Firming Technologies to Reach 100% Renewable Energy Production in Australia's National Electricity Market (NEM)

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Australia has committed to reducing its greenhouse gas emissions in a manner consistent with limiting anthropogenic climate change to no more than 2 degrees Celsius. One of the ways in which this commitment is being realised is through a shift towards variable renewable energy (VRE) within Australia's National Electricity Market (NEM). Substituting existing dispatchable thermal plant with VRE requires consideration of long-term energy resource adequacy given the unpredictability of solar and wind resources. While pumped hydro and battery storage are key technologies for addressing short-term mismatches between resource availability and demand, they may be unable to cost effectively address 'energy droughts'.

In this article, we present a time sequential solver model of Australia's National Electricity Market (NEM) to determine the optimal mix of firming technologies in a system where effectively all energy is generated by renewable resources (wind, solar and hydro). Rather than dissecting the (necessary) transition from today's system, we focus on identifying the end goal: how today's system would be rebuilt with the low emissions technologies assuming expected cost reductions have eventuated.

The model optimises across three forms of firming technologies: pumped hydro; batteries; and 'zero emission' open-cycle gas turbines (OCGT). Our findings are relatively clear that some form of green fuel-based peaking generation is likely to be required, even if costs are relatively high (both capital and operating). Peaking generators are deployed to address 'energy droughts' and run at capacity factors of 2-8%, comparable to existing peaking capacity operating in the NEM today. Energy storage also plays a key role in smoothing supply and demand, by charging during high price periods to address later reliability constraints. This is not a theoretical result – for example, in March 2021, a NEM battery charged at ~$10,000/MWh in order to generate at ~$15,000/MWh.

These findings are important. A diverse range of firming technologies will be required to deliver an affordable and reliable system, just as we did not rely on a single technology in the past. Policy makers should be focused on facilitating a mix of storage and zero-emissions peaking technologies, as well as supporting infrastructure around zero-emissions fuels. Governments could consider the introduction of a Green Gas Target modelled on Australia's existing Renewable Energy Target to drive investment in hydrogen and biofuel production.

Market settings will also likely need to be adjusted: we find existing price caps could result in 17-27% 'missing money' for firming assets. In particular, the NEM's Cumulative Price Threshold (CPT) that caps average prices over a 7 day period to limit consumer risks may need to be higher to incentivise long-duration firming. There will also be value in developing new operating reserve markets and forward looking signalling of market price cap settings.

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