and centre, but so too should be environmental considerations. This means that all options that can provide minimal externalities (environmental damage, health effects, greenhouse gases) must be on the table for consideration.

Furthermore, there needs to be a national organisation established with the responsibility of monitoring developments of all technologies worldwide so that the best innovations can be quickly adopted. There also needs to be a better connection between university and industry, as while there has been great development in prototypes in universities, they can struggle to be realised in practice. What is critical is that the operating regime of any technology is fully understood, modelled and tested when being introduced to the grid. The specialist skills and knowledge of Australian engineers would play a major role in this process.

Not only will new technologies for distribution and transmission play a key role in modernising the grid, but also new generation technologies will change the system. Technologies need to be viewed together at every level of the process chain.

Grid options which can be considered and deployed:

- *Increased interconnection*: Studies should be undertaken into the value of constructing new interconnectors, particularly between regions. This would identify opportunities where some regions that may have more synchronous capacity may assist others by providing ancillary services to increase security. The analysis is critical, particularly with the announcements of further retirement of synchronous generation in the NEM.
- *Distributed generation:* Distributed generation gives the power back to the consumer by allowing them to charge a battery at the right time, and eliminated the cost and inefficiencies that are generally associated with distribution and transmission. Smart grids improve resilience as smaller generators increase 'N-n' reliability, though system inertia needs to be monitored and may require electronic control of Frequency Control Ancillary Services (FCAS) and synchronicity. There is a further grid option issue created when distributed generation is installed within the grid owned by network service providers (who cannot sell power), which complicates the feasibility of good technical solutions, and further investigation is required.

Grid support generation

- *Synthetic inertia and synchronous condensers:* Synchronous condensers are spinning motors whose shafts are not connected to a mechanical load, and consume very little real energy while providing inertia[9]. New controllers are available that will transiently convert the non-synchronous mechanical inertia of a wind turbine into synthetic inertia[10]. These are already being used in wind turbines installed overseas.
- *Energy storage*: Energy storage provides the capability to allow energy to be scheduled for delivery at a later time than when it is produced, or to a different location, and is an important enabling technology for many forms of renewable energy. The major forms of energy storage are heat, chemical energy, kinetic energy and gravitational potential energy (e.g. pumped storage hydro discussed below).
- *Concentrated solar thermal:* Concentrating solar thermal covers a number of different collector and power production technologies. Typically, the technology is close to being commercial, but currently constrained by higher cost. Technology trends are to improve economics of the technology by improved conversion efficiency and reduced material costs.

[9] Chief Scientist, December 2016, *Independent Review into the Future Security of the National Electricity Market, Preliminary Report*.
[10] Ibid.

- *Hydro*: The major types of hydro-electric power stations are stored-water, pumped storage and “run-of-river’. The carbon intensity of pumped storage hydro systems depends on the source of electricity taken from the grid to power the pumping cycle and the efficiency of the entire pump-run cycle. The ‘run-of-river’ technology provides opportunities for small scale implementation, with lower environmental impact. For pumped hydro to be successfully deployed, the grid and the market would need to be configured and operated in a way that optimises the use of renewable energy.

End user options

- *Energy efficiency and optimal integration*: It is here that engineers employ the latest digital technology to optimise flows between generators and users, matching forecasted demand with supply. Implementing an energy efficiency program offers dual benefits: it is an effective way for Australia to reduce its emissions, and it avoids the opportunity cost associated with unnecessary expenditure on energy.

- *Hot water storage*: Hot water storage allows consumers to match the high supply of solar power with the peak time of hot water usage. The development of smart meters and devices will be essential in the development of this technology. This technology is already in Australia.

- *Energy storage*: Energy storage is also an end-user option as there has been the development in recent years for behind the meter energy storage, mainly in the form of battery storage. Companies already exist in Australia which offer this service.

Supporting generation options worthy of further consideration providing further research and development:

- *Geothermal*: Geothermal technology has a number of different manifestations:

    - Low-grade heat for heating and cooling buildings

    - Tapping underground steam sources in thermally active areas

    - Tapping heat from deep hot rocks or hot sedimentary aquifers.

  Advantages of the technology are the capacity to be scheduled to meet demand, the capacity to load follow, and a lower exposure to international energy prices. Disadvantages of the technology are long construction times, and water demands (or production from sedimentary aquifers) during operation and earthquake issues.

- *Nuclear energy:* Nuclear power has the ability to provide long term energy security as modern nuclear power reactors are built with sixty-year life spans, and they also have near-zero carbon emissions[11]. Before nuclear energy is pursued further as an energy option there are issues which will first need to be addressed which are:

    - Two pieces of Commonwealth legislation that prohibit the licensing of a nuclear power reactor in Australia.

[11] Engineers Australia, 2015. Submission to the Nuclear Fuel Cycle Royal Commission. www.engineersaustralia.org.au/about-us/government-submissions

- The ability to generate electricity at a price that generates profits that are large enough to create a return on investment. As there is a wide difference in the costs of projects in different countries, a full feasibility study would be required to establish the cost of a nuclear project in Australia.
- Public concern over the safety of nuclear energy. There are concerns that the nuclear industry is unsafe and has waste disposal problems, and these concerns cannot be ignored and public debate is essential before any possibility of the option of nuclear energy being used in Australia. Strong political leadership is required to address these issues.

• How can the grid better accommodate the rapid pace of technological change, including an increasing level of variable electricity generation?

National electricity rules and reforms to accommodate technological change have been slow. This has not led to an efficient or effective technological revolution in the integration of new technologies, including demand management and the grid needs to incorporate this. The visibility and forecasting of the grid must improve. To drive that forecasting, there must be more storage for back-end data correlation. If the input data is visible, and open to checking by academic institutions, generating and storage opportunities will be visible to investors.

• What possibilities are there for alternative pricing models (for example, cost-reflective pricing) to better reflect the true cost of services provided by a modern grid?

There is a need for market reform, as there is a need for updated resources (such as energy storage) to be fairly included in the market. A truer market for services is required to incentivise market participants, particularly the new technologies to incorporate services features in their design and operation. Modern meters, information systems and fast communications can now handle 5 minutes' settlement. The current 30 minutes is a legacy of the 1990's and a five-minute market could open up short duration response opportunities.

Tariff reform, including structures such as time-of-use or critical peak pricing must consider both the appetite of consumers to receive what could be complex billing, and the benefit to energy reliability, affordability and security. Where network service providers in Australia have rolled out demand side management programs, direct payments have been used to reward customers while lessening the burden on the network, increasing network reliability. Without cost reflective pricing (CRP), this is often done outside the Retailer's billing systems, and represents a form of "network support payment".

Smart meters need to be accompanied by 'smart pricing'. As meters are deployed, the energy usage charges should better reflect the costs. Consumers will respond accordingly by shifting discretionary loads or adding storage. Smart pricing and smart meters also requires smart appliances, and there needs to be incentives for manufacturing more efficient appliances.

Recent heatwave events have reinforced the need to address the issue of peaking load. This is especially relevant as consumers utilise certain electrical appliances during extreme weather events (such as air conditioning on a hot day) and place a heavy load on the grid. During peak when demand is highest, CRP provides no benefit to customer energy consumption affordability. However, during high demand, security and reliability can only be sustained with CRP that uses automated signalling to control customer load, otherwise user intervention will exacerbate the high demand. Mechanisms such as air conditioning demand manipulation (by way of retail control of thermostat set points and availability), mandating the sale of smart-compatible appliances that can be 'integration-enabled', as well as planning approvals through Greenstar programs to enforce the use of 'integration-enabled' appliances, can all provide overall customer affordability benefits.

'Stepped' technology of new inverter technologies in appliances are more efficient which helps to reduce consumers' energy bills. During heatwaves, older air conditioners that operate above their designed ambient temperature cannot cool the air sufficiently and remain on at all times. A replacement program would reduce demand and market operating price. Current government subsidies provide an advantage to those who can afford to take up these new technologies, but at a cost to the whole community, as only those who can afford it benefit from it. Policies which incentivise inverter technology would be of great advantage during the hot summer months as they have the ability to run all day while remaining efficient, and using less energy.

- *What opportunities are there to improve governance and regulation in the grid?*

Policy makers need to give greater attention to reducing energy consumption through energy efficiency, as reducing total consumption of energy is one of the most cost-effective methods of improving energy security, lessening demand on the system. Research shows that energy efficiency improvements not only save on the cost of energy used, but could achieve large emission reductions over the next 20 years[12]. The Prime Minister's Task Group on Energy Efficiency previously proposed targets on energy efficiency in 2010, and re-assessing these targets should be addressed.

Consideration must be given to all low emission technologies which can also provide baseload, high capacity electricity, and this includes nuclear energy. As discussed above, there are issues and prohibitions that need to be addressed before nuclear energy could be considered on a level playing field with all low emission energy options.

Furthermore, there are serious problems with the current regulatory model for network determinations. There is a disconnect between long-term grid planning that is required and having just five-year regulatory cycles. There has been an upswing in the size of regulatory decisions, with some of these decisions taking around 20 to 30 times longer than they were 20 years ago[13]. Single point leadership on a national level is required to enable innovative reform in regulation. In a modern grid where information is provided to optimise, the regulatory framework needs to be adjusted so that budgets are not set via capital or operational expenditure, but by total expenditure.

[12] ClimateWorks Australia, 2015, *Australia's Energy Productivity Potential.*
[13] King. S, 2016, *Our electricity network regulation is in trouble.* The Conversation. www.theconversation.com

• What opportunities are there for consumers to benefit from the modernisation of the grid? How can we ensure that these benefits are able to be shared equitably by all consumers?

Engineers Australia agrees that there is great importance in consumer choice. This applies more broadly than just consumers own personal selections, but must also include market structures and rules to facilitate this. These topics have previously been raised in the Australian Energy Market Commission Power of Choice Review with key recommendations put forward. Topics covered in this review including being given choice in selecting service providers for what have historically been monopolistic services (e.g. Residential metering).

Engineers Australia supports the three key reforms put forward in this report being:

1. Rewarding demand-side participation in the wholesale market.
2. Providing appropriate consumer protection arrangements and gradually phasing in efficient and flexible pricing.
3. Introduce competition in metering services and develop a framework for smart meters and their services.

An increasing proportion of customer appliances are ‘smart devices’ that are capable of being remotely controlled with the aid of modern telecommunications. Customer installations can have control agents embedded in the control systems to interactively respond to system demand. Greater attention should be given to sending the appropriate signals to customer installations so that they can be set to optimally utilise the combination of appliances, embedded generation and storage capability to respond to system conditions and reduce maximum demand. At the same time the algorithm would be set to meet the performance objectives within the household.

Customers can expect that the appliances they purchase will become more efficient, or could offer different features. Consumers should also expect that information will be portrayed to them in an easily readable format.

• What sort of community attitudes or concerns will need to be addressed in order to successfully modernise the electricity grid?

Community concerns will need to be addressed as the transition to a more modern grid continues. In particular:

Community licence

The concerns of consumers must be at the forefront in establishing policy for modernising Australia’s electricity grid. It is noted that much of the significant price increases of the past decade can be attributed to the network sector, where in some jurisdictions network charges comprise half the customer’s end bill.

Transparent information for ease of customer choice

This is the confusion around the price of electricity that consumers are charged. Information needs to be available that can easily explain the costs of energy and network charges, helping consumers to understand their electricity bills.

4. Terms of Reference Questions 3

3.The Committee welcomes evidence on the progress of grid modernisation (including the integration of variable electricity generation) in comparable countries, and any lessons that could be applied to the Australian context. Questions for stakeholders to consider:

• What are the key similarities and differences between the electricity system in Australia and those of other countries?

There are a number of key similarities between the Australian system and a number of systems in other countries. Key similarities between Australia and other countries are:

- Australia utilises extra high voltage transmission with weak interconnectors.
- Australia has a national consumer voltage standard.
- Australians expect almost 100% reliability at consumer level, and mass power outages are not accepted by the general public.

Key differences are:

- The Australian Electricity Grid is long and thin and predominantly overhead lines susceptible to extreme weather events such as cyclones, bushfires, and high winds. Additionally, it can be vulnerable to encroachment from vegetation and vulnerable to bird and animal interference. Other large systems (United States, Europe) have reliability due to meshed connections.
- Australia has extensive low voltage networks that are common in some countries but in other countries such as the United States this is not the norm.
- The rural distribution network is 'voltage constrained' rather than 'capacity constrained'.
- Geographic area barriers, and setting of different renewable energy targets in different states mean that business cases cannot be assessed.

• How does Australia compare with other countries in the rate of adoption of variable electricity generation and other new technologies?

Australia has a great advantage being a land of large renewable resources such as solar and wind and this is reflected in the number of Australians currently installing rooftop solar, as this is now at world-leading rates[14].

However, Australia has an issue with university to industry collaboration, which significantly restricts national productivity and progression. The World Economic Forum ranks Australia 21st for university-industry collaborations, 27th for spending on research and development and 25th for capacity for innovation[15]. Support and Mentorship programs for all young engineers and other professionals willing to build their own vision should be encouraged.

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[14] Energy Networks Australia, CSIRO, 2016, *Electricity Network Transformation Roadmap: Key concepts report 2017-27*.
[15] Engineers Australia, 2017, *Engineers Make Things Happen.*

- *How does Australia compare with other countries in progress towards electricity grid modernisation?*

There has been discussion for a long time that Australia has the capacity to be a world leader in smart grids, but there has consistently been very little action taken. Australia still lacks a comprehensive long term plan in the development and implementation of grid modernisation even though discussion about smart grids has been around for over 15 years. Resting on proven technology prevents the discussion on technology advancements, and this is coupled with technology implementation costing millions more than what was originally budgeted for. This usually will guarantee that grid modernisation will not be considered.

- *What are examples of best-practice governance and regulation in other countries?*

One example that Engineers Australia can point to is the North Eastern Reliability Council (NERC), who are one of the biggest regulated network operating environments. NERC has major international test and plant manufacturers all producing products for the highest requirements. Implementing regulations from that system could add structure to the distribution and transmission operators and could improve reliability through enabling informed decision processes.

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