A bluefield atlas for lower cost pumped hydro energy storage

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Global renewable electricity generation growth is outpacing all fossil fuels and nuclear combined. Solar photovoltaics and wind are the most cost-effective method to produce electricity, but even with much greater uptake of energy efficiency and demand management, some output must be balanced and stored in order to follow grid demand (Blakers et al., 2021b).

Pumped hydro energy storage is one of the most mature and low-cost forms of energy storage, with over 170 GW installed around the world. Installations of batteries are increasing, but they generally do not provide sufficient energy storage for daily energy balancing of solar energy (Blakers et al., 2021a). There are also possible resource constraints for lithium, and competition for this resource from the transport sector (Teske, 2019).

Pumped hydro projects require two reservoirs (the lower one can be the sea), a tunnel between the two reservoirs, and generators and pumps to generate electricity when required and pump water when there is excess electricity available. A higher difference in height between the reservoirs, or head, results in lower cost energy storage (Blakers et al., 2021a).

Pumped hydro has historically been associated with conventional hydroelectricity, which generally involves damming of river valleys, and can have adverse environmental and social impacts. Further utilisation of these river valleys for conventional hydroelectricity faces social, political, and environmental pushback (Blakers et al., 2021a). For whatever reason, although pumped hydro is very cost effective, and could be installed throughout the world in hundreds of thousands of locations with low environmental and social impact (Blakers et al., 2017; Stocks et al., 2021), this technology did not feature prominently in the recent Intergovernmental Panel on Climate Change WG3 report on mitigation (*Climate Change 2022: Mitigation of Climate Change*, n.d.).

In fact, pumped hydro energy storage installations can (and often should) be located away from river valleys, in order to maximise the head and lower costs. Constructing new reservoirs can be expensive. By using reservoirs that already exist as one half of a pumped hydro installation, the cost to balance renewable electricity can be further reduced (Blakers et al., 2021a).

The ANU pumped hydro energy storage atlas, which uses geographic information system (GIS) techniques to identify potential pumped hydro energy storage sites, has been further updated to include pumped hydro systems that would use existing reservoirs. To the best of the authors' knowledge, this is the first time such an atlas has been created and made available. The ANU Greenfield atlas has been used by several Governments and institutions to choose sites for new PHES schemes.

The Bluefield atlas is an innovative update to the previous atlas. Other potential advantages of using an existing reservoir for an energy storage system include: the reservoir probably has existing water licenses, many reservoirs are owned by government-controlled entities, social license already exists for one reservoir, and the environmental impact of the project could be far lower than a greenfield development.

However, there are also possible disadvantages to using existing reservoirs, such as: low heads because many mountainous reservoirs in Australia are surrounded by national park and therefore excluded from our study, water use may already be prioritised for irrigation, drinking, environmental or recreational purposes, environmental impacts of pumped hydro use such as increased suspension of sediments in reservoirs and changes to water turbidity and chemistry, and clearing for construction access. Changes to rainfall and water availability due to climate change will also impact the viability of existing reservoirs to be used for pumped hydro energy storage, which will be critical to avoid electricity outages. Although there is a huge operational water saving in moving from a fossil fuelled electricity system to a 100% renewable grid supported by pumped hydro, access to water for pumped hydro will still be critical for a resilient electricity supply. Some forms of battery storage can further reduce operational water consumption (Tarroja et al., 2020).

Developing our renewable energy infrastructure should be a sensitive proposition – care should be taken to avoid loss of biodiversity and habitat, particularly for endangered ecological communities. This is one of the key reasons for the development and dissemination of this atlas.

From more than 450 possible existing reservoirs around Australia, 111 had at least one suitable match. In total, 1479 possible bluefield pairs with a cumulative 37.6 TWh of energy storage were found. Even accounting for overlaps, this represents a sizeable fraction of the required energy storage for a 100% renewable Australian electricity grid (Lu et al., 2021). When combined with the greenfield survey there are many prospective sites at low cost, many more than enough to provide balancing for an entirely renewable Australian economy (even assuming no improvements to energy efficiency and productivity except via direct electrification). There are many other improvements that would not only lower energy consumption but improve quality of life and lower cost of living, such as increasing modal share of active and public transport etc. (Woodcock et al., 2009) (International Energy Agency (IEA), 2022; *Sustainable Transport Policy Recommendations | Climate Council*, n.d.)

As a case study, we present some possible sites that are of particular interest, for example due to their location within Renewable Energy Zones, the ability to support new offshore wind sites, proximity to Snowy 2.0 or existing transmission lines or load centres, or their location away from existing National Parks. There are many steps needed before determining whether these sites would be good candidates for construction, but as the number of locations that are suitable is so high, sites can be carefully selected to minimise environmental and other impacts.

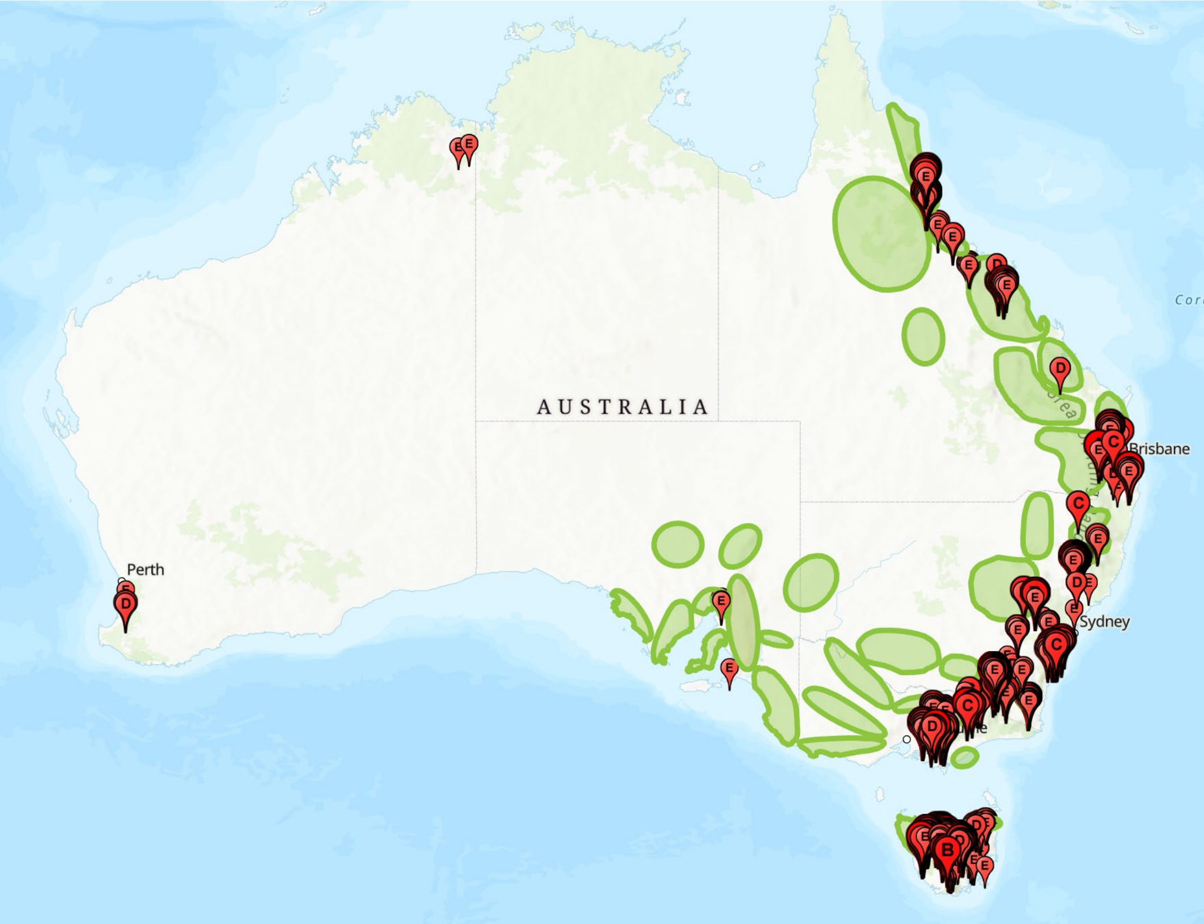

Figure 1. AEMO 2021 REZ zones mapped with 2GWh, 5GWh, 15GWh, 50GWh, and 150GWh sites

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