


Storage Requirements for Reliable Electricity in Australia

Report prepared by the
Institute for Sustainable Futures for the
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About the authors

The Institute for Sustainable Futures (ISF) is an interdisciplinary research and consulting organisation at the University of Technology Sydney. ISF has been setting global benchmarks since 1997 in helping governments, organisations, businesses and communities achieve change towards sustainable futures. We utilise a unique combination of skills and perspectives to offer long term sustainable solutions that protect and enhance the environment, human wellbeing and social equity.

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Executive Summary

Key findings

This study provides reassurance that power system reliability can be maintained in Australia's electricity system at very high penetrations of renewable energy. Reliability has two components, with very distinct requirements, for energy adequacy (is there enough energy at any given hour) and energy security (can the system withstand sudden changes).

This study found only very minor storage requirements for energy adequacy until renewable energy supplies well above 50% of electricity. Estimated requirements for system security, which may be met by storage or other technologies, already occur and will dominate until very high penetrations of renewable energy are reached. The requirements for energy adequacy and security in 2030 are summarised in Figure 1 for three possible scenarios of renewable electricity generation.

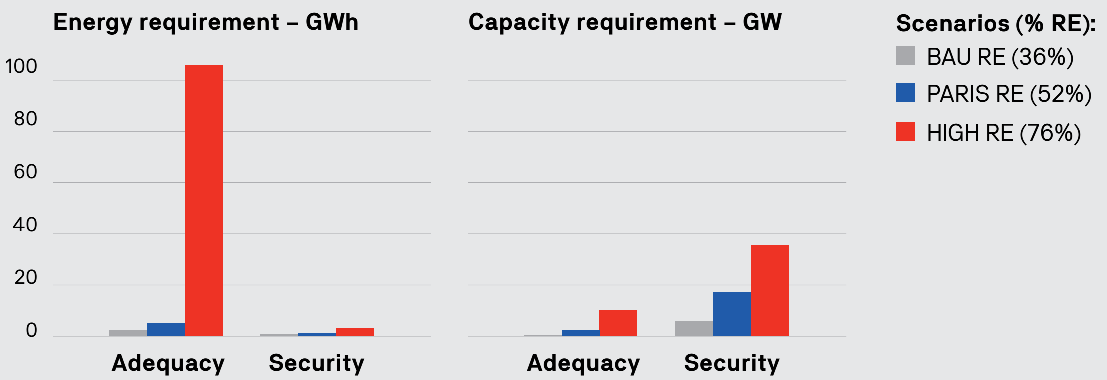
The study provides reassurance that both adequacy and security requirements may be met with readily available technologies, although the policy and regulatory environment may require modification to ensure that we get the most cost effective system outcome. The projected cost for meeting the security requirements at 2030 in the PARIS RE scenario (52% renewable generation) by batteries alone, for example, would be in the order of $11 billion at 2030 prices , and this would also easily meet the adequacy requirements at that time. Of course, requirements for security are likely to be met by a mix of generation and storage technologies, and not by a single solution.

Australia should undertake strategic planning now to meet the requirements for energy adequacy with a zero emission electricity sector in order to get the best outcomes. Firstly, while energy security requirements dominate in the short term, the lowest cost solutions for adequacy may well mitigate security requirements at much lower renewable penetrations. Planning should not be left until high penetrations of renewables are achieved, as some technologies, for example pumped hydro or development of power to gas storage capability, have long lead times. Secondly, there may be strategic advantages attached to storage solutions, such as the potential to become a zero emission energy exporter via one of the hydrogen pathways.

Research is therefore needed on the optimum balance of generation, storage, and interconnection taking into account both cost and the long term strategic opportunities for Australia.

It would be highly advantageous to extend this study to undertake cost optimisation between generation, storage, interconnectors, and demand side measures, factoring in the requirements for both security and energy adequacy. This should include a quantitative market impact analysis, as energy storage may become a price setter rather than a price taker for some energy services. The study would best be undertaken with a stepped approach to reaching a zero emission electricity system, and should include extensive analysis of weather data.

Figure 1: Adequacy and security requirements at 2030, three scenarios



The main requirement for **ADEQUACY** is for energy storage (GWh)

The main requirement for **SECURITY** is for additional capacity (GW)

Penstocks feeding the Tarraleah Power Station, a pumped-storage hydroelectric power station in Tasmania, Australia.

Introduction

The study identifies the energy storage requirement for power system reliability, or “keeping the lights on”. This requirement has two components that in engineering terminology are called adequacy and security. System adequacy is the ability to supply enough energy at the right times to meet customer demand. System security is the ability of the system to withstand sudden changes or contingency events, such as the failure of a large generator, load or transmission line. Providing both adequacy and security is a core function of the Australian Energy Market Operator (AEMO).

Different approaches were used for assessing power system adequacy and security. Understanding adequacy, and the impacts of daily and seasonal variability of demand and variable renewable energy sources, required an hourly model of potential generation and energy demand. This was performed for each state in the National Electricity Market, including the southwest of Western Australia, for an entire year.

The study identified a worst case for energy adequacy, based on low wind output, within the available seven year dataset for wind and solar . It would be prudent to extend this study to allow for further interrogation of wind and solar data, and to calculate storage requirements based on data for multiple years.

Security, on the other hand, is about the ability of the power system to make a rapid transition after contingency events like the loss of a major generator, load or transmission line. An initial assessment of security was based on the potential decrease in system inertia due to the increase in asynchronous supply, such as wind and solar PV generation, in each state. Inertia, typically from turbines in coal, gas or hydro power plants, has been used to keep the grid frequency stable due to the rotating mass of turbines. Wind turbines also have inertia, that is used in some jurisdictions (for example, Hydro Quebec, Brazil, and Ontario) to increase security, given suitable control settings. Other forms of fast frequency response (FFR) may also be required.

The energy scenarios

The energy generation mix is a crucial input to this assessment, and for this study it is bounded by a "business as usual" scenario (BAU RE) that has continued growth of renewable capacity under present conditions and assumes about half of currently proposed projects go ahead, and by a "High Renewables" scenario (HIGH RE) that has aggressive growth to reach 100% renewable electricity by 2035. Between these two is a third scenario (PARIS RE) that has been designed to meet Australia's emission reduction obligations under the Paris COP21 agreement.

It should be emphasised that the generation mix used in each scenario does not represent either the least cost generation mix, nor the optimum mix of generation and storage. Generation scenarios were used from published sources in order to explore the range of storage which might be required by 2030, and one of the key findings of the work is that an optimisation study of generation, storage and interconnection should be undertaken.

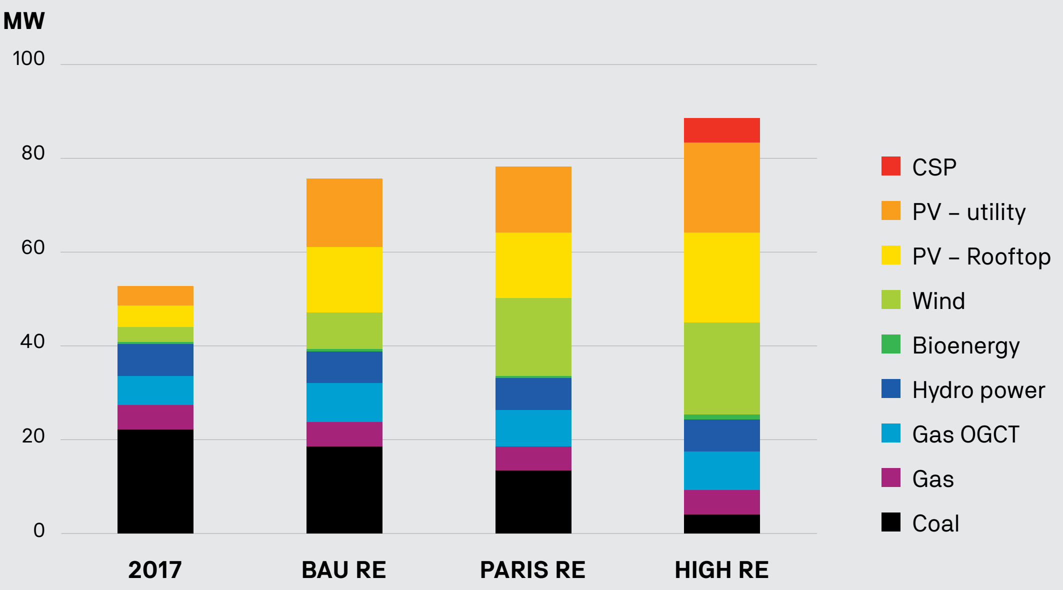
The generation capacities used in each scenario are compared to the current energy mix in Figure 2. Energy generation by type is an output from the model, which depends on both the hourly demand, and the dispatch order. The proportion of renewable generation by scenario was 36% in the BAU RE, 52% in the Paris RE, and 76% in the High RE.

BAU RE
36%
Renewable Generation by 2030

PARIS RE
52%
Renewable Generation by 2030

HIGH RE
76%
Renewable Generation by 2030

Figure 2: Total generation capacity by scenario in 2030



The storage requirement

Table 1 shows the calculated energy storage requirements for Australia's power supply to 2030 according to three possible scenarios. Note that any storage installed for adequacy purposes is likely to contribute to the requirement for security, and vice versa.

The adequacy requirement is primarily for a quantity of energy (GWh). While demand response and demand management could reduce this requirement, it is likely that the majority will need to be provided by stored energy within the given supply mix.

The security requirement is primarily for near-instantaneous delivery of power (GW) as FFR to compensate for sudden shocks to system operation. The figures given in Table 1 are based on the assumption that this FFR is provided entirely by energy storage, although there are many options to provide this service.

The requirements for system security were found to exceed the requirements for adequacy until very high renewable penetrations. In the HIGH RE scenario, the energy storage requirement for adequacy is 105 GWh. However, using energy storage solutions to provide system security capacity would also make a significant contribution to meeting the adequacy requirement. Assuming that the security requirement is met by batteries and that these provide two hours of storage, which is a common configuration in today's battery market, the need for energy storage for adequacy in the HIGH RE scenario is reduced by two thirds at 2030, based on the outcomes shown in Table 1. Pumped hydro storage capable of operating in synchronous condenser mode can also help to meet both security and adequacy requirements, although a pumped hydro facility would not be installed purely to meet a security requirement.

The findings of this study concur with an analysis of Germany's storage requirements by the Fraunhofer Institute (Pape et al. 2014), which similarly concluded that the requirements for FFR dominate the requirement for energy storage until very high penetrations of renewable energy generation, and that the energy adequacy storage requirement is relatively low even at penetrations of 50% renewable energy.

Table 1 Summary of storage requirements: BAU RE, PARIS RE, and HIGH RE (2030)

		2017	BAU RE 2030	PARIS RE 2030	HIGH RE 2030
Renewable % of generation		17%	36%	52%	75%
Storage requirement for energy adequacy	GWh	-	1.5	5	105
	GW	0.2	0.4	1.5	9.7
Storage requirement for system security	GWh	0.1	0.5	1.4	2.9
	GW	**1.3**	**5.8**	**16.8**	**35.2**
Total demand	GWh	216,955	239,134	239,134	239,134
Total capacity	GW	60	79	85	101

The energy storage requirements for reliability are low until very high proportions of renewable energy are reached. Even then, storage solutions used to provide system security can go a long way to also meeting adequacy requirement.

The effect of interconnectors

Interconnectors play an important role in providing system adequacy. The option of doubling the existing interconnector capacities rather than installing storage was tested for the HIGH RE and PARIS RE scenarios by running the energy adequacy model with existing interconnector capacities doubled. The storage requirement went down by 15 GWh (14%) in the HIGH RE scenario, and by 1 GWh (less than 1%) in the PARIS RE scenario. Increasing interconnectors would be a capital intensive undertaking, and this study has not attempted to compare the costs with installing storage. However, it is noted that in the High Renewable scenario curtailment was a significant issue prior to installation of storage. This may be more effectively addressed by bulk storage technologies than interconnectors, as there may be a large overlap in periods of over- and under-production. from renewable energy generators in adjacent states.

Northern Australia

Northern Australia, comprising northern WA, the NT, and northwest Queensland, are not included in this assessment because their electricity generation is dominated by gas and diesel. There will be limited demand for storage to provide system adequacy for the foreseeable future, when supplying local loads, and using batteries to help manage hybrid diesel-renewable or gas-renewable local power stations is already a well-understood proposition. Nevertheless, there is an interesting opportunity to scale up the energy storage industry in Northern Australia in order to facilitate the development of a renewable energy export industry, by one of several proposed pathways.

The PS10 solar power plant near Seville in Spain is the world's first commercial concentrating solar power tower. It stores superheated and pressurised water that is evaporated and used to run a steam turbine to generate electricity.

Cost comparison of storage technologies

The energy storage technologies that should be deployed to meet the requirement are not specified. Rather, cost projections were undertaken to quantify one of the factors that will determine this choice. Other factors include the suitability of each technology for meeting adequacy or security requirements, public response to large-scale infrastructure projects, geographical constraints and planning requirements, uptake of energy storage for purposes other than power system reliability, and the availability of alternative solutions that are not energy storage.

A restricted set of energy storage technologies was considered: pumped hydro storage, compressed air storage (in the form that uses compressed air to increase the efficiency of a turbine fuelled by natural gas), hydrogen produced by hydrolysis, molten salt to store heat for concentrating solar thermal generation, and lithium ion, zinc bromine, and advanced lead acid batteries. This is not a comprehensive set of options; it is intended to represent a range of technologies suitable for deployment at very large scale. The cost projections indicate that molten salt is the cheapest storage option overall, although it is only suitable to store electricity from the associated CSP generator. The most cost-effective bulk energy storage suitable to store electricity from diverse generation sources was projected to be compressed air, then pumped hydro storage, followed by zinc bromine or lithium ion batteries (projected 2030 prices). However, cost comparisons between storage types are fraught with difficulty as the costs are highly dependent on the use case.

Presently, pumped hydro is the cheapest form of storage to meet an adequacy requirement, although project development times are significant, which increases the risk profile of these investments. Batteries are already cost-effective for FFR if installed with a high power-to-energy ratio and appropriately configured inverters, and systems specifically designed for FFR are already available. Installing GW capacity for the purpose of FFR creates the opportunity to expand their GWh capacity at a lower marginal cost than would be the case without the FFR purpose. Although compressed air storage is potentially cost effective there are limited locations where it would be possible to build at large-scale in Australia, as suitable stable rock formations are restricted. There are also only two existing plants worldwide, which makes reliable cost data problematic. Molten salt storage is the cheapest form of storage, and is likely to be incorporated into every concentrating solar thermal generator as the additional cost is very low compared to the added value derived from dispatchable power.

Policy considerations

Given the internal and external environmental factors involved, it will be important for energy storage policy to promote market growth (on strength and opportunity) while also managing risk (mitigating against weakness and threat). Table 2 gives some guidance on the key elements that government should consider, divided into those policies relating to reducing risk, and those aimed at promoting opportunities. Policy considerations based on SWOT analysis include:

Policy for growth

- **Promote an energy storage mix** that meets Australia's near-term and long-term system needs, and supports our climate targets
- **Pursue timely energy market reform** to create a competitive marketplace for new technologies, services and business models
- **Foster Australian expertise** in storage to build a comparative advantage in both research and deployment
- **Explore the potential for hydrogen** to provide Australia with the capability to export renewable energy to the Asia-Pacific region

Policy for risk

- **Consider intervening** when the market is not promoting investment in potentially lower-cost technologies with longer lead times
- **Respond to changes in renewable energy policy** to ensure that the expansion in variable generation does not adversely impact electricity reliability
- **Monitor the resource availability** for the proposed energy storage mix and consider options for alleviating this risk e.g. lithium recycling
- **Promote knowledge sharing** in the industry with regards to deployment i.e. lessons learned to reduce costs
- **Monitor any flow-on impacts** of energy storage uptake to other technologies in the energy mix, particularly gas generation, and ensure this does not adversely impact system reliability.

In South Australia the 100 MW/129 MWh Tesla Powerpack energy storage system (due for completion in December 2017) will charge using renewable energy from the nearby Hornsdale Wind Farm to deliver electricity to the grid during peak hours.