

## 100% renewable electricity futures

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*Deployment of wind, solar photovoltaics (PV) and off-river pumped hydro energy storage (PHES) allows the National Electricity Market to reach 100% renewable electricity with high reliability and at modest cost. Wind and PV will replace retiring coal and gas plant at lower cost than the alternative replacement (new coal and gas).*

1. Wind and PV constitutes nearly all new generation capacity in Australia, and half the world's new generation capacity (equal to the combined amount of coal, oil, gas, nuclear, hydro and all others)
2. Pumped hydro energy storage (PHES)\* constitutes 97% of worldwide energy storage.
3. Wind, PV and PHES combine to ensure affordable grid stability.
4. The cost of both wind and PV continues to fall rapidly. There is no end in sight to cost reductions.
5. The cost of electricity (\$/Megawatt-hour) from single new-build generators is approximately:

Wind	\$65/MWh (in 2016) falling to \$50/MWh (2020s)
Solar PV	\$79/MWh (in 2016) falling to \$50/MWh (2020s)
Supercritical black coal	\$66/MWh
Gas	\$78/MWh

6. We have modeled the cost of electricity in a 100% renewable electricity system (90% wind and PV plus existing hydro and bio). The cost includes not just the wind and PV, but also pumped hydro storage and high voltage (HV) interconnectors between states.
7. At 2016 prices the whole-system cost is \$93/MWh. At 2020s prices the cost is \$75/MWh.
8. About two thirds of Australia's fossil fuel generators will reach the end of their technical lifetimes by 2036, and will need to be replaced.
9. Wind and PV, supported by HV interconnectors and PHES, will be decisively cheaper in the 2020s than new coal and gas.
10. PHES offers ancillary services including high-inertia, fast-ramping and synchronous capacity for frequency and voltage support.
11. Wide distribution of wind and PV over a million square kilometres to access different weather, coupled with increased HV interconnection and PHES, confers high reliability at modest cost.
12. Any desired degree of grid stability can be achieved at modest cost by adding more off-river PHES at multiple locations (and/or demand management).
13. Rooftop PV will continue to expand as costs continue to reduce.
14. Several thousand people will be employed during 2017 and 2018, and beyond, constructing several gigawatts (GW) of new ground mounted PV, and several more GW of wind, in regional areas.

\* Off-river PHES can provide effectively unlimited storage at modest cost, even in dry states such as South Australia. There are hundreds of potential sites outside national parks in all states. Pairs of reservoirs, typically 10 hectares each, are separated by an altitude difference of between 300 and 700 metres, in hilly terrain or ex-mines outside national parks and away from rivers, and joined by a pipe with a pump/turbine. Water circulates between the upper and lower reservoirs in a closed loop to store and generate power. Very little water is required relative to conventional fossil fuel power stations.