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Mr. Andrew Broad MP
Chair
Standing Committee on the Environment and Energy
House of Representatives
Parliament House
Canberra
ACT 2600

Our Ref: JC 2017-006

21 April 2017

Dear Mr. Broad,

S&C Electric Company submission to the Inquiry into modernising Australia's electricity grid

S&C Electric Company welcomes the opportunity to provide a submission to the House of Representatives Standing Committee on the Environment and Energy inquiry into modernising Australia's electricity grid.

S&C Electric Company has been supporting the operation of electricity utilities in Australia for over 60 years, while S&C Electric Company in the USA has been supporting the delivery of secure electricity systems for over 100 years. S&C Electric Company not only supports "wires and poles" activities but has delivered over 8 GW wind and over 1 GW of solar globally. S&C Electric Company has been actively engaged in deploying Battery Energy Storage Systems for over 10 years, supporting a full range of business models and using a range of battery technologies, at the kW and MW scale, and currently has 76 MW/189 MWh in operation. In Australia, S&C projects include the Ergon Grid Utility Support System in Queensland, which reduces peak loads and provides voltage support on rural Single Wire Earth Return lines and the 2 MW battery for PowerCor in Victoria.

S&C Electric are particularly interested in facilitating the development of markets and standards that deliver secure, low carbon and low cost networks and would be very happy to provide further support to the Standing Committee on the Environment and Energy on the treatment and potential of these technologies.

Yours Sincerely

Dr. Jill Cainey
Global Applications Director – Energy Storage

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Introduction:

The Australian electricity system, like many internationally, is experiencing rapid change as the result of a transition to low carbon generation, which tends to be both intermittent and distributed at the base of the system. This is in contrast to the "traditional" electricity system with centralised large high carbon thermal plant, which provide a steady output and where the electricity is then transported long distances to the bottom of the system to meet demand.

The connection of intermittent generation causes technical issues with voltage control and power quality and the location of the majority of intermittent generation on the distribution system, rather that the transmission system creates other challenges, including reverse power flows – that is "traditional" consumers that were only demand, are now also generators.

These technical issues and challenges are not insurmountable or unmanageable and in other countries, notably the USA, UK and Ireland, new system services have been developed to deliver low carbon electricity to consumers at least cost. The flexible tools needed, such as energy storage (both electrical and thermal) and demand-side response are already well-developed. In some cases, the approach has been one of "evolution", with a gradual adaption of system and services to meet the new model (e.g. USA and UK) and in some cases the approach has been a "revolution", most notably in Ireland-Northern Ireland where network planning and management has been entirely replaced to ensure that the island system can accommodate 60 % of its generation being provided by wind.

It should also be noted that the new low carbon systems have resulted in a huge amount of innovation and the creation of many new business models and jobs. The modernization of the Australian electricity system is a major opportunity, but if not managed correctly or if there is a lack of foresight (e.g. Finkel Review's call for a "strategy"), then rather than delivering a secure and reliable, low carbon system at lowest cost, one or several of these aims, likely low cost, will not be meet.

Summary

- Ensure we are efficiently using the assets we currently have to deliver a stable system, as this is a low cost, low risk approach;
- Have a coordinated strategy / plan for delivering the future electricity system as this will deliver a low carbon system at the lowest cost;
- Have a strategy that is independent of politics and independently reviewed (e.g. The UK with the Climate Change Committee and National Infrastructure Commission);
- Delivering a secure, low carbon electricity system at lowest cost encompasses more than just energy policy. It needs coordination between multiple Government departments, State Governments and agencies. Building and appliance standards, inter-operability ("smart" approaches), transport etc. are all key;
- Closer coordination between Federal and State interests to ensure a joint approach;
- Ensure that new technologies are supported, so that they can be deployed when needed (e.g. storage);
- Focus on resiliency rather than reliability;

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- Look at innovative and low cost ways to deliver security, it won't always be the traditional approach;
- Look at all energy, not just electricity to understand the role of heat and cold (and gas) in energy costs and management;
- Understand where consumers spend their money and ensure that the approach (behind-the-meter batteries (electricity only) versus a hot water tank/solar thermal (heat and hot water)) are targeted appropriately to where energy spend is greatest;
- Empower communities, rather than individuals to take control of their energy use and spending;
- Facilitate partnerships between communities and networks to deliver low cost, low carbon solutions

Additional Points

Following the system issues in Australia, arising from low rainfall in Tasmania, winter storms in South Australia and high temperatures in many states, there has rightly been penetrating focus on the operation of Australia's electricity system and its markets. There are and continue to be a large number of inquiries and consultations on the future of our electricity system. One of the key issues is the management of frequency. Every electricity system in the world is inherently fragile and to deliver a secure system takes a great deal of complex effort, with individuals in control centres ensuring that generation *exactly* matches demand every moment, of every day. The sign that generation is meeting demand is stable frequency and in Australia that means maintaining frequency at 50 Hz.

Australia has been struggling to maintain a stable frequency since the (a) introduction of new rules, with wording that changed a mandatory requirement to deliver system support into a capability requirement; (b) controllers (governors) at large high carbon thermal plant have been replaced and updated to accommodate the new rules and (c) market requirements take precedent over system (technical) stability requirements.

Prior to the introduction of the new Frequency Control Ancillary Service (FCAS) and more importantly the frequency standard (deadband settings) contained within, frequency was tightly constrained between 49.95 and 50.05 (±0.05) Hz. Currently, frequency is constrained within a much broader range of 49.85 and 50.15 (±0.15) Hz. This is stark contrast to other jurisdictions which have reduced their deadband settings to more tightly constrain frequency, as more intermittent generation connects (e.g. ERCOT and CAISO). As large thermal plant disconnect, the remaining providers of inertia and primary frequency response need to deliver more efficiently. In Australia, we have loosened our constraints on frequency.

The combination of widening deadbands and strict requirements to meet dispatch targets in the energy market, has resulted in an increase in the number of frequency exceedance events and in the cost of managing these events. Total Regulation costs in 2014 were $5M and in 2016 were $65M and these costs are passed on to consumers.

The Australian Energy Market Commission (AEMC) has been consulting on a new Fast Frequency Response (FFR) service, which would see new assets, such as batteries, deployed and requirements on newly connecting generators to have the capability to deliver the FFR service. These services will eventually be

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needed, but it seems critical to first ensure that the existing assets we do have are functioning correctly, with correct settings, and that market arrangements (delivering energy) mean the technical and physical needs of the system take priority, since if the system fails (or struggles) delivering energy will not be possible anyway.

By ensuring that existing large thermal plant are using settings that allow them to respond automatically and rapidly to frequency events and that market signals do not override the requirement to support the physical system, we can deliver a stable and secure system at lowest cost, without the premature introduction of new services.

New services, such as FFR, will be needed in the future and we should take the opportunity to use and understand how these new approaches will impact on *our* system now (as opposed to their current operation on other international systems), ahead of need, so that we can specify and procure exactly the service we require.

Response

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?

The "Energy Trilemma" has been well-stated as the need to deliver secure (reliable) low carbon energy at lowest cost, but it is extremely challenging to deliver a three variable problem successfully. It is politically undesirable to have security of supply issues, so security is often non-negotiable, the absolute "must have" of the trilemma, which means trying to tweak the desire for a low carbon (sustainable) energy system against cost. Rising energy prices are also politically undesirable, since consumers do not want to spend more on energy. Both security of supply and energy price are directly linked to votes. Leaving a single variable, reduction in carbon emissions, which is often left unaddressed or scaled back, even in the face of international and national requirements.

This has been seen in the UK ("green crap", David Cameron, PM, November 2013) and in the expansion of the coal industry in both Australia and the USA. The UK, with the Climate Change Act, and binding national emissions targets, has resolved to work again on addressing emissions, with the announcement in November 2015 of the closure of all coal plants by 2025. This is not without challenges and has resulted in the creation of an expensive Capacity Market to ensure security of supply in winter.

Getting a balance between the three variables would be incredibly difficult, even without political motivations and success only seems possible if climate change mitigation is the primary focus, along with a great deal of well thought out planning and strategy (e.g. DS3 Ireland). In the absence of planning the electricity system, policy, market arrangements and system development are all reactive and responsive and likely to lead to higher costs, than a well-coordinated approach that allows the efficient deployment of assets. This is why calls for a "System Architect" in the UK has been so strong (http://www.theiet.org/factfiles/energy/brit-power-page.cfm) and the Finkel Review calls for a "strategy" to deliver the future secure and low carbon system at lowest cost.

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Security can be very expensive, particularly if a system is being designed to meet peak demand, which may only occur on a few days a year – this means an over-engineered and expensive system is delivered to meet relatively rare occurrences. For instance, should more wires and generation be built (at great cost) to ensure that on a hot day everyone can run an air conditioner set to 20°C (or what is currently deemed “comfortable”)? Or are there other ways to deliver “comfort” that are not dependent on an expanded network and increased generation?

And there are other ways, such as using electricity to create a cold energy store (thermal storage) for later use, education that helps consumers understand the impact of air conditioning settings on the ability of the energy system to be secure (e.g. 24°C versus 20°C), how the operation of an air conditioning system can be optimised (always running versus a big blast in the early evening) and better policies and standards around building design and construction (orientation to north, external shading and insulation/double glazing).

Australia has the tremendous advantage of having a solar resource that Is highly likely to be correlated to air conditioning demand, so if a household wants air conditioning, they should also be required to have rooftop solar PV generation. The issue is that we tend to turn on air conditioning as we walk into the house after work, at peak demand, rather than run the air conditioning constantly through the day to maintain a lower internal temperature, reducing the work that the system might need to do at the time of peak demand and maximum electricity system stress.

Security of supply might be more cheaply delivered by not being connected to the system/network, but through community micro-grids, incorporating elements of generation and storage. Long wires are not only expensive to maintain, but are the source of system losses of around 5-7%, since electrical energy is lost as heat as it travels through wires. Australia’s peak demand is 35-40 GW, which means that approximately 2 GW of electricity is lost as heat, or the electricity system requires a slightly more than a “Hazelwood” (1.6 GW) or a “Liddell” (2 GW) to cover that loss.

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

It is not possible to predict the future with any certainty, so flexibility is required, in approach and regulation, and rather than reliability and 100% security of supply, we need to focus on resilience.

We know enough about the impact of climate change already, to know that there will be challenges ahead for our electricity system.

Climate change has already resulted in more energetic storms, with intense winds and rain (South Australia, winter/autumn 2016). There have been droughts, which have already impacted on the ability of Hydrogeneration (Tasmania, summer 2015-2016) to meet demand. There has been an increase in maximum temperature, with record highs and persistent high temperatures resulting in difficulty in meeting air conditioning load and “load shedding” (South Australia, New South Wales and Victoria, Summer 2016/2017). Dry conditions increase the number and risk of bushfires, which are ignited by electricity networks and lightning will increase, increasing the impact of strikes on networks.

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Climate change is therefore already having an impact on our electricity system (and the electricity systems impacts on climate change) and as further adaption is required we will need to change how we deliver electricity and think about "security".

In Victoria, networks are required to disable reclosing (automatic reconnections following a trip caused by a fault on the electricity system) either completely for the fire system or reduce the number of recloses on a high fire danger day. This is because some reclosers (but not all) cause arcing, which can ignite a fire. However, disabling reclosing may mean leaving a community without the power they need to respond to a fire.

So rather than reliability and security we should focus on "resilience" or the ability of the power system or a smaller sub-section of the power system to recover after a problem. Faults will occur and climate change means weather related faults are likely to occur more often. It would be prohibitively expensive to create a 100% secure system. Singapore has one of the most reliable systems in the world, in a region of intense storms. This is largely because its networks are underground and so protected from the weather and falling trees, but undergrounding an entire system is expensive.

A resilient network, such as a microgrid (a small "island" that is self-contained and can be independent, within the wider and larger system), would recover quickly from the inevitable problems. A resilient system may not be 100% secure, but the impact of outages should be minimised and recovery should be quicker.

<u>What are appropriate standards for the security and reliability of the electricity system?</u>

Ensure that the frequency standard is appropriate and that plant are responding appropriately to a frequency excursion to minimise the impact on the system and hence the cost. The current interaction between the FCAS, particularly the allowed deadband settings and energy market requirements mean that frequency control in Australia is currently inadequate. The capability is there, but it has been lost through bad settings.

Security costs money. Loss of power costs money. Do we adequately understand in Australia what a loss of power really costs the nation (e.g. http://www.icecalculator.com/)? What level of power loss are customers prepared to tolerate? It will depend very much on the type of customer (commercial/industrial versus domestic) and at what time the loss might occur (peak versus non-peak). A commercial or industrial customer may need much better reliability and quality than a domestic customer and can chose to invest in technology (microgrid, battery, uninterruptable power, diesel generation, generation etc.) to deliver the desired security and quality. Domestic customers too may invest to improve their own access to secure electricity (e.g. behind-the-meter batteries coupled with rooftop solar PV). But there will be those who can't afford to invest and may end up carry a greater burden of the network costs as those that can manage their energy more effectively, reduce their demand and hence their contribution to the maintenance of the system. This is largely a facet of how we levy costs currently, but whether costs are socialised or not is a critical issue.

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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?__

The reliance on a high carbon grid may appear to offer lower electricity prices, but there are costs in terms of air quality, environmental pollution and health, aside from the issue of climate change.

The traditional approach of long wires and hardware may no longer be the most cost-effective way to deliver electricity to consumers. Some lines are exceptional long, bringing technical challenges as well as maintenance challenges and it may be that taking communities off-grid, but managed by a regulated network company (e.g. Western Power proposed rule change) will deliver secure electricity at more affordable prices.

Our networks are aging and electricity network assets typically last for 40-60 years, so we are at a point where assets are coming to the end of their natural life. Major investment is needed now and has been needed for some time, but the unpalatability of higher electricity prices for the consumer makes funding the very necessary improvements hard.

How we fund our networks needs to be reassessed, since a "demand" based (volumetric) funding of network assets is not appropriate as demand falls, due to improvements in appliance efficiency and distributed generation (which appears as a reduction in demand, since demand is met by local generation). The current charging approach means that the very real costs of investment in our future networks, falls on fewer consumers, some less able to pay than others.

As the infrastructure ages, it will fail. It is hard to predict where those failures will be, the magnitude of any one failure and its impact. But dealing with a failure after it has occurred (reactive mode) rather than a calm and planned approach, will be more expensive in the long run.

__What might be the role of new technologies in improving system security, reliability, sustainability, and affordability?__

A low carbon system needs a great deal of flexibility to support the intermittent source of generation. Flexibility can be delivered by some forms of generation (gas that can be ramped up a down), interconnectors, demand-side response and energy storage.

New technology and IT/communications technology will be instrumental in delivering the flexibility needed in the low carbon system, particularly through the provision of demand-side response and the use of storage. This flexibility could be fully automated through customer systems or via aggregator models and applies at the domestic and industrial/commercial scale. These responses could be related to tariffs (avoiding cost) or through new services (new income). There are as many new business models as there are ideas and it will be critical to ensure interoperability so that all consumers have choice about providers and appliances.

__What is the potential for new technologies to alter the inter-relationships between these objectives?__

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New technologies, such as batteries, may be deployed behind-the-meter in homes and on commercial/industrial premises or could be deployed at the community and utility-scale (perhaps in partnership). 200 5 kW batteries aggregated together behind-the-meter in homes are not directly equivalent to a single 1 MW (1000 kW) community or utility-scale battery. The latter allows for economies of scale, can be maintained and managed by qualified engineers, on safe sites, gives priority to system support and can access or provide many more services, so earning a greater income and reducing overall costs further.

Additionally, Australia has developed forecast for solar PV generation to help with managing the networks and market. Solar PV panels on their own produce generation that is largely dependent on weather and cloud cover, which can be modelled and forecast. Even rooftop panels, with some degree of self-consumption, can behave predictably. However, by introducing a battery behind-the-meter, with no visibility to the network or market and no requirement to communicate its state of charge, the battery will negate forecasting, making it harder for networks to manage their systems and harder to predict export of generation of when demand (no longer met by solar or the battery) will increase. These complications will make it more expensive to run the system overall.

Solar thermal or the production of heat and hot water from the sun, seems very overlooked in Australia, even though (dependent on state or territory) the spending on hot water and heating can be the most significant part of a consumer’s bill. (60-80%).

Appliance standards that support energy efficiency and interoperability to allow “smart” operation, either to maximize the self-consumption of rooftop solar PV generation or to provide demand-side response, is critical.

Building design and standards are also important. Homes should be well-insulated to provide comfort in both the heat of summer and cool of winter. They should be designed to address passive principles, while not needing to be “passiv houses”, with shading in summer and exposure to winter sun. If air conditioning (cooling) is required, then it should be linked to supporting solar generation. Understanding how to sue the thermal mass of a building to act as energy (cool and heat) storage will reduce demand at critical times.

Technology can support behavior change and while change is at an individual level, community action is a great support and driver. Communities should be empowered to take control of their own generation, storage and demand, engaging them directly in their energy use and addressing climate change.

A number of Regulator-funded innovation projects have shown that by providing consumers with access to their own consumption data (energy use) on reasonable time resolution, particularly if associated with a cost to use at that time, results in a 7-10% reduction in peak demand. Technology has a critical role in engaging consumers and communities with energy.

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

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The development of the grid has to be flexible and regulation and policy have to recognise the need for flexibility (not "one size fits all"), while accommodating rapid change and things that we can't predict. Regulation and policy tends to be rigid, which is not conducive to new approaches and this is not restricted to Australia.

Electricity storage is an area of growing interest and rapid deployment with some nations choosing a very hands off approach to regulation (e.g. USA) by allowing innovation, with careful observation to ensure no competition infringements, versus considering a license and regulation (UK and Europe). Progress seems more rapid in the USA, but this is because new services have been mandated that are favourable to the technical capabilities of storage, plus specific mandates and incentives for utility-scale storage. The rise of storage is directly related to increasing intermittency, as storage likes problem-plagued systems.

The adequate management of frequency is also key to delivering security with increased connection of intermittent generation. Both the balancing area of Texas and California have tightened their deadband requirements to more tightly constrain frequency in the face of increasing intermittent generation.

Australia's electricity system is very focused on the "stick", rather than the "carrot", that is, there are more penalties than there are rewards and rewards could be in the form of new services/income streams, rather than fines.

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?

The model of funding network operation and investment based on a consumption levy is outdated. As demand decreases, the increasing system costs fall on fewer people, who are likely to be those who are unable to unwilling to invest in new technology such as solar PV generation. However, total grid defection is unlikely. The traditional networks and suppliers are still likely to be needed as "last resort" and so a fairer way of paying for our networks is needed.

Time of use tariffs that reflect the true cost of using the system, for both demand and generation, may have an impact on how and when the system is used and while Europe has recently included amendments to the Third Energy Package, that would expose all users to the full wholesale energy price and system costs, this is likely to be complex. Trials in the UK have shown that customers are willing and able to respond to price signals, but that only relatively simple tariffs are needed, rather than "real time" tariffs. However, time of use tariffs can result in rebound and shoulders in demand, that while shifting demand, may move it a time that is less palatable to the network or result in continual adjustments to tariffs to drive desired behaviour.

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

There appears to be little coordination between State and Federal energy policies. This would be fine if each state energy system was a disconnected island of its own, but the NEM is interconnected and so the actions in one state will have an impact on connected states. This push and pull between States and the Federal Government is very unlikely to deliver a secure, low carbon system at least cost to all Australian consumers. This can only be achieved through coordinated and planned national action.

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Broadly, the regulation and governance of the grids in Australia is good, but it is complicated by national entities seeming to be on the back foot with State Government actions (e.g. State Governments unilaterally deciding to build their own batteries and backup generation). It is not immediately clear whether the State or the energy system regulator/operator have control and this is further tension in the already complicated State-Federal relationship.

In countries with clear regulation and system operation progress to a secure, low carbon electricity system at lowest cost is on track, even in the single island system of Ireland-Northern Ireland, with two Governments, two regulators and two system operators, there is more clarity and forethought than in the Australian system.

What opportunities are there for consumers to benefit from the modernisation of the grid?

A low cost system will not be delivered without the full support and participation of consumers. Consumers of all sizes will need to engage with their energy use, which may encourage them to create their own energy (become generators) and think about how they use their energy. This could be facilitated through tariffs or new services.

Care will be needed to ensure the domestic consumer is protected and treated fairly and community-based projects may deliver economies of scale, that individual or single households will not.

How can we ensure that these benefits are able to be shared equitably by all consumers?

Appropriate network charging and tariffs are needed, with the development of income streams for system services, which allow consumers to participate either directly or through aggregators. The cost of the networks represents a significant proportion of bill that all have to pay and it typically based on a consumption levy – the more you use, the more you pay. However, as local generation and behind-the-meter battery deployment increases, self-consumption is likely to increase, minimizing import and the opportunity to levy a cost on demand. Solar PV generation and domestic scale batteries increase the cost of operating the network. This will mean that fewer consumers will pay more of the increasing costs and often it will be the consumers less able to invest in generation (and/or batteries) that will be penalised. Network charging is currently under review in a number of countries, including the UK, for just this reason.

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

A willingness to be involved and to change behaviour. Electricity demand can no longer be passively received, but demand will have to change to meet generation/supply.

Fears related to the very technical nature of electricity and the changes that are coming (e.g. smart meter resistance, although not so great as in other countries).

Communities and consumers will need to fully understand why our system needs to change and what their role can be. If the changes are imposed, then acceptance will be poor.

What options are there for addressing geographical barriers to achieving a truly national grid?

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Do we need a truly national grid? Is a national grid the best way to deliver a low cost, low carbon and secure system? Instead of running long, long lines that lose energy, in a futile attempt to connect everyone to a national system, we need to embrace the vast geography and independent spirit of Australia and create islanded grids or microgrids that allow communities, with the support of their network operator (who has the technical skills and expertise), to make their own energy (electricity, heat and cold), store and use it, perhaps even trade it locally in local markets, rather than in national markets.

These smaller grids could be interconnected, where practical and cost effective to share resources and provide wider support.

This is a major change to the centrally operated generation trickling to the bottom of the system, but it empowers individuals and communities to engage with energy creation and use.

Community energy and microgrids do not, however, mean that there should be no national system operator or national regulation. Uniform standards will still be required and central coordination and management of the entire system will be needed.

3. International experiences and examples of electricity grid modernisation in comparable jurisdictions.

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

Many of the issues Australia faces in decarbonising its energy systems are global, however responding to these issues is complicated by the multi-level interactions needed between Federal and State Governments and the interactions between these parties and the Regulators and Operators. There is great tension in all relationships and sometimes responsibilities are not immediately clear and as a result there is no clear leadership and no clear direction.

Australia’s electricity generation is still incredibly high carbon in an environment that is already having to adapt to climate change, but also has the benefit of significant renewable resources. Australia has been slow to grasp the opportunities of low carbon generation.

Australia’s geography poses both challenges and opportunities and solutions from other locations may not be applicable, for instance, does Australia need to be fully interconnected? (see above question on achieving a truly national grid).

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

Australia has not moved as far forward as might have been expected with deploying renewable generation. This is largely for political reasons, but now finds itself lagging behind, when at one point, particularly for wind, it was a world leader. Given the short parliamentary terms in Australia, a steadying influence is needed to ensuring that Australia meets international commitments to reduce emissions. An independent body, like the UK Climate Change Committee, with the power to set strategy / carbon budgets and independently assess Government policy (Federal and State), would provide some certainty and impetus to decarbonisation.

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Australia, more than any other nation, bar the small islands of the Pacific, is harshly impacted by climate change and climate variability (e.g. El Nino / La Nina), leading to issues in the power system, problems with food production and bushfires. Water supply is becoming an issue too and yet, action on tackling climate change locally stagnates, alongside attempts to run down Australia's world-leading atmospheric and marine science.

Australia has fantastic renewable resources in solar, wind and tide and it should be leading the world in deployment and exporting technology and skills globally.

Australia has discovered electricity storage only because of system problems, but should be thinking more broadly about energy storage, particularly the storage of heat and cold and should be actively considering solar thermal for the production of hot water and heat.

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

Networks are working hard within their budgetary determinations, but if Australia truly wants a modern system then investment is required and the regulatory and political constraints on spending are unlikely to deliver the required future system.

Australia's generation fleet is overly reliant on coal, when many other systems have moved to gas, which produces much less carbon than coal (gas is typically produces two thirds less carbon than coal and is more efficient at producing electricity per CO_{2eq} emitted). However, gas supply in Australia is complex, but a transition away from coal is urgently needed.

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

Ireland-Northern Ireland DS3:

Northern Ireland has a target of providing 40% of electricity via renewable sources by 2020 and Ireland has a target of 16% of energy consumption to be meet by Renewable sources by 2020. In order to achieve these targets the single energy market operators of Northern Ireland and Ireland have responded by setting up a suite of 14 new system services (http://www.eirgridgroup.com/how-the-grid-works/ds3-programme/ and http://www.soni.ltd.uk/Operations/DS3/) to support the delivery of those targets at least cost, while ensuring security.

UK:

The UK Regulator, Ofgem, and the Department of Business, Energy and Industrial Strategy is the middle of a Call for Evidence on "A Smart, Flexible Energy System" (https://www.gov.uk/government/consultations/call-for-evidence-a-smart-flexible-energy-system). A strategy was expected in May-June 2017, but it is unclear how the call for an election will affect that timetable.

There has been a great deal of work in the UK by the Transmission System Operator, with the Future Energy Scenarios (http://fes.nationalgrid.com/) and Power Responsive programme (Demand side: http://powerresponsive.com/), reports from the National Infrastructure Commission (https://www.gov.uk/government/publications/smart-power-a-national-infrastructure-commission-

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report) and the Carbon Trust (https://www.carbontrust.com/resources/reports/technology/energy-storage-report/), plus the very broad work of the Department of Energy and Climate Change (DECC) and Ofgem Smart Grid Forum (https://www.ofgem.gov.uk/electricity/distribution-networks/forums-seminars-and-working-groups/decc-and-ofgem-smart-grid-forum).