THE
Frontier Line

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Network level challenges facing Australian renewables

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Martin Thompson is a Senior Consultant at Frontier, having joined the firm as an Associate in 2009. Martin provides consulting support to a number of clients and undertakes investment and manager research. Prior to joining Frontier, Martin worked at Starfish Ventures, an Australian venture capital fund manager focused on high growth life sciences, information technology and clean technology companies. Prior to this Martin has worked in technology commercialisation at the University of Melbourne, virology research at Murdoch University and undertook a PhD in cancer research at the University of Western Australia. Martin has a Master of Applied Finance through Macquarie University, a PhD in Molecular Cell Biology and a Bachelor of Science with first class honours.

Introduction

The Australian electricity system has experienced significant disruption in recent years, driven by a rapid buildout of new renewable energy generation capacity, particularly wind and solar generation. This has caused several issues for the system as the national electricity grid (comprising transmission and distribution networks) was designed to accommodate traditional forms of thermal generation which have fundamentally different characteristics to wind and solar generation. This includes:

- Solar and wind generation being geographically dispersed, often concentrated or in abundance in remote locations;
- Being intermittent and providing unpredictable output, which creates additional challenges for balancing supply and demand; and
- Solar and wind generation not providing characteristics needed to stabilise the grid, unlike traditional generation.

These changes have manifested in several ways and have resulted in financial losses for several renewable energy investors. Key challenges include:

- curtailment of output due to constraints in grid capacity and stability;
- reduced revenues for electricity generated due to increased transmission losses (as measured by the "marginal loss factor"); and
- tighter technical standards for connection to the grid, which has meant additional costs and connection delays.

The solution to these problems is a redesign of Australia's energy network to account for increasing renewable electricity generation.

The Australian Energy Market Operator (AEMO) is implementing changes in this direction, albeit slowly. AEMO has been addressing the issues on an ad-hoc basis, but importantly it has also developed a forward-looking plan called the Integrated System Plan (ISP) which charts the way forward for our energy grid. Ultimately these changes need to occur as the energy mix in the 21st century will be very different to that of the 20th century.

The conditions of the past few years has meant that Frontier has taken a cautious approach to investments in the renewable electricity generation sector in Australia. We expect the risk-return trade-off to improve over the medium to long term given the need for energy transition to cleaner fuels. Over the shorter-term, risks are elevated, and investment selection and structuring are of utmost importance. Moreover, investors need to be alert to grid related issues and finding ways to protect against grid related risks. The disruption itself may also present investment opportunities, such as in distressed assets. The opportunity set will change over time and may lead to new investment segments such as battery storage.

The infrastructure managers that Frontier covers are across these issues and are positioning their portfolios accordingly. It is important that managers and investors are disciplined and have the expertise to select appropriate assets for the conditions; this will remain a key focus area for Frontier in our ratings process of new renewable energy investment strategies.

This is just the latest paper written by Frontier covering renewable energy and related sectors. Previous papers include "Renewable Energy: Don't be a Fuel" (130) and "Grid Scale Energy Storage" (131), which are available on the Frontier website.

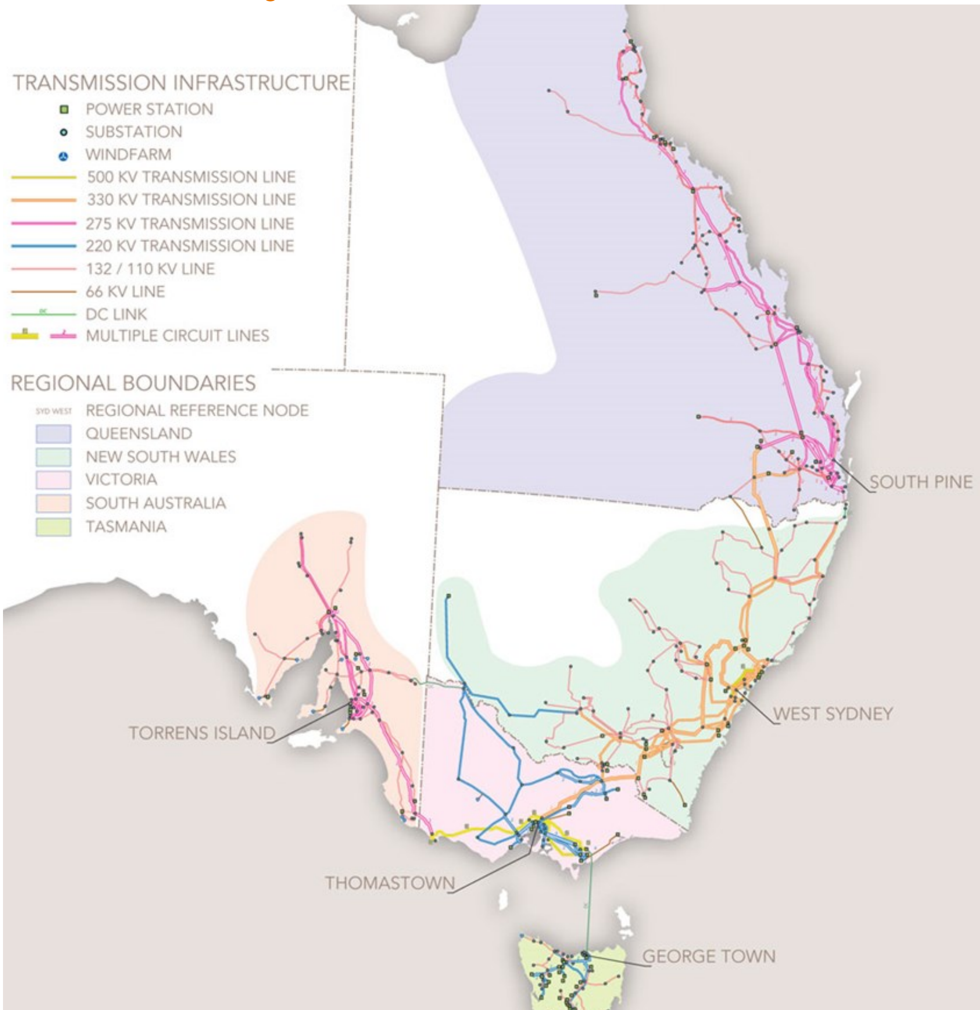
Overview of the National Electricity Market

The focus of this paper is the National Electricity Market (NEM), which is the electricity system covering the eastern and southern Australian states and territories, covering about 80% of all electricity consumption in the country. We will use NEM to reference both the market itself and the underlying infrastructure. The operator of the market is the Australian Energy Market Operator (AEMO). The underlying assets within the NEM are owned by a range of separate entities including generators, transmission network operators and distribution network operators.

The NEM was designed around large-scale traditional electricity generation sources such as coal, gas and hydroelectric generation.

This resulted in transmission networks being built to transmit energy between centralised sources of supply (such as large-scale coal generators) and centralised locations of demand (i.e. primarily large metropolitan centres). Any required grid characteristics were built into the network where this was not provided by the generators. The concentrated and coastal-based nature of Australia's population has resulted in a long, thin transmission network up the east coast of Australia (see Figure 1) and it is in fact one of the longest electricity transmission networks globally.

Figure 1: Transmission lines in the NEM



Source: AEMO

The National Electricity Market (NEM) is one of the longest and narrowest electricity grids in the world. The system was originally designed around large-scale thermal generation, but generation from renewable sources is increasingly becoming part of the generation mix.

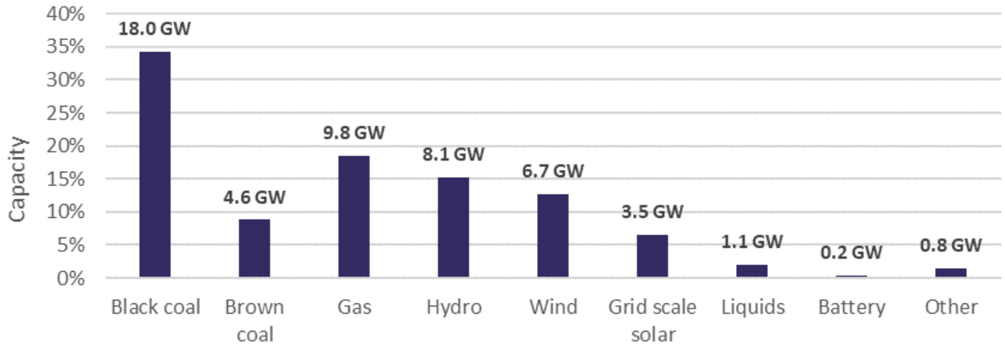
The peak electricity generation capacity of the NEM is around 57 Gigawatts (GW) which includes circa 9 GW of rooftop solar. Chart 1 shows the breakdown of utility scale generation by fuel source.

Chart 2 highlights the surge of investment in renewable electricity generation that occurred over 2017 and 2018. The fall in investment in 2019 is notable and is due to the limitations of the transmission grid and the resulting financial consequences for investors (covered in the following sections).

Small scale renewable energy generation in the form of solar generation on residential rooftops has also progressed at a rapid pace over recent years as highlighted in Chart 3.

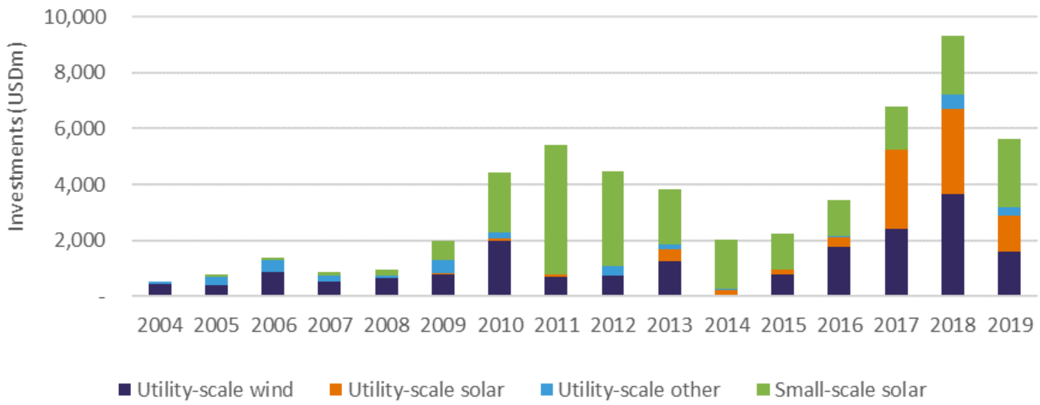
Australia now has the highest uptake of rooftop solar globally with over 21% of homes having installed solar panels.

Chart 1: NEM generation capacity by fuel source (utility scale)



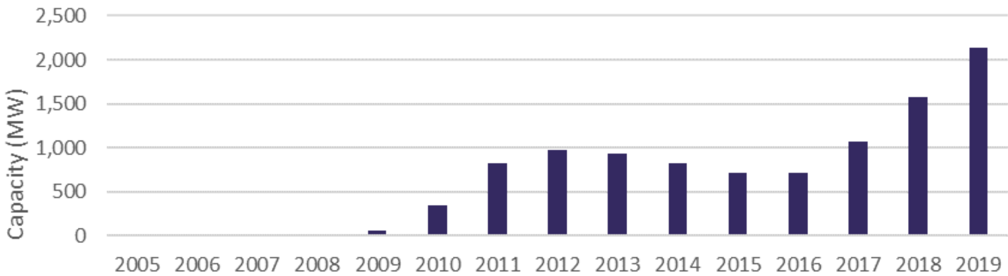
Source: Australian Electricity Regulator

Chart 2: New investment in Australian renewable energy capacity



Source: Bloomberg New Energy Finance

Chart 3: Small scale solar installed per year



Source: Sunwiz

Impact of increased renewable energy

The NEM was built around traditional forms of thermal generation that are largely predictable, centralised and dispatchable. Incorporation of distributed renewables generation into the network has resulted in numerous challenges for the system. These have been exacerbated by the rapid pace of renewable generation build out within the NEM.

Displacement of traditional generation

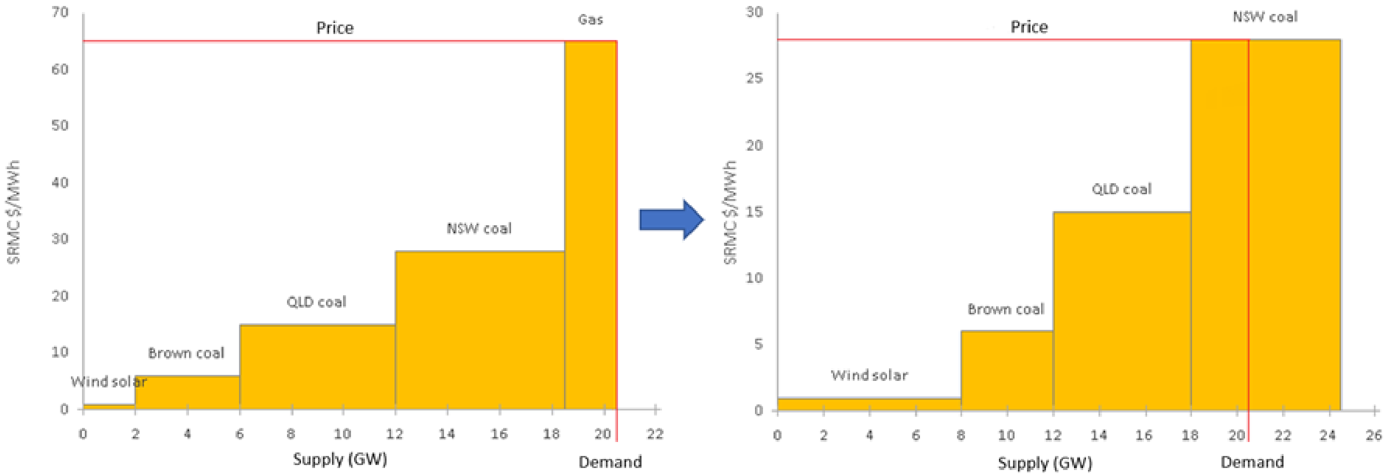
Electricity markets operate by estimating electricity requirements and then supply is dispatched from available generation. Dispatch commences from the cheapest source of generation (which is effectively one with the lowest cost to generate a unit of electricity) through to more expensive forms, until all requirements are met. The electricity price is then the cost of the last unit of electricity that is dispatched. How different generators are positioned in this marginal cost structure is called the merit order.

Because the marginal cost of generation from solar and wind sources is essentially zero (as the fuel source is free and can't be stored), wind and solar are typically dispatched before other forms of generation. The effect of this is to 'displace' - reduce the utilisation of more traditional forms of generation.

Chart 4 shows a theoretical example where an increase in solar and wind generation has displaced gas generation and a large amount of NSW coal generation.

Going forward, renewables will replace traditional forms of generation; total cost, including the capital costs of various renewable technologies are rapidly falling. Solar power is already cheaper than coal and gas in many jurisdictions. Much of Australia's coal-powered electricity generation fleet is old and will retire over the next two decades. Renewables are the most likely source of new generation to replace this retiring capacity.

Chart 4: Impact of renewables on the merit order



Source: reneweconomy.com.au

The rapid build-out of renewable energy generation in the NEM has led to several challenges for the system including the displacement of traditional generation due to the low cost of renewables, and grid stability and capacity constraints.

Increased variability of electricity generation

Solar and wind generation are variable forms of generation (production depends on sun irradiance and wind conditions), which has imposed additional demands on keeping supply and demand balanced in the NEM. This has meant a greater requirement for electricity generators that can modulate their generation (such as peaking gas and hydropower) and less for those that operate continuously (such as coal-based generators).

One potential solution to the variability of renewables generation is energy storage. At present this is mostly in the form of hydroelectric generation, but battery storage is becoming increasingly viable as the capital cost reduces.

Grid instability

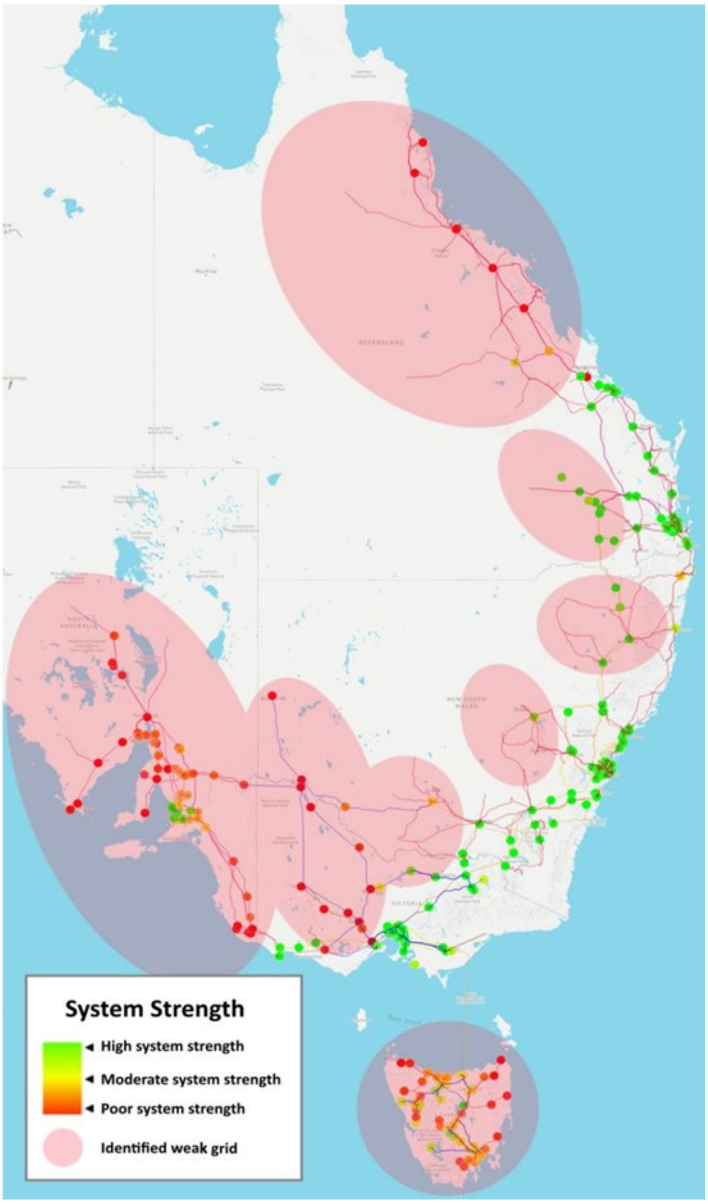
An electricity grid needs to transmit electricity to where it is needed within tightly defined parameters (specifically voltage and frequency). Stability refers to the ability of the system to keep these parameters within required bands when faced with disruptions over short time frames. Stability is also influenced by the "structure" of the network. The NEM's long and narrow structure makes it intrinsically less robust and less stable than a highly interconnected network, such as those in the US and Europe.

The increasing penetration of renewable generation in the NEM has had negative impacts on stability on parts of the system for several reasons: renewable generation often occurs in less stable parts of the grid; limited ability of renewable generation to provide stability; and displacement of traditional generation that provides stability.
Figure 2 shows regions in the NEM that AEMO has identified as having low system strength.

Grid capacity constraints

Specific transmission lines have a maximum limit on the amount of electricity they can transmit at a given point in time. Additionally, the closer transmission is to this limit, the greater the proportion of electricity losses for electricity generators located along that transmission line. Much of the wind and solar generation is on the fringes of the NEM where transmission capacity is low; capacity related issues have arisen due to these transmission lines becoming increasingly congested for part of the day (typically around mid-day when solar farms are at peak operation).

Figure 2: Identified and emerging weak grid areas



Source: National Transmission Network Development Plan, December 2018 (AEMO)

Key challenges for renewable generation in Australia

Curtailment of generation

Curtailment is the act of reducing or restricting energy delivery from a generator to the electrical grid. The three main reasons for curtailment of power are grid capacity constraints, grid stability issues and negative power prices. AEMO will direct curtailment to maintain grid capacity and stability when the system could be overloaded in a certain region (i.e. when supply exceeds transmission capacity), or to keep higher priced resources online (i.e. prioritise traditional generation that prove grid stability support). On the other hand, a project owner (generator) may also make an economic decision to curtail its output under negative prices.

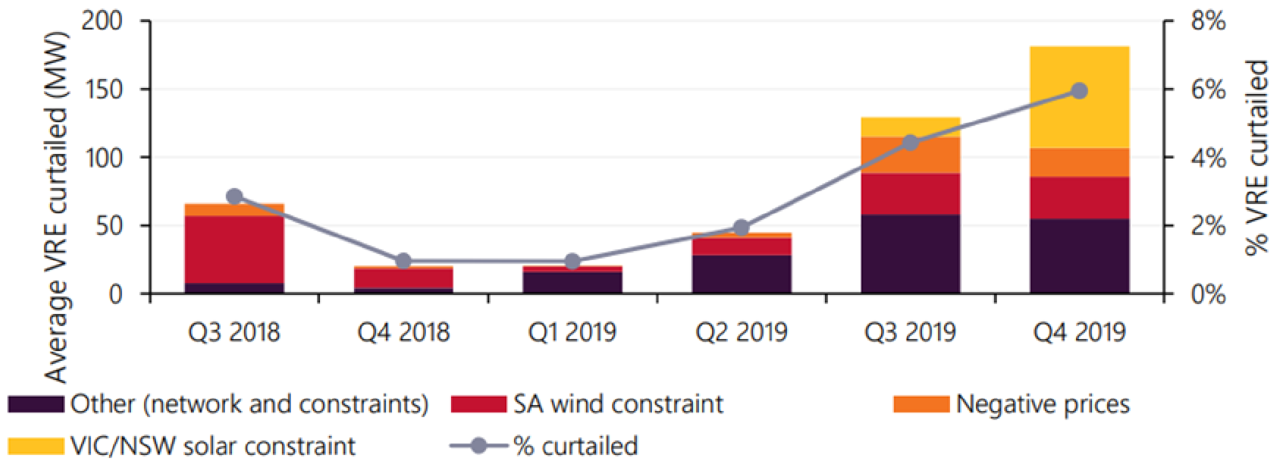
Curtailment of renewable generation means lost production and lost revenue for the generator.

Chart 5 shows the level of curtailment due to these factors over recent years in the NEM, demonstrating a clear increase over time; the SA wind constraint and VIC/NSW solar constraint are grid stability related, while 'Other' includes curtailment due to grid capacity limitations.

In the West Murray region, which spans across South Australia, Victoria and NSW, several operational solar farms have had generation limits placed on them (in the order of 50%) due to stability issues in the network. Other examples have included limits placed on renewable generators undergoing commissioning until grid stability issues are resolved, which can take many years. The cost of increasing stability in this case is borne by the generator, materially impacting project returns. Specifically, we see this as a shorter-term risk since AEMO may apply this curtailment at any time without prior indication or warning thus introducing a financial penalty for an investor.

Curtailment due to grid capacity constraints occurs where generation would exceed the safe capacity of transmission lines to transmit the electricity. The solution is to increase network transmission capacity. Battery storage is another solution, as it allows electricity generation to be shifted to when the grid is not congested. However, battery storage is costly, and its addition will likely make many projects uneconomical at today's prices.

Chart 5: : Average NEM Variable Renewable Energy (VRE) curtailed by curtailment type



Source: Quarterly Energy Dynamics Q4 2019 (AEMO)

Network related challenges have had negative consequences for renewables; a number of renewable generators have operated at reduced capacity (curtailment) or faced reduced revenues for electricity generated due to increased transmission losses.

Marginal loss factors

Marginal Loss Factors (MLFs) represent the value of electrical losses in transmission, from the source of generation to a regional measurement point. The amount of electricity lost during transmission is a function of physics; as electrical energy moves through the wires, some of that energy dissipates as heat in the atmosphere. The application of the MLF by the AEMO affects how much generators are paid for their electricity generation, with lower MLFs resulting in lower payments. Congestion of transmission lines is a key cause for reductions in the MLF. Hence, MLFs are reviewed annually by AEMO.

Renewable generation often occurs in remote locations with limited transmission capacity; where there is sufficient land available for wind or solar plants and strong natural resources (wind and solar irradiance). As a result of the rapid build out of renewable generation during 2016-2018, multiple new generation sites have been built in similar regions. Additionally, solar plants tend to generate simultaneously (in the middle of the day). All these factors increase network congestion and losses which in turn result in lower MLFs for electricity generators. An extreme example is Silverton Wind Farm in NSW where the MLF in FY19 was reduced to 0.83 from 1.01 the previous financial year. This will result in an 18% fall in payment for producing the same amount of power.

The reduction in MLFs has been stated as a key driver behind the reduction in renewables investment in 2019.

Tightening connection standards, connection delays and contractor insolvency

AEMO has been introducing a range of new requirements on electricity generators in order to minimise the grid related issues we outlined previously. These have included more detailed grid testing, more stringent new generator performance standards and installation of additional equipment. These changes have led to substantial connection delays and additional costs for several projects, impacting developers, contractors and equity investors.

One of the high profile cases reported last year involved the liquidation of the prominent Australian construction and engineering contractor, RCR Tomlinson, as a result of cost blowouts and delays across most of its 15 solar projects, the contracts for which bore the risks of on-time and on-cost delivery.

Another recent casualty involved the withdrawal of John Laing from the Australian renewable energy market, citing issues such as loss of revenue, project delays and additional expense to provide grid stability support.

Photograph courtesy of Powering Australian Renewables

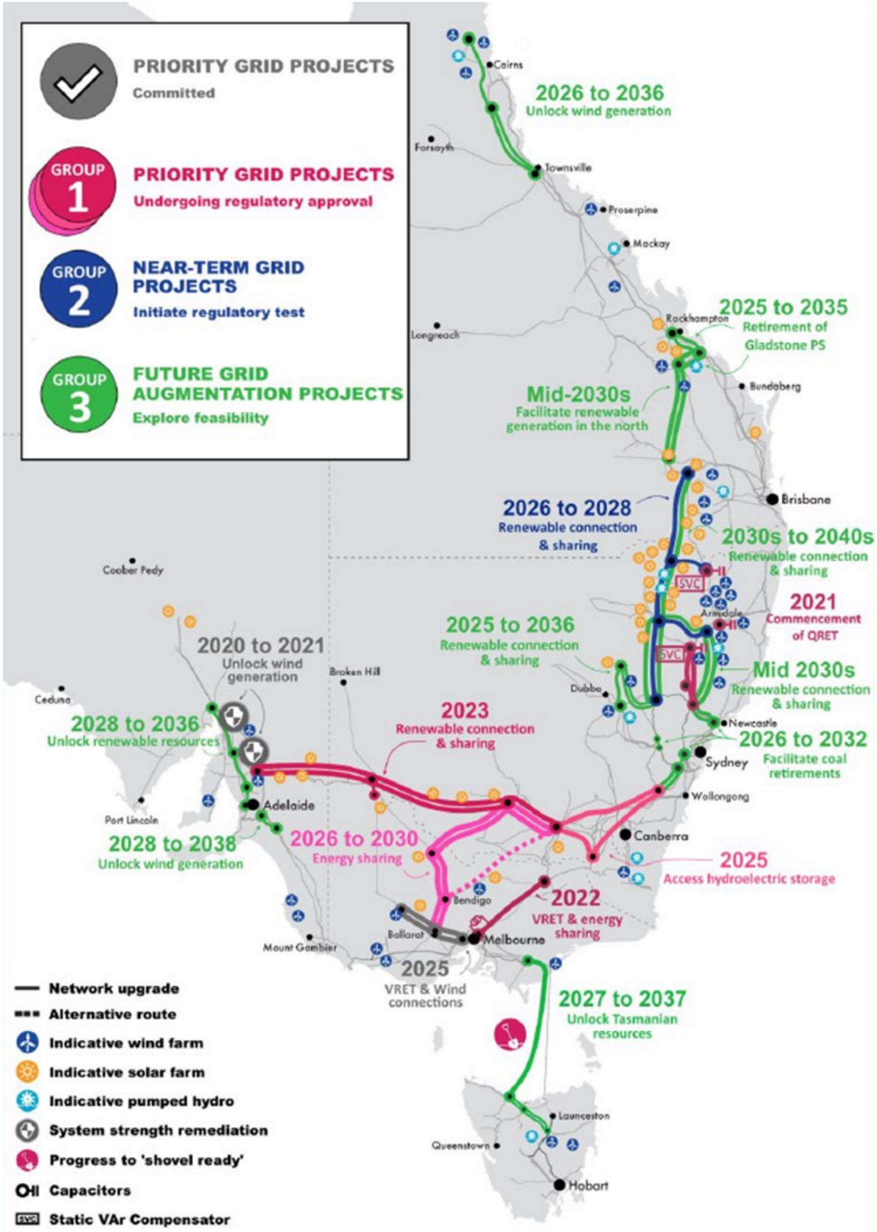
Solutions

The current challenges facing Australia's electricity system are complex and numerous. Not many comparable electricity grids globally have faced problems on this scale. Any attempt to solve the electricity grid related issues facing Australian renewable generation will need to utilise multiple mechanisms and technologies. In this section, we present a number of solutions that are currently being progressed.

Central planning

Given the level of change that needs to occur in the NEM, having a long-term plan considering the whole electricity system is necessary to optimise the overall outcome. Undertaking ad-hoc fixes to problems as they arise will not only be more expensive but may also lead to long delays before issues are solved due to the long lead time on most grid development. In order to address Australia's grid issues, AEMO has established the Integrated System Plan (ISP) which is a forward-looking plan for the NEM, outlining the development of the power system under various scenarios. Notably, this acknowledges that renewable generation will be a significant part of our energy mix in the future and identifies projects to strengthen and upgrade existing transmission lines, as well as additional projects to facilitate the build-out of renewable generation. Figure 3 provides an overview of some of the projects identified by AEMO.

Figure 3: ISP development paths



Source: Draft 2020 Integrated System Plan (AEMO)

Several solutions are underway to solve the issues being faced by the renewables sector. A key step has been AEMO's long-term plan for grid development, the Integrated System Plan.

Grid strengthening and reconfiguration

Strengthening and reconfiguring the NEM is necessary to account for the developing energy mix. Initiatives that are underway to achieve this include upgrading interconnectors between the states (e.g. Heywood Interconnector between South Australia (SA) and Victoria), and installation of synchronous condensers[1] across weak grid locations. It is worth noting that in some situations installation of synchronous condensers is at the expense of the renewable generator and can materially impact the project economics.

Government support/intervention

Government intervention and support can be beneficial to address some of the bottlenecks in the current regulatory processes. An example is the interconnector between New South Wales (NSW) and Queensland, which was underwritten by the federal and NSW governments, allowing the project to be advanced in parallel with the regulatory processes. Other areas of government support include new legislation to support development of the grid, such as the Victorian government's proposed legislation to fast track electricity transmission development.

The final word...

The issues outlined in this paper mean infrastructure managers and investors in the Australian renewables sector need to exercise caution and ensure they are across all the technical challenges.

- Grid stability and capacity constraints will need to be evaluated prior to committing to any project; suitable grid location should be the primary focus in the current environment (unlike in the past where much of the renewable energy development was focused on regions with the highest resource – wind or solar irradiance).
- Incorporation of technologies which mitigate grid risks, such as battery storage and synchronous condensers should also be evaluated in the project economics.
- For greenfield assets, the potential for connection delays and additional costs (required by AEMO to provide grid stability) needs to be factored in.

These are not insurmountable issues and other countries, such as the US have experienced and overcome similar challenges throughout their renewables journey.

Ultimately, a capable manager or investor should be able to account for, manage and adequately price these risks.

On the other hand, disruption faced by our electricity network can also provide opportunities; investments that enhance system security or manage power flows (e.g. financing behind-the-meter synchronous condensers and batteries), interconnectors between states (e.g. the EnergyConnect project between SA, NSW and Victoria), as well as improvements to existing electricity transmission lines, are already providing opportunities for investors.

In the medium to long term, the outlook for renewables in Australia is positive given the need for energy transition to take place and numerous government and AEMO initiatives underway.

It is important that managers and investors in the sector are disciplined, selective and have the expertise to select assets appropriate for the conditions. The managers that invest in Australian renewable energy, and that Frontier covers, are across the range of technical issues and are positioning accordingly, often drawing on their experiences in other regions. Frontier is monitoring a number of opportunities that are positioned to participate in the energy transition.

Frontier has taken a cautious approach to investments in the renewables sector in Australia. Opportunities exist, but asset selection is extremely important. We believe the medium to long-term outlook for renewables is positive given the need for energy transition to cleaner fuels to take place.

[1] A synchronous condenser is a device that connects to the electricity grid to help maintain voltage and frequency stability; two characteristics of the grid that must be maintained within tight ranges. This support for frequency stability (known as inertia) is one characteristic of thermal and hydropower generation that is not provided by wind and solar generation.

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