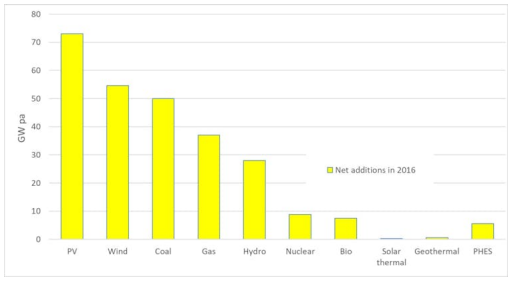
The race is on for storage solutions that can help provide secure, reliable electricity supply as more renewables enter Australia's electricity grid.

With the support of the Australian Renewable Energy Agency (ARENA) , we have identified 22,000 potential pumped hydro energy storage (PHES) sites across all states and territories of Australia. PHES can readily be developed to balance the grid with any amount of solar and wind power, all the way up to 100%, as ageing coal-fired power stations close.

Solar photovoltaics (PV) and wind are now the leading two generation technologies in terms of new capacity installed worldwide each year , with coal in third spot (see below). PV and wind are likely to accelerate away from other generation technologies because of their lower cost, large economies of scale, low greenhouse emissions, and the vast availability of sunshine and wind.



New generation capacity installed worldwide in 2016.ANU/ARENA, Author provided

Although PV and wind are variable energy resources, the approaches to support them to achieve a reliable 100% renewable electricity grid are straightforward:

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Energy storage in the form of pumped hydro energy storage (PHES) and batteries, coupled with demand management ; and

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Strong interconnection of the electricity grid between states using high-voltage power lines spanning long distances (in the case of the National Electricity Market, from North Queensland to South Australia). This allows wind and PV generation to access a wide range of weather,

climate and demand patterns, greatly reducing the amount of storage needed.

PHES accounts for 97% of energy storage worldwide because it is the cheapest form of large-scale energy storage, with an operational lifetime of 50 years or more. Most existing PHES systems require dams located in river valleys. However, off-river PHES has vast potential.

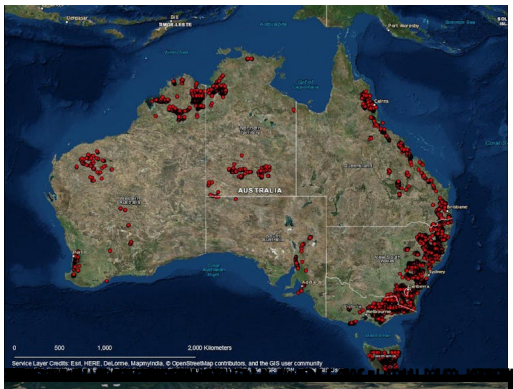
***Read more**: How pushing water uphill can solve our renewable energy issues .*

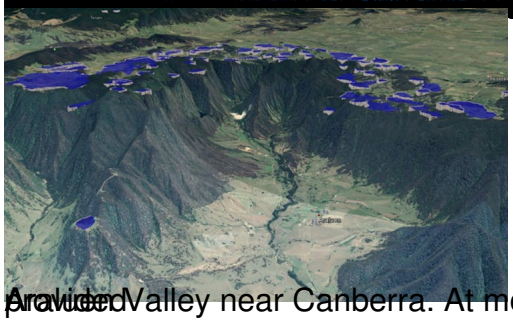
Off-river PHES requires pairs of modestly sized reservoirs at different altitudes, typically with an area of 10 to 100 hectares. The reservoirs are joined by a pipe with a pump and turbine. Water is pumped uphill when electricity generation is plentiful; then, when generation tails off, electricity can be dispatched on demand by releasing the stored water downhill through the turbine. Off-river PHES typically delivers maximum power for between five and 25 hours , depending on the size of the reservoirs.

Most of the potential PHES sites we have identified in Australia are off-river. All 22,000 of them are outside national parks and urban areas.

The locations of these sites are shown below. Each site has between 1 gigawatt-hour (GWh) and 300GWh of storage potential. To put this in perspective, our earlier research showed that Australia needs just 450GWh of storage capacity (and 20GW of generation power) spread across a few dozen sites to support a 100% renewable electricity system.

In other words, Australia has so many good sites for PHES that only the best 0.1% of them will be needed. Developers can afford to be choosy with this significant oversupply of sites.





Arvidsdal Valley near Canberra. At most, one of the sites shown would be developed. ANU/ARENA