Benefits of Interconnector Upgrades in a Transforming Electricity Sector in South Australia

Clean Energy Finance Corporation

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Benefits of Transmission Upgrades in a Transforming Electricity Sector in South Australia

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Executive Summary

Technological innovation and climate change policies are casing a major transformation of Australia's electricity supply sector. The structure of the electricity market will need to evolve to allow for an optimal transformation. South Australia is at the forefront of this transformation with the highest penetration of renewable energy in Australia and this penetration level is set to increase. Further action to curb emissions or to increase uptake of renewable energy will accelerate this transformation.

In response to the call the ElectraNet for submissions into a new interconnector with NSW, the CEFC has commissioned Jacobs to provide insights into the potential role that enhanced interconnection to South Australia could play in a transformed electricity sector. The insights were gleaned from three recent studies conducted by Jacobs and AEMO, which had the aim of assessing the impacts of a range policies (under a range of targets) to reduce emissions. While the studies synthesised in the report were not intended to be a review of any specific interconnector, they do provide insights into the upgrades that would be required under a transformed market.

The studies had common features. First, they all examined scenarios where substantial emission reductions were required by 2030, ranging from 28% to more than 45% reduction from current levels. Second, the studies examined a variety of policies to meet the target a high proportion of the existing coal fleet was required to be retired by 2030 under all policies. Third, under most studies examined, interconnector upgrades played a material role in the transformed electricity sector.

The studies found that:

- For the emission targets examined, the entire brown coal fleet and some of the black coal fleet needed to be retired over the projection period.

- Retired coal plant were replaced with a mix of low emission plant, with the portion of new gas-fired and renewable energy required dependent on the policy deployed and underlying assumptions on emission reduction required, gas-prices, capital costs and demand growth. However, in most studies there was a high level of new renewable generation required, with deployment of new renewables required soon after the emission reduction policy is enacted (typically this was assumed to be 2020).

As far as the proposed interconnector with NSW is concerned, a range of benefits are possible and will no doubt be examined under a RIT-T. However, recent recommendations by COAG require the potential benefits under carbon abatement and renewable energy policy be examined as part of the RIT-T. In this vein, it should be noted that:

- Under most circumstances, there is likely to be further development of renewable energy projects in South Australia due to its high quality wind and solar resources. However, development of these resources will be limited by the ability to export power to other regions of the NEM

- Because of the increasing level of penetration of renewable energy, substantial further development could see a significant increase in the number of negative price periods and/or curtailment of generation from renewable energy. As several studies have already demonstrated, enhanced interconnection would minimise periods where generation is constrained.

- More generally, given the differing time profiles of generation across NEM regions, enhanced interconnection would see more trading of renewable generation across interconnectors. The high utilisation of interconnectors in other (overseas) jurisdictions highlights the importance of interregional trading.

- If more renewable energy is developed in South Australia, the financial viability of existing gas-fired generation would be more at risk than with the absence of augmented interconnection. With the declining surplus of coal-fired capacity in the NEM, enhanced interconnection would allow mid merit gas-fired plant to improve utilisation and sustain financial viability.

- Improve the reliability of South Australia electricity supply by building in additional redundancy (allowing imports during an outage of one of the interconnectors).
- Reduce price volatility in South Australia both on the wholesale electricity market and on the FCAS market, reducing the incidence when prices diverge from levels in the rest of the NEM

Although the analysis points to the potential benefits of the enhanced interconnector capacity, further analysis to confirm the benefits will be required.

1. Introduction

The electricity sector is undergoing a transformation. The drivers for this transformation include a move towards renewable generation, uptake of a greater diversity of supply sources and increasing levels of embedded generation. Uptake of additional renewable generation as part of the federal LRET scheme and perhaps as part of State based targets as well as moves to reduce emissions of greenhouse gases will see this transformation continue. In South Australia, this transformation has already commenced with the State having the highest penetration (as a proportion of underlying demand) of renewable energy.

The structure of the electricity market will need to evolve as the level of distributed generation increases, including developments in network services. In this paper, we explore the role that interregional interconnectors could play in the transformed market in South Australia and the rest of the NEM.

The analysis draws upon the results of recent published studies which have examined the likely nature of the transformation in a carbon constrained world. The recent analysis will be used to provide some insights into the potential role of interconnection, with a focus on how enhanced interconnection to South Australia could benefit the South Australian region and the rest of the NEM.

South Australia’s electricity market is currently characterised by:

- Large-scale renewable energy capacity currently operating of 1,500 MW, mostly wind generation.
- Installed solar PV capacity at the end of December 2016 of 695 MW.
- Peak demand representing around 3,210 MW (on a 10% probability of exceedance basis), with average demand of around 1,550 MW and minimum demand of around 850 MW.

The analysis in this paper is not intended to be a full benefit-cost evaluation of the upgrades of interconnection. We understand ElectraNet will undertake a full RIT-T for three options for interconnection with the NSW grid. Rather the aim in this paper is to provide insights into the role of the proposed upgrades into South Australia in facilitating the longer term transformation of the sector and to discuss the potential benefits in a market that has high levels of renewable penetration and highly distributed generation systems.

2. Transformation of the electricity market

In this Section some of the trends leading to the transformation of the electricity sector are briefly discussed. The implications for interconnections are also outlined.

2.1 Policy development

Australia has ratified the Paris Agreement on Climate Change. Under that agreement Australia will commit to net zero emissions of greenhouse gases by 2050.

The Australian Government has promised to reduce emissions by 26% to 28% below 2005 levels by 2030. The Opposition promised in the last election to achieve a 45% reduction by 2030. For the electricity sector, these targets are shown in Table 1. The government target would see emissions falling from the current 187 Mt CO_2e to around 144 Mt CO_2e. This reduction of 43 Mt CO_2e is equivalent to removing nine 600 MW black coal units from generation or removing the entire brown coal generation fleet with exception of Loy Yang B in the space of 13 years. Achieving a 45% reduction would see emissions reduce to around 108 Mt CO_2e or nearly 80 Mt CO_2e less than currently emitted.

Table 1: Targets assumed, Mt CO_2e

Item	Estimates
2005 Actual emissions	197
26-28% Target in 2030	144
45% Target in 2030	108
Emissions in 2030 to meet 2°C limit on temperature increase	60
2013 Emissions	187

Source: Analysis by Jacobs based on data provided by Department of the Environment (2015), *Australia's Emissions Projections: 2014/15*, Canberra (and previous issues).

The Federal Government has a number of initiatives to help achieve its target. For the electricity sector, the main initiative driving emission reductions is the Large-scale Renewable Energy Target Scheme. It is projected that meeting the target will require around 4,500 MW to 5,000 MW of additional renewable generation to be installed by 2020, with the bulk of this likely be shared between Queensland, Victorian and New South Wales. Under the current interregional network configuration, additional uptake in Tasmania under the LRET is likely to be limited to around 500 MW[1], with low local demand and limited export capacity on the current link constraining any further increases. Without further upgrades of interconnection with the rest of the NEM, uptake in South Australia will also be limited by the impacts that additional renewable generation will have on depressing South Australian regional prices at times of high levels of renewable generation (affecting their profitability).

Several States are investigating targets for renewable generation. The ACT Government has a legislated target of 100% of the Territory's energy needs. The Victorian Government is assessing a target of 25% by 2020 (not additional to the LRET) and a 40% target by 2025. The Queensland Government is reviewing a target of 50% (of energy generation) by 2030. South Australia is also considering increasing its target for renewable energy of 45% of total generation (which it has largely met) to 50%.

If all the State schemes proceed, the total portion of renewable energy in the NEM in 2030 will be around one-third of total grid based generation in the NEM[2].

More stringent targets to reduce emissions of greenhouse gases would require even more low emission generation. A recent study conducted for the Climate Change Authority modelled a target that limits emissions

[1] This is determined by taking the deficit in demand (10,500 GWh after roof-top PV is deducted) and potential net export across the cable of around 1,200 GWh and deducting existing renewable generation in Tasmania (9,000 GWh long term average output for hydro and about 1,000 GWh for existing wind). New wind farm capacity required to meet this gap was determined by using a capacity factor of 38% for new wind farms.

[2] This does not include the contribution of embedded renewable generation such as roof-top PV.

so that global temperature rises are less than 2° Celsius. In order to meet this target, emissions had to fall to around 60 Mt CO_2e by 2030.

2.2 Technological and social trends

A number of key trends are emerging within the NEM that will impact on the economics of interconnections.

The first trend is flat demand growth. AEMO's most recent projection has (grid-based) demand remaining flat for the period to 2035 but new loads may change the trajectory. There is also the prospect of major industrial loads closing their operations, particularly for aluminium smelting.

The stable demand has a number of implications for development of transmission interconnection. On the one hand, stable demand could mean there is no need to build new infrastructure. But on the other hand, differences in interregional prices at times of high or low local renewable energy generation could create an incentive for interconnection to close the gap in prices. If large loads leave the market, there could also be a need for generators in the affected region to export generation from surplus capacity.

Technology development is also proceeding in somewhat uncertain direction and rate. The cost of large-scale solar PV generation has fallen dramatically to the point where this generation is becoming more competitive with other renewable alternatives. But wind generation technology has also developed and recent tender prices for wind generation has seen falls in its cost, principally due to improved energy capture (leading to improved capacity factors). The latter development is opening more sites to the possibility of wind generation. However, different regions will have differing qualities in wind and solar energy resources and capturing lower cost resources may require transmission upgrades and radial extension of the existing network into new areas.

One development that may compete with interregional transmission development includes the development of energy storage. With large scale adoption of storage, surplus energy within a region could be stored for later use rather than being exported to other regions. There are around 200 MW of storage projects proposed for South Australia, including battery storage (in conjunction with solar PV projects) and an off-river pumped hydro storage project proposed for the Eyre Peninsula. Whilst there is room for some storage capacity, an issue is at what level of storage the market could sustain before the energy arbitrage margin is diminished. Usually margins between energy purchase price and energy discharge price would need to be high enough to cover operating costs plus expected returns to the investment.

The role of major transmission systems could diminish in the future with the development of embedded generation and micro-grids. Certainly uptake of embedded generation, principally roof-top PV has continued with just over 5,000 MW of roof-top PV systems installed Australia wide, and around 4,500 MW in the NEM regions. Based on current trends, uptake is predicted to continue growing at around 600 MW, to reaching around 19 GW by 2035[3].

However, even with this uptake[4] a large amount of energy would still be supplied through the grid. Currently embedded generation accounts for around 10% of total capacity but it is projected to increase to over one-quarter of total installed capacity. Even with this degree of uptake, grid based demand is still projected to be high. It is worth noting that the flat demand projected by AEMO in its neutral scenario, has grid based demand at around or just above current levels even with the projected uptake rates for roof-top PV systems. For example, even with the installed capacity of embedded generation currently around 10%, the contribution to reducing grid based energy is still only around 3% of total energy demand.

The uptake of embedded generation may actually enhance the role of interconnectors. One impact already being felt is that the embedded generation is reducing daytime loads, leading to a shift to a later afternoon or early evening peak. In accordance with the overall decrease in demand over the period 2009 to 2015, an irregular decrease in average hourly demand has been observed over the years across the NEM. On an average hourly demand basis, demand has decreased by 7% overall, and by as much as 10% during the middle of the day. Average demand during peak afternoon period of 6:00 PM to 10:00 PM has decreased by

[3] Jacobs (2016), *Projections of uptake of small-scale systems*, report to the Australian Energy Market Operator, June
[4] Achieving this level of uptake would mean that nearly 60% of residential premises would have installed systems.

less than 6%. The loss of the off-peak hot water heating load accelerated during the carbon pricing period of 2013 and 2014 which made the overall load profile less well matched to base load thermal power generation and has increased the value of energy storage and interregional power trading in non-peak periods.

Figure 1: Average hourly demand across South Australia and Victoria

The change in load profile will have different repercussions on the wholesale price of electricity, with price decreases in the middle of the day, when solar generation is occurring and leading to a shift in the peak price period to the evening. This price pattern may limit the uptake of solar PV unless sufficient large scale storage or more interconnection is developed to soak up the high levels of generation from solar PV during the middle of the day. As shown in Figure 1, South Australia peak demand period has shifted to the evening times when solar PV generation is diminishing. If wind generation is low during the evening period and with limited interconnector capacity, then pricing would tend to be set by local gas-fired generation, leading to high prices during these periods

It is likely that a grid based system with more interconnectors will be required even if the cost of electric battery energy storage falls rapidly as such devices are not currently suited to energy storage over a yearly cycle.

2.3 Role for renewable generation

Analysing recent trends and developments as well as some of the insights from various modelling studies it is likely that renewable energy generation will play a more prominent role in the future. Some insights include:

- Another 4,500 to 5,500 MW of capacity will be required to meet LRET target. Recent modelling has found that some 5,500 MW of new renewable generation will be required to meet the proposed Queensland 50% target[5], all to be developed next decade. And the Victorian target could require around 5,400 MW of additional renewable generation[6]. If all schemes proceed, some 16,000 MW of new renewable capacity will be required over the next decade.

  Even more will be required if the Australian Government imposes policies to meet its emission targets. Based on work undertaken for the Energy Networks Association[7], without the two state based renewable targets, meeting the 28% target will require another 5,000 MW to 10,000 MW of new renewable generation with the actual amount depending on the structure of the abatement policy. An additional 22,000 MW to 25,000 MW would be required if the 45% target is adopted.

- There will be diversity in the location and type of renewable energy developed. Although the Victorian and Queensland targets will likely see more renewable generation in those States, meeting the LRET target

[5] See Queensland Renewable Energy Expert Panel (2016), *Credible pathways to a 50% renewable energy target for Queensland*, Draft Report, October (Figure 22, page 68)
[6] Victorian Department of Environment, Land and Water Planning (2016), Victorian Renewable Energy Auction Scheme: Consultation Paper, 2015, page 2
[7] Jacobs (2016), *Australia's Climate Policy Options: Modelling of Alternate Policy Scenarios*, report to the Energy Networks Association, August.

could require generation to be more dispersed[8]. However, the size of the requirement will likely mean that most of the generation will occur in the Eastern States. The location of this generation will be in part determined by regional export opportunities – if there is a limit in export capability then there will be a limit to the development of renewable generation in some regions in the near term. This limit is already becoming apparent in South Australia.

- Following on from the previous comment, over the longer term the amount of renewable energy in any region is limited by the ability to export any generation that is excess to local demand
- The recent AEMO demand forecasts now show the minimum regional wholesale demand in each region which is expected to eventually become negative in South Australia by 2035/36[9].

In South Australia, although penetration of renewable energy is already high, there are a significant number of proposed projects:

- 320 MW of solar PV projects
- Around 5,970 MW of wind projects, although only about 722 MW are under active development.

It is unlikely that all these projects would proceed unless there is enhanced interconnection into the eastern seaboard regions of the NEM.

[8] Either because of intraregional transmission constraints or due to downward pressure on a region's price (relative to the prices in other regions) if there is a high proportion of renewable energy locating in that region.
[9] Table 9 at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEFR/2016/2016-National-Electricity-Forecasting-Report-NEFR.pdf

3. Potential benefits of enhanced interconnection

In this section, the potential benefits of a adding to interconnector capacity from South Australia to the rest of the NEM are examined. Currently there are two links into South Australia – the Heywood interconnector, a 650 MW AC link from the Victorian grid, and Murraylink, a 220 MW HVDC link from Redcliffs in northern Victorian to Berri in South Australia.

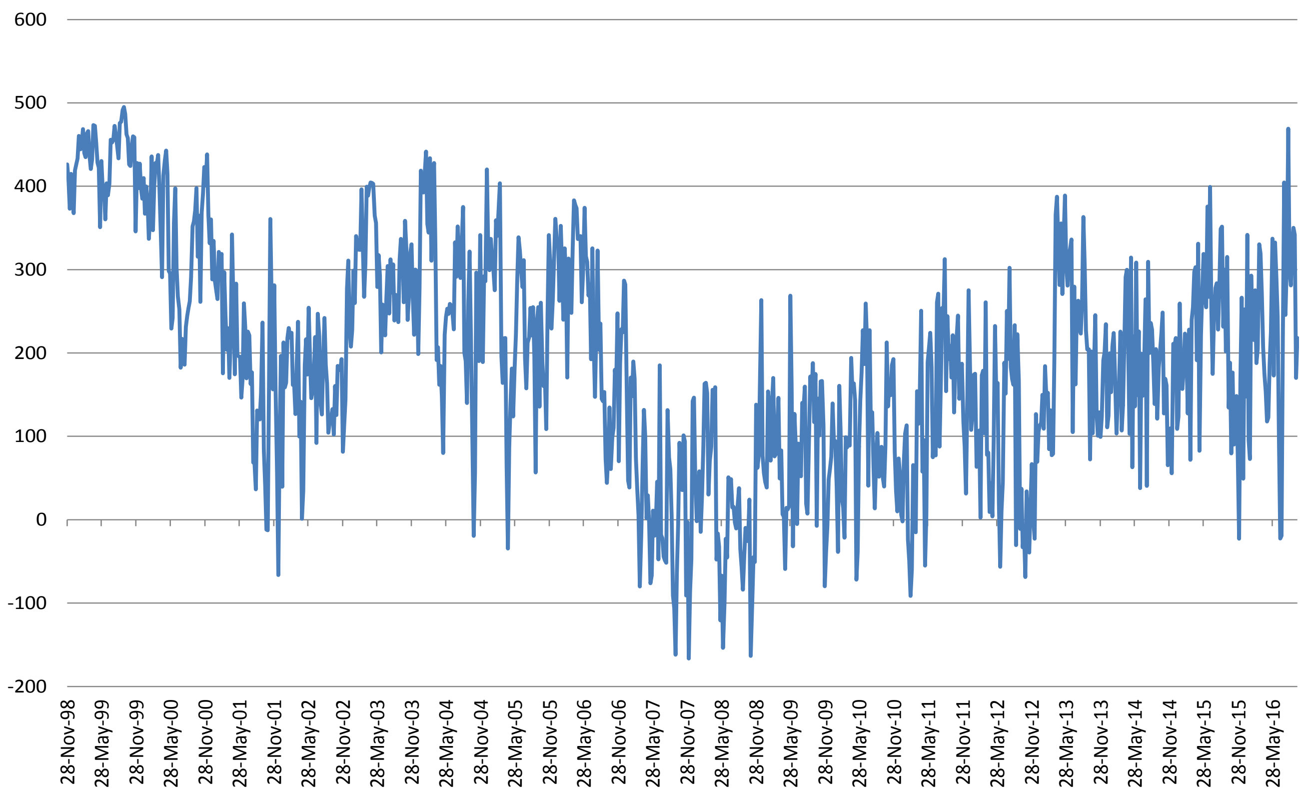
ElectraNet is examining options to upgrade the interconnector capacity, with a link from the South Australia to NSW. The benefits of enhanced interconnection are derived from the otherwise unrealisable potential of further development of wind and solar PV resources in South Australia to support decarbonisation (especially given the high quality of South Australia's underdeveloped renewable generation resources compared to the marginal resources elsewhere in the NEM) and the diversity of renewable generation resources between South Australia and the eastern seaboard of the NEM which will allow some sharing of renewable energy across the regions.

3.1 Market benefits

Potential benefits of an enhanced interconnection for the South Australian market could include:

- Lower market prices. The second interconnector would reduce prices in a region with low generation resources and bring prices across regions more aligned. South Australia prices generally track higher than Victorian prices, but during periods of low inflow or when the import capacity is constrained, the prices could go well above Victorian prices as local gas-fired generation is required. Increasing the interconnection capacity would reduce this price difference and pass this economic benefit to South Australian power users (with lower prices) and Victorian generators (with slightly higher prices).

Figure 2: Flows across the Victoria-South Australia interconnection system



Note: Each point represents average weekly flows from Victoria to South Australia. A negative number implies average net exports to Victoria for that week. The interconnector capacity is being upgraded from 460 to 650 MW, with AEMO stating that it has been gradually increasing the capacity of the link (to 650 MW) since the commissioning of major works in July 2016.

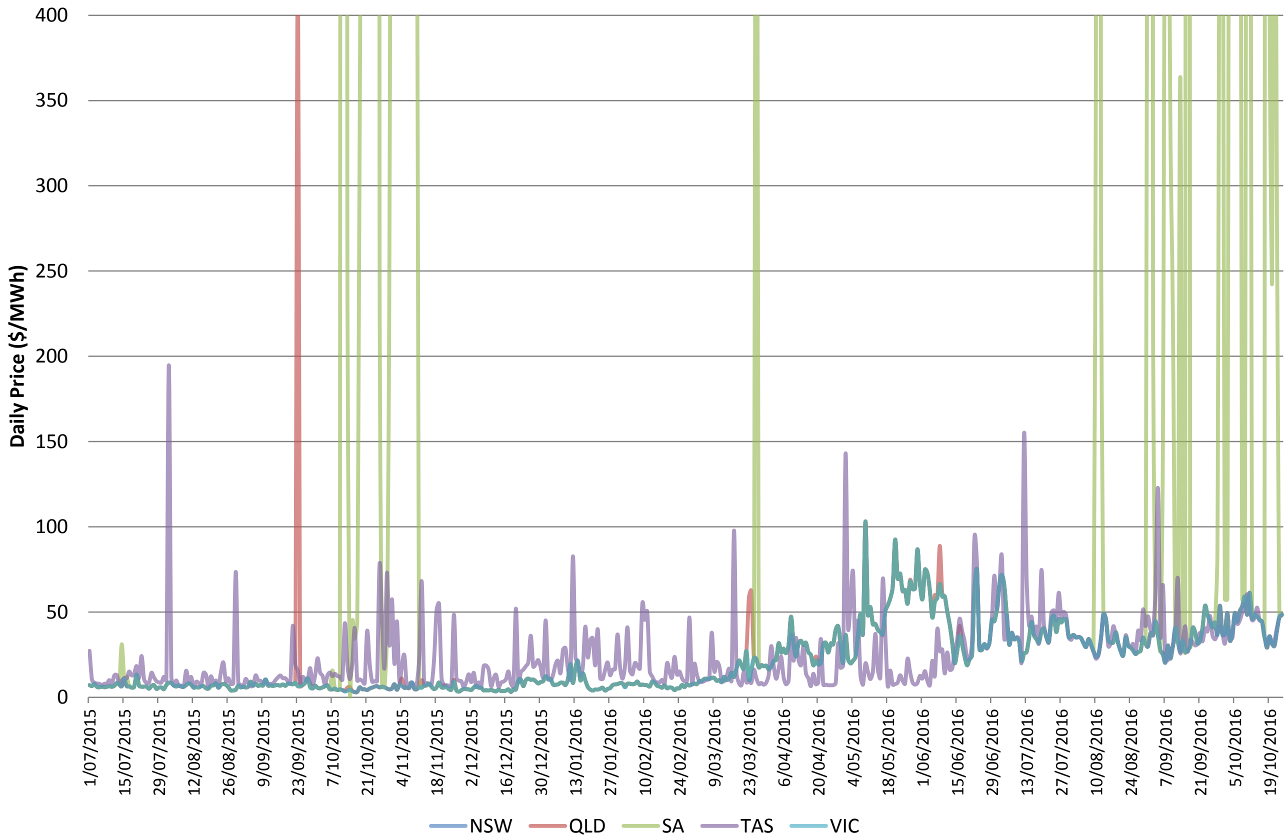
- Enhanced competition. Currently there are only two major generators in the South Australia region and when the imports into the region are constrained, then prices in South Australia could separate and there is the potential for an incumbent generator to bid in higher prices through strategic bidding. Strategic bidding has been cited as a factor for exacerbating recent price spikes occurring in South Australia during the outage of the Heywood interconnector. Estimating the extent of this benefit is very difficult in a RIT–T, as any higher prices often occurs when unforeseen events constrains available supply and it is difficult to disentangle strategic bidding from other economic or technical factors that may have led to higher bids.

- Improves supply reliability. Enhanced interconnection can cover for an outage of existing interconnectors (see Section 3.2) and provide additional firm capacity into South Australia when renewable generation levels are low.

- Reduces ancillary service costs. Enhanced interconnection would reduce the number of times South Australia is isolated requiring more expensive local FCAS services. The chart below shows how FCAS costs increase when the current interconnection capacity is constrained.

  Since July 2015 there have been some significant developments in FCAS price trends in Australia. Figure 3 shows the history of the daily average price of FCAS services in the NEM states. The prices shown represent the sum of all raise and lower FCAS prices, on a time-weighted average daily price basis.

Figure 3: Sum of regulation and contingency FCAS prices, July–October 2016



In the past, FCAS markets in Australia have been characterised by a low or negligible cost for the vast majority of dispatch intervals, with occasional brief price spikes caused by low-probability contingency events or constraints in energy markets. However, the minor price volatility in the past typically has not lasted for more than a few dispatch intervals, which is not enough to have a material impact on the market.

However, during the past year the volatility in some FCAS markets has increased, particularly in the case of South Australia. In October 2016 there were three days where the average combined cost of all FCAS services exceeded $5000/MWh in South Australia, and four additional days where prices exceeded this threshold since October 2016. The duration of extreme FCAS price periods has also risen significantly, with periods of high (>$300/MWh) prices in some services sometimes lasting 8 to 10 hours or longer. In November 2015, Regulation Raise services traded above $300/MWh for more than 50 consecutive hours.

Most of these high price periods where associated with limited import capacity on the interconnector to Victoria.

- Diversity benefits. Enhanced interconnection would minimises grid wide swings in intermittent generation by allowing increasing levels of wind generation in one region to cover for lower levels of wind generation in another region. This could be of benefit to mainland intermittent generation for smoothing out generation on the mainland. This would also be useful between Victoria and SA because these two regions often have different wind and weather patterns.

- Can improve security of supply by opening up new regions for generation. This is the greatest potential benefit of an enhanced interconnection – two of the three options being examined by ElectraNet could allow for the opening up of new regions for renewable generation.

3.2 Enhanced supply reliability

Additional interconnection should of itself lead to improved supply reliability as it would allow for greater sharing of available generation across regions, allowing sharing of spare plant in one region to supply power in another region. To the extent that peak demand periods are not correlated across regions, sharing of peak reserves across also means less investment in peak reserves overall.

However, there is a concern that an increased level of imports from the enhanced interconnection could force the retirement of thermal generation plant in South Australia. This could decrease supply reliability in periods when interconnection capacity is reduced and there is a low level of renewable generation.

Increased imports would reduce the level of generation from gas-fired power stations in South Australia[10]. To test the sensitivity we conducted some simulation analysis using our Strategist simulation model of the NEM. The simulations were conducted over the period from 2015/16 to 2024/25, with an enhanced interconnector to NSW (of 400 MW) entering the market in July 2021. Four scenarios were simulated based around 4 parameters: with and without the interconnector upgrade; and with and without additional investment in renewable energy generation (beyond Hornsdale wind farm) of 200 MW in 2018/19.

The key assumptions for the analysis included:

- AEMO's demand projections as per the neutral scenario in the NEFR 2016 (including projections of uptake of roof-top solar PV)

- Gas prices increasing to over the period to 2020 (ending up around $9.00/GJ in 2019/20 for flat base load gas contracts) and gradually declining to around $7.00/GJ to the period to 2025.

- LRET target of 33 TWh being met in 2020.

- Retirement of Hazelwood Power Station in March 2017 and retirement of Liddell at the end of 2021. No retirement of gas-fired plant in South Australia.

The results from the analysis are shown in the following table. The key results include:

- Additional interconnection capacity, with or without additional renewable generation in South Australia, does reduce generation from existing gas-fired plant. However, the level of reduction is less with additional renewable generation. There are more times where gas-fired plants are available to generate for export particularly for for mid-merit plant (such as the combined cycle plant at Pelican Point).

[10] At least until there is a sufficiently high carbon price.

- The analysis also indicates that increased renewable energy in South Australia of itself would reduce profits of gas-fired plants and that an interconnection upgrade minimises this impact by allowing an alternative market for some gas fired generation in South Australia. Profitability is higher with enhanced interconnection because of the additional revenue earnt whilst exporting to NSW. Exports from South Australia supplied the market in NSW during peak demand periods in winter and summer.

Table 2: Changes in profitability and generation of gas-fired plant in South Australia through the interconnection upgrade

	With additional renewable energy	No additional renewable energy
Generation, GWh	-305	-386
Profit, $M	66	-19

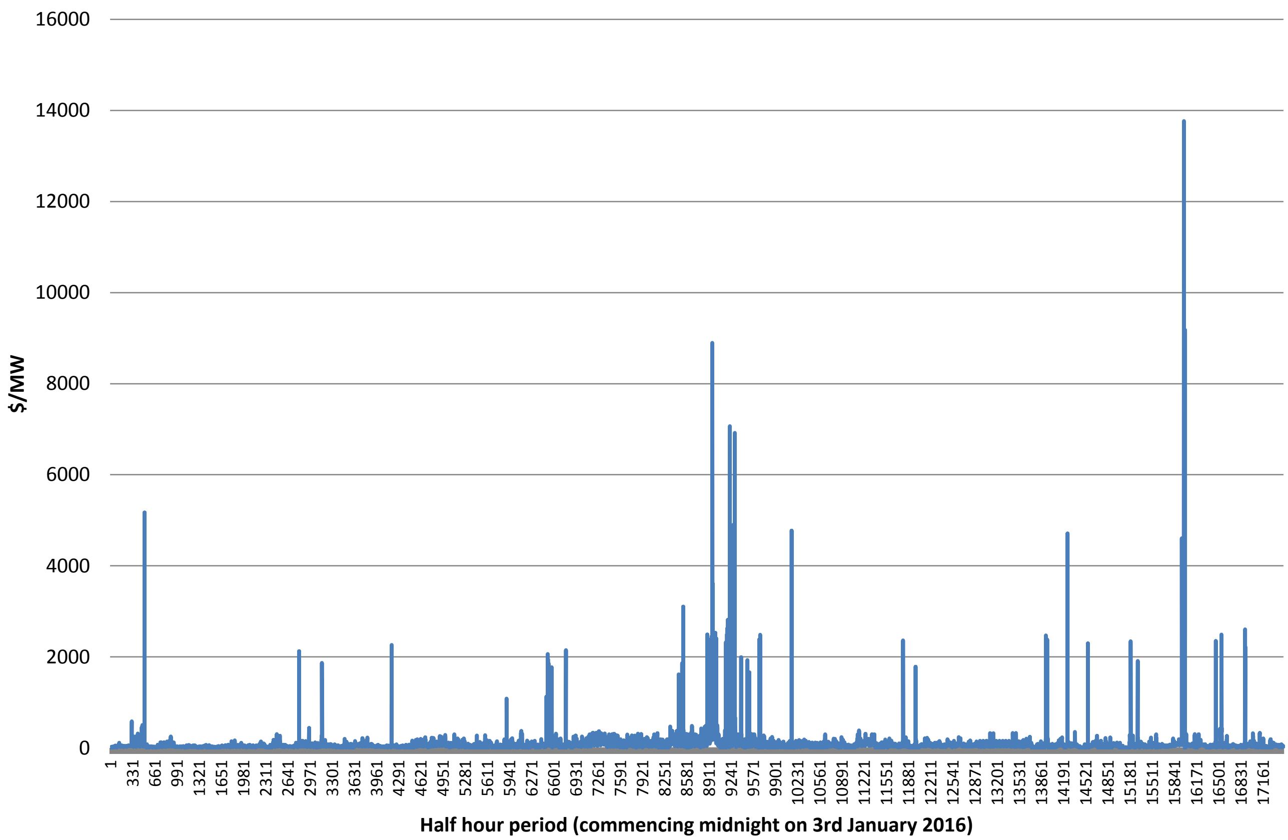
Source: Jacobs. A negative number means lower generation and profits with the interconnector upgrade. The analysis covers the period from 2021/22 to 2024/25.

3.3 Reduced price volatility

Enhanced interconnection is likely to reduce price volatility by allowing lower cost imports to supply the market in South Australia.

The level of price volatility in 2016 is illustrated in Figure 4. For around 18% of the trading intervals prices were above $100/MWh. Prices were above $300/MWh for 3% of the trading intervals. The average price for the year was $83/MWh with a standard deviation of $216/MWh[11]. Although there were some unusual circumstances occurring in South Australia in 2016 (including extended outages of the interconnector with Victoria), the level of price volatility is the highest in South Australia, with the degree of volatility increasing over the last two years.

Figure 4: Hourly prices in South Australia in 2016



[11] The average and standard deviation was high in 2016 due to a high proportion of extreme prices. From 1998 to 2015, prices (in real December 2016 dollar terms) in South Australia averaged around $60/MWh with a standard deviation of around $19/MWh. If you only consider prices in 2016 under $500/MWh, the average price was $68/MWh with a standard deviation of $66/MWh.

An additional 400 MW interconnector would have reduced the price during around two-thirds of high price periods[12]. As an indication of the potential impact, allowing 400 MW of imports from an enhanced interconnector to be in at $300/MWh during periods when prices were greater than this level would have reduced the average price for the year from $83/MWh to $70/MWh and would have reduced the level of volatility[13] by half.

Other options (such as more generating capacity or storage capacity) may have also achieved these benefits. A proper examination of the interconnector option would need to consider these alternatives against the interconnector option.

3.4 Interregional trade

The level of utilisation as a percentage of total import capacities of the existing interconnector to South Australia was around 40%. Traditionally, the interconnector has allowed low cost energy from the rest of the NEM to supply the South Australian market.

Interconnectors appear to have an important role in facilitating interregional trade. Examples include:

- In New Zealand, there are around 1,200 MW of HVDC cable connecting the north and south Islands allowing excess hydro-electric generation (and now also some wind generation) in the South Island to be exported to the North Island. Average northward flow per annum is around 250 MW, or around 20% of total capacity (the actual rate is higher since one of the cables is used to back-up the system in case of failure of one of the other HVDC cables).

- The HVDC cable connecting the United Kingdom to France (2 GW capacity) has had an average utilisation of 56% since 2011, allowing excess power in each region to be traded.

- The United Kingdom to Holland interconnector (1 GW capacity), has had an average utilisation rate of 70% since 2011, again mostly through trade of power across the regions.

3.5 Development of local renewable resources

There have been a number or recent developments that will affect the economics of an enhanced interconnector into South Australia. Preliminary analysis (from the modelling described above) has provided the following insights:

- Increasingly imports to South Australia is being “sourced” from NSW black coal generation, as the Victorian brown coal generation is either being used to meet Victorian demand or is being utilised to exports into Tasmania and NSW. Overnight there are some exports to South Australia from the Victoria region. With the closure of Hazelwood Power Station, this trend is likely to intensify. The modelling above indicated that although flows into South Australia increase most of the trade across the new interconnect actually occurs through diversion of flows through Victoria.

- The period of excess coal-fired capacity is drawing to a close. If the planned closure of Liddell Power station in 2022 proceeds, there is likely be only limited excess coal capacity and this means that there is likely to be limited additional imports into South Australia from an enhanced interconnectors in the absence of other developments

- This suggests (and supported by the modelling undertaking by Jacobs and AEMO – see Chapter 5) that the key benefit of the enhanced interconnector will likely be to allow further development of renewable resources in South Australia, either under the LRET scheme or as part of broader carbon reduction measure.

[12] Defined as periods when prices were greater than $300/MWh.
[13] As measured by the coefficient of variation

- Penetration of renewable energy is already high in South Australia and it is possible that penetration could further increase with continuing uptake of roof-top solar PV and further large scale projects under consideration in South Australia. It is possible that there could be an increasing number of periods when production from renewable energy could be greater than regional demand so that with limited export capacity there will be more periods with curtailed renewable energy generation. More than 800 MW of additional renewable energy build would likely see significant curtailing of generation during non-peak periods unless additional interconnector capacity is built[14].

[14] There are more than 1,000 MW of renewable projects under active consideration in South Australia.

4. Barriers to realising benefits

There is no doubt that the capacity of the current transmission systems will affect the optimal uptake (timing and location) of renewable energy technologies both under the LRET scheme or any subsequent carbon mitigation policy.

There are two main issues associated with renewable energy generation and interconnector upgrades. Some upgrades would assist in developing renewable energy projects in some regions but such upgrades could not be justified (or have high risks) because their benefits depends on the renewable energy projects proceeding. There is the risk of stranded assets if the renewable energy projects do not proceed[15]. Second, some benefits of interconnector upgrades may not be easily captured or recognised in formal assessments under the assumption of a transforming electricity market. For example, interconnector upgrades have an option value in allowing uptake of renewable energy in resource rich (but poorly networked) regions should circumstances require more renewable energy. There is also an insurance value for support during low probability but high impact events: witness the value that enhanced interconnection could have provided during last year's storm events in South Australia.

Upgrades of interconnections can also allow more competition by reducing the times that imports to a region are constrained (when imports are constrained is when generators in the constrained region can more successfully bid strategically to increase prices).

There are a number of inquiries into the appropriateness of the RIT-T process. COAG conducted a review of the process in 2016, and found that[16]:

- The RIT-T is still appropriate for ensuring that new transmission infrastructure is built to the long term benefit of consumers.
- System security and emission reduction goals should be adequately considered under the RIT-T. It recommended that guidelines be reviewed and updated by the AER, including on guidelines for a consistent approach to considering carbon mitigation and renewable energy policies.
- Low probability but high impact electricity system events should be appropriately considered.
- Allow for the provision of better information on transmission capability to allow non-network solutions to be better developed. Also to consider the option value inherent in some non-network solutions.

At the December Energy Council meeting, Ministers agreed to the recommendations of the review, including that the AEMC further explore the merits of increasing Australian Energy Regulator oversight of the RIT T[17].

[15] There is also the issue of network externalities associated with installing new networks to renewable rich areas.
[16] COAG Energy Council (2017), *Review of the Regulatory Investment Test for Transmission*, final report of the RIT-T Review, February
[17] COAG Energy Council (2016), *Eight Meeting Communique*, 14th December.

5. Insights from recent modelling

In this section, we provide insights from a number of recent studies into the potential need for and benefits of a second interconnector with Tasmania. The studies cited are:

- A study undertaken for the Climate Change Authority[18].
- A study for the Energy Networks Association[19].
- A study undertaken for The Climate Institute[20].
- Recent studies undertaken by AEMO for the NTNDP 2016.

All studies had emissions targets at least equivalent to a cut in emissions of 28% by 2030 or more stringent. In the CCA study, emissions fell by 60% by 2030.

5.1 Need for interconnection

In all studies, there was marked change in the generation mix by 2030:

- For the 28% target scenario in the ENA study, coal generation in the NEM fell from 155 TWh to 82 TWh to 100 TWh. Gas-fired generation increased from 20 TWh to 76 to 93 TWh in 2030 and renewable energy generation increased from 55 TWh to around 80 TWh. Brown coal generation in Victoria reduced by over half.
- For the 48% target scenario in the ENA study, coal generation fell from around 155 TWh in 2020 to 39 TWh to 54 TWh in 2030. Only one brown coal power station remained in operation by 2030. Although gas generation increased, renewable generation had the largest increase, going from 55 TWh in 2020 to 99 TWh to 120 TWh in 2030 requiring substantial increases in renewable energy resources across all regions.
- For the two degree scenarios in the CCA study, the entire brown coal fleet was retired by 2025 and the black coal fleet in the NEM was retired by 2031. For Victoria, this meant replacing over 55 TWh of brown coal generation with other forms of generation in less than 5 years. Although additional black coal and gas-fired generation played a role, the study found that renewable energy played a significant role in this replacement.
- Similarly in the TCI study, which examined mixes of policy approaches to reduce emissions, the brown coal generation in Victoria fell within a decade, with Yallourn closing before 2025 and Loy Yang A/B commencing closing before 2030 under the policy scenarios with a mixture of regulated closures of coal plant (by age), higher renewable targets or suboptimal carbon prices. Higher gas prices were assumed in this study than for the ENA studies and so more renewable generation was need to replace the brown coal generation.
- AEMO in its NTNDP 2016 study using high level modelling found that an enhanced interconnector from South Australia to either Victoria or NSW would have net benefits with a 2021 commencement date. The study also found net benefits from interconnectors upgrades from other regions of the NEM and that "modelling shows greater total net benefits when these developments are combined, creating a more interconnected NEM"[21].

None of the studies included modelling of the State based renewable energy targets but the level of renewable energy uptake was in line with the mooted targets for Victoria in almost all scenarios.

[18] Jacobs (2016), *Modelling Illustrative Electricity Sector Emission Reduction Policies*, report to the Climate Change Authority, August
[19] Jacobs (2016), *Australia's Climate Policy Options: Modelling of Alternate Policy Scenarios*, report to the Energy Networks Association, August
[20] Jacobs (2016), *Electricity Sector Impacts of Emission Abatement Policies*, report to The Climate Institute, April
[21] AEMO (2016), *National Transmission Network Development Plan for the National Electricity Market*, December

The studies found that significant interconnection upgrades were required. The extent of the upgrades was as follows:

- In the CCA study, the level of required upgrades ranged from 3,500 MW to around 7,000 MW with higher upgrades required for the higher the level of renewable generation. Around half of the upgrades were required by 2030, reflecting the severe reduction in coal fired generation in that period.
- In the ENA studies, only around 1,000 MW of upgrades were required in the period to 2030 for the 28% target. Around 1,750 MW of upgrades were required for the 45% target scenario.
- In the TCI studies around 2,200 MW of upgrades were required to the period to 2030 in the scenarios were there was a mix of policies to achieve the emission target.

The order of upgrades was consistent across the studies. In all studies examined, a doubling of the import /export capacity from South Australia and Tasmania was required by 2025. Upgrades to the Queensland/NSW were also required by 2030. The principle reasons for this were the low cost of the renewable resources in Tasmania and South Australia, and the exhaustion through development of the available low cost wind resources in Victoria in particular.

However these results are sensitive to assumptions on renewable resource availability and quality and the relative cost of renewable energy across regions.

5.2 Conditions for interconnection upgrades

The modelling provided the following insights into the determinants of the upgrades:

- The level of and rate of retirement of the coal-fired generation and particularly the brown coal fleet. Replacement of the brown coal fleet required all the low emission sources of generation that could be obtained. And the faster the rate of closure the sooner the upgrades were required. In the 2^{o} Celsius target simulations for the CCA, the entire brown coal fleet had to be retired by 2025, which pushed the interconnector upgrades closer to 2020. Even for the 45% target simulation for the ENA the upgrade of the interconnection to Tasmania occurred around 2022. The lower 28% target still required the second interconnector by around 2025.
- The higher the level of renewable energy required the higher the level of interconnector upgrades and the sooner those upgrades occurred. In policies that targeted renewable forms of generation as the main source of emission abatement, interconnector upgrades were required to facilitate least cost development of the renewable energy either by allowing access to lower cost resources or by facilitating more efficient levels of dispatch of those resources. Higher levels of connectivity also minimised periods of curtained production from renewable energy resources.
- In the CCA study, sensitivities were performed to lower and higher rates of growth in demand. Clearly this lead to lower or higher levels of interconnector upgrades and the delay or bringing forward of upgrades. However, the need for and timing of the interconnector upgrade across the Bass Strait was only marginally affected, as the brown coal fleet still retired around the same time in these sensitivities.

5.3 Modelled benefits

From the modelling, it is difficult to estimate precisely the magnitude and range of benefits brought on by increased interconnection across the NEM. But a review of the modelling results gleaned the following insights:

- Interconnector upgrades facilitated the rapid replacement of coal fired generation. In Victoria, with the requirement for rapid replacement of the brown coal fleet, interconnector upgrades allowed more renewable energy resources to be developed in time to replace the brown coal fleet. . For other regions, the upgrades also allowed for a more optimal retirement of the black coal fired fleet (allowing lower cost black coal generation from Queensland to retire later than the black coal plant in NSW).

- Accessing resource rich renewable areas. Interconnection opened up resources in areas with limited access or limited need for additional renewable generation. Upgrades allowed for greater development of intermittent resources in South Australia.

- Under most assumptions used, even in cases with assumed lower costs for alternatives to interconnector such as battery storage systems, interconnector upgrades were still required as part of the least cost solution to supply electricity. This is because interconnector upgrades provides a greater range of benefits and because of the need for new interconnection early on in the next decade. In none of the alternative technology cases, did alternative options become cheaper in the early 2020s and hence the interconnector upgrades went ahead due to the need for the upgrades. In scenarios with high levels of intermittent renewable generation the level of interconnection (across regions with divergence in peak demand times and lower correlation of intermittent generation profiles) reduced the need for additional simple cycle gas turbines to provide backup to the intermittent generation.

- One of the key findings of the analysis was the rapid uptake of intermittent sources of generation, which led to high levels of generation at certain times of the day and even the potential for curtailed energy (if there was too much generation compared to local demand). Interconnector upgrades were essential in avoiding excessive curtailed energy.

- Similarly interconnector upgrades were often found to be economic to narrow potential price differences between regions and thereby replace higher cost generation with lower cost resources despite the additional power transfer loss across the interconnection.

In summary, in a world where greenhouse gas emissions are required to be reduced and the electricity sector is being transformed so that the existing coal fleet is being retired within 15 years, interconnector upgrades appear to be part of the least cost solution for replacement of the coal fleet with low emission plant. Enhanced interconnection to and from South Australia appears consistently as one of the earlier upgrades required mainly to allow access to the lower cost wind and PV generation in South Australia, to avoid curtailing energy from intermittent forms of generation and to provide backup services to higher levels of intermittent generation in South Australia.