Pumped hydro, solar and wind can deliver a 100% renewable NEM: ANU

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A 100% renewable energy NEM is possible using solar, wind and pumped hydro, say researchers at the ANU.

"The cost of a 100% renewable energy future is low," says Andrew Blakers. "PV and wind, although variable, can supply demand in every hour of the year."

Blakers, a professor of engineering at the Australian National University in Canberra, can make this amazing claim because his research team designed an optimisation model which sought to minimise the cost of a 100% clean energy national electricity market using solar, wind and pumped hydro augmented by any necessary high-voltage transmission lines.

Once the researchers had fed their massive, iterative model into a supercomputer they sat back and waited 15 hours for an answer.

It was $90/MWh.

That price is "way below" other estimates for a clean energy system, Blakers says, because the researchers restricted themselves to using mainstream technologies. He expects the price to fall, perhaps below $75/MWh, as technology becomes ever cheaper.

The model is telling the team a 100% renewable NEM would need between 15-20GW of pumped hydro, or between 50 and 80 systems throughout the country. A high-voltage transmission line would also be required west of the Diving Range down the east coast and along the south.

Pumped hydro would supply the least energy of the three sources in an optimal NEM, he says, but it is important “as a means to an end”.

“It’s by far the lowest cost storage technology available, which is why it’s 99% of all energy storage, and remarkably it has been completely overlooked in most high-renewable energy studies.”

Technologies that currently generate less than 100GW around the world are not included in the study, Blakers says, leaving PV, wind and pumped hydro storage.

“On that basis we exclude solar thermal, batteries, geothermal, tidal, ocean energy…” The list goes on.

The right sites

The project consists of three components: identify all sites suitable for pumped hydro in Australia not within national parks and other sensitive areas; build cost models for pumped hydro systems by site that developers can use as a starting point, and; incorporate the site and cost information into a 100% renewable energy scenario for the future, where all electricity in the NEM is supplied by solar, wind and pumped hydro.

To begin, the national electricity market (which as we all know includes Queensland, NSW, Victoria, the ACT, South Australia and Tasmania) is divided into 43 geographical cells, with historical solar and wind data included for each cell. Then, an algorithm looks for optimal levels of solar, wind, pumped hydro and numbers of high-voltage interconnectors to match demand with energy output for every hour of the day on the entire NEM, again using historical data.

So, if all goes well, the model will deliver an optimal blend of renewable energy and additional infrastructure to satisfy the NEM. With no reliance at all on coal, gas or nuclear.

“We simply place the solar and PV in sensible zones,” says Blakers. “The idea is by having the solar and wind data for every cell then the algorithm decides whether or not to put any PV or wind in a particular cell then crawls over this huge solution space until it finds a solution that meets demand, then finds another one and another one and so on, then looks at the levelised cost of energy for each of the solutions it finds and chooses the lowest one."

The model will be looking for a solution that meets demand for every hour of 2006 to 2010, the data set the researchers have chosen as a good enough approximation of the future. "If it meets every hour of demand [for that period] then we can be fairly sure we're on the right track for meeting demand in the future given demand is almost flat and sun and wind doesn't change very much year to year."

By including weather systems all up and down the NEM, Blakers says the probability of there being lots of cloud and no wind is very low.

"The algorithm teaches you very quickly that you want very wide distribution of PV and wind in order to access many different weather systems."

The project drew $449,000 in funding from the Australian Renewable Energy Agency, with an emphasis placed on the mapping of potential short-term off-river pumped hydro energy storage sites. "This study will help us see just how cheap, efficient and effective pumped hydro systems can be in providing large-scale, reliable, clean energy storage that can feed into the grid on demand, in a range of suitable locations across Australia," said ARENA CEO Ivor Frischknecht.

Avoid the current

But where should pumped hydro systems be placed? Somewhere close to plenty of water, you'd expect. But Blakers says the best spots can be created on the tops and bases of hilltops far away from any flowing water.

"When we think of pumped hydro we think of anything but a river," Blakers says, following the logic that there are vastly more suitable sites far from rivers, and that sites close to rivers invite the risk of flooding. "Flood control is a very important part of the overall cost of a river-based system."

Blakers says reservoirs for humped hydro systems can be "tiny", at between 10 and 100 hectares, where bulldozers scoop out basins atop and at the base of a steep hill. A pipe connecting the two will have a pump turbine somewhere inside it and the same water will be sent up and down over and over again, to generate power when rushing downhill or take advantage of cheap power to pump it up top again.

Sourcing the water for pumped hydro systems, which may be dotted in some pretty far-flung places, is no big deal, he says. “The amount of water required is trivial,” being evaporation minus rainfall, or about 0.1% of annual extractions from the Murray-Darling basin.

Most of the eligible sites are on the western side of the Great Diving Range, outside national parks, where rainfall is fairly reliable and water is available nearby.

“Even in the hottest, driest place we’re looking at – east of Port Augusta in South Australia – they’re only 10 or so kilometres from the main water supply. So although there is not a lot of rainfall there is unlimited water.”

Power shift

Blakers says it looks as though the pumped hydro component will store during the day and shift the solar power into the night. “In the typical daily cycle the pumped hydro fills during the day when the sun’s shining and is drawn down in the evening peak when the sun’s not shining and is refilled overnight by wind energy, ready for the morning peak.”

And around and around it goes.

The more often they run, the cheaper they get, he says. It costs almost nothing to run them, but quite a lot to build them, so if you run them twice a day you’re amortising the cost of building over two cycles a day, not once, “so you’ve just halved the cost”.

The cost of a 100% renewable electricity grid is about $90/MWh, the model tells them, split into a levelised cost of PV and wind generation around two-thirds that amount and levelised cost of balancing (pumped hydro, transmission lines and spilled PV and wind) about one-third.

The current pooled price in the NEM is about $60/MWh and the cost of a new black-coal power station with no carbon price is about $80/MWh.

“In other words, a 100% renewable PV and wind system matches the price of a new fossil-fuel system, without a carbon price,” Blakers says.

Estimates are based on wind prices from the ACT reverse auctions, PV prices from the most recent ARENA large-scale solar round and high-voltage DC and pumped hydro from published models.

The team has gathered “enough data to get started” and has completed an initial integration study.

The renewable energy target may act as a reverse carbon price until 2020, Blakers says, and push along deployment of PV and wind, but after then we’re back to the point where new green energy plants will have to compete against gas- and coal-fired power stations that look good because capital was sunk decades ago and the externalities of pollution are ignored.

“That is the single largest obstacle,” he says. “If there was something equivalent to the RET continuing beyond 2020 to encourage further growth of PV and wind or to penalise existing coal and gas then the high-voltage transmission and pumped hydro would simply grow organically.”

He cites the 50MW Genex Power pumped hydro proposal in North Queensland, which has attracted a $4 million ARENA grant, as an example of the types of assets that would suit a 100% clean NEM.