



Generator Replacement Study

Like for like assessment

A Public Summary Report for the Liddell Taskforce

Introduction, approach and limitations

The purpose of this Generator Replacement Study (the Report) was to assess generic power generation and storage technology options that could replace Liddell's current operations and meet the electricity system needs of New South Wales (NSW). The comparison was performed by developing and applying **like for like assessment criteria** that describe the services that Liddell and the generic replacement options provide to the electricity system.

A scoring system was developed to assess the replacement options against the following **two references: (1) Liddell's current operations** (with all four generation units at maximum availability) and **(2) 2025 system needs**. The system needs are based on committed changes in generation (as per the 2019 Electricity Statement of Opportunities (ESOO)), new interconnection (specifically the proposed Victoria and NSW interconnector (VNI) and the upgraded Queensland and NSW interconnector (QNI)) and demand (as per the 2019 ESOO) until that time. The relative importance of these system needs were qualitatively assessed beyond 2025 and applied as weightings in the assessment.

The Report has focused on investigating NSW's electricity system needs in 2025, which aligns with the scheduled availability of all major replacement options, specifically Snowy 2.0. However, with the major replacement options only likely to become available well after Liddell is currently scheduled closure date in April 2023, there is a risk of a supply gap emerging prior to 2025. This report highlights the most suitable near term generic replacement options to address the potential shortfall based on the assessed options.

This Report used a high level framework, which greatly simplifies complex inter-related engineering concepts. It is therefore best suited to highlight key issues for further technical and economic analysis.

The Report does not discuss all aspects relevant in project development; for example, it does not include an assessment of capital costs, (non-fuel) running costs, fuel costs/risks, revenues, operating regimes, technical design life, bankability, and other differentiators, all of which would be key considerations in future work to establish the optimal project(s) to meet system needs. Most of the options assessed in this report are generic technologies, not specific projects, and therefore have inherent simplifying assumptions surrounding the capabilities and size of the plant.

Any investment decision in the New South Wales energy system will require a much broader suite of economic and technical assessments to provide sufficient and appropriate information to make an investment decision. Further in-depth technical analysis will be needed to appropriately assess and mitigate any future system security and reliability risks in NSW. The key findings and conclusions of the Report should be considered within the context of these limitations.

Location and rating of replacement options

The replacement options assessed, along with their assumed location and maximum (max) power output, are shown in the table below. Sizing of the generic options was based on averages of existing and/or publicly announced projects in Australia, if available. Renewable options have been assumed to be located in one of the NSW Renewable Energy Zones (REZ) identified in AEMO's 2018 Integrated System Plan (ISP), as these are the most likely locations to be chosen.

Location and rating of replacement options

Replacement Option	Nominal location	Max power output (MW)	Comment
Liddell coal life extension (two units to 2026)	Liddell, west of Newcastle	840	No change in location.
Reciprocating engines	North or south of Sydney	210-500	Size range of publicly announced reciprocating engines. Located close to the main NSW load centre.
Grid-scale solar & battery	West of Dubbo or Wagga Wagga*	100 [100 MWh]	Size based on similar projects NEM-wide. Located in one of the identified NSW REZ with solar resources.
Pumped hydro	West of Coffs Harbour, West of Canberra or south of Canberra**	280	Average size of pumped hydro in the NEM, excluding large outliers. Located in one of the identified NSW REZ with suitable locations for pumped hydro.
Open Cycle Gas Turbine (OCGT)	North or south of Sydney	265	Average size of publicly announced OCGTs. Located close to the main NSW load centre.
Large scale industrial demand response	Where available in NSW	+100	AGL's NSW generation plan calls for 100 MW demand response. This value could be much larger depending on size of participants.
HumeLink with Snowy 2.0	South-west of Canberra	2,000	Transmission size based on Option 1A of the HumeLink Project Specification Consultation Report (PSCR).
HumeLink without Snowy 2.0	Tumut/Bannaby/Wagga Wagga	+200	Assuming an average level of import from Victoria (VIC) to NSW of 200 MW as per the HumeLink PSCR.

The replacement options were individually assessed, as well as potential combinations of replacement options to identify a portfolio of assets that fully meet the system need on a technical basis. Key findings from this assessment are outlined on the following page.

Key findings

The key insights from the high level assessment based on the weighted like for like assessment criteria against Liddell's current performance, and against 2025 system needs are outlined below.

The minimal **expected 2025 system need** generally requires more flexible and responsive generation and less dispatchable capacity than Liddell's current operations, as a result of additional generation and interconnection already coming online.

HumeLink with Snowy 2.0 has the closest performance to **Liddell's current operations** (four units).

HumeLink with or without Snowy 2.0 meets all **expected 2025 system needs**, and no other options were assessed to be individually capable of meeting the 2025 system needs. HumeLink with or without Snowy 2.0, however, will not be delivered before the currently scheduled closure date of Liddell in April 2023. Furthermore both projects may be subject to delays, which could create a 'gap' in the provision of key system needs.

To avoid any gap, two combinations of projects could be delivered prior to the closure of Liddell and would also meet the expected 2025 system needs. Note that AGL and Maoneng Group recently announced four large-scale batteries with a combined capacity of 200 MW / 400 MWh. This project provides about twice the output and four times the capacity of the generic solar & battery project. It could therefore be considered as a key option, to fill the role of solar & battery for the combinations that meet expected 2025 system needs shown below:

- **Solar & battery + Reciprocating engines**
- **Solar & battery + Open Cycle Gas Turbines**

Pumped storage scores highly in the 2025 system needs assessment but does not meet all needs, and any new pumped storage project is expected to be available in 2024 at the earliest, which is after the scheduled closure of Liddell in April 2023.

Liddell's current operations and its life extension option were found to fall short of some 2025 system needs and represents one of the lowest ranked replacement options.

Comparison of options against Liddell

Comparison of replacement options to Liddell current operations (4 units)

Category	Like for like criteria	Relative weighting beyond 2025	Reference	Replacement options (merit order 1 st to 8 th)							
			Liddell current operation (4 units)	1 st HumeLink with Snowy 2.0	2 nd HumeLink without Snowy 2.0	3 rd Reciprocating engines	4 th Pumped hydro	5 th Open Cycle Gas Turbine	6 th Battery & solar	7 th Liddell coal life extension (2 units)	8 th Large scale industrial demand response
Generator Performance	A) Max power outputs	High	1,680 MW ¹	✓	✗✗	✗✗	✗✗	✗✗	✗✗	✗	✗✗ / ✗**
	B) Minimum generation	Medium	440 MW	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	○	✓✓
	C) Ramp rate	High	240 MW/h	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✗✗	- / ✓✓*
	D) Cold start time	Low	12 h	✓✓	✓✓	✓✓	✓✓	✓✓	NA	○	NA
	E) Forced outage rate	Medium	>11%	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✗-✓*	✗✗
	F) Network export capacity	Medium	100%	○	○	○	○	○	○	○	○
Ancillary Services	G) Fault current	Medium	12 kA/6% ²	○	✗✗	✗✗ / ✗*	✗✗	✗✗	✗✗	✗	-
	H) Grid forming capability	Medium	Yes	○	○	○	○	○	- / ○*	○	-
	I) Frequency/Active Power	High	80-400 MW	✓✓	✗✗ / ○	✗ / ✗✗*	✗✗ / ✓*	○ / ✗✗*	✗ / ✗✗*	✗	-
	J) Inertia	Medium	6,500 MW.s	✓✓	○	✗✗	✗✗	✗✗	✗✗	✗	-
	K) Voltage/Reactive Power	Low	760 MVar	✓✓	○	✗✗	✗✗	✗✗	✗✗	✗	-
L) System restart capability	Low	Yes	○	○	○	○	○	-	○	-	
Available prior to Liddell's scheduled closure in April 2023				No	No	Yes	No	Yes	Yes	Yes	Yes

¹Maximum offered capacity by Liddell current operation expected during peak events

²Average contribution to fault level above the minimum node requirement at the 5 NSW fault level nodes

*Uncertainty in technology selection, overlapping ranges and/or available information means either score is possible

**Depends on size. AGL's NSW generation plan calls for 100 MW demand response, but eventual value could be significantly larger depending on the industrial sites

Legend: Performance of replacement option, relative to Reference

✓✓	Outperforms	✓	Somewhat outperforms	-	Unable to deliver service	○	Similar
✗✗	Underperforms	✗	Somewhat underperforms	NA	Not applicable	▨	No system gap identified

Comparison of options against 2025 system needs

Comparison of replacement options to 2025 system needs

Category	Like for like criteria	Relative weighting beyond 2025	Reference	Replacement options (merit order 1 st to 9 th)								
			2025 system need	1 st HumeLink with Snowy 2.0	2 nd HumeLink without Snowy 2.0	3 rd Pumped hydro	4 th Reciprocating engines	5 th Open Cycle Gas Turbine	6 th Liddell current operation (4 units)	6 th Liddell coal life extension (2 units)	8 th Battery & solar	9 th Large scale industrial demand response
Generator Performance	A) Max power outputs	High	215 MW	✓✓✓	○	✓	○/✓✓✓*	○	✓✓	✓✓	xx	xx-✓✓✓**
	B) Minimum generation	Medium	0 MW	○	○	xx	x	xx	xx	xx	○	○
	C) Ramp rate	High	6,000 MW/h ⁴	✓✓✓	✓✓✓	✓✓✓	x	xx	xx	xx	✓✓	-/✓✓✓*
	D) Cold start time	Low	5 min	✓✓✓	✓✓✓	✓✓✓	x/○*	x	xx	xx	NA	NA
	E) Forced outage rate	Medium	2%	✓✓✓	○	x/○*	○/✓*	x	xx	xx	xx	xx
	F) Network export capacity	Medium	See note ¹	○	○	○	○	○	○	○	○	○
Ancillary Services	G) Fault current ²	Medium										
	H) Grid forming capability	Medium	Capable	○	○	○	○	○	○	○	-/○*	-
	I) Frequency/Active Power	High										
	J) Inertia	Medium										
	K) Voltage/Reactive Power	Low										
L) System restart capability	Low	See note ³	○	○	○	○	○	○	○	-	-	
Available prior to Liddell's scheduled 2023 closure				No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

¹Sufficient local network capacity to have all available capacity (MW) sent out into the region without being limited by local network constraints.

²Minimum fault levels at the NSW fault current nodes identified in the System Strength Requirements & Fault Level Shortfalls review.

³Enough available generators to restore power to NSW in a timely manner. Additional analysis required, including locational criteria.

⁴6000 MW/h corresponds to the highest ramp rate required in NSW; 500 MW/5min. Needed rate then reduces to 700 MW/15min, 1000 MW/30min, and 1500 MW/60min (based on preliminary AEMO data).

*Uncertainty in technology selection and/or available information means the option could have either score

**Depends on size. AGL's NSW generation plan calls for 100 MW demand response, but eventual value could be significantly larger depending on the industrial site

Legend: Performance of replacement option, relative to Reference

✓✓	Outperforms	✓	Somewhat outperforms	-	Unable to deliver service	○	Similar
xx	Underperforms	x	Somewhat underperforms	NA	Not applicable		No system gap identified

