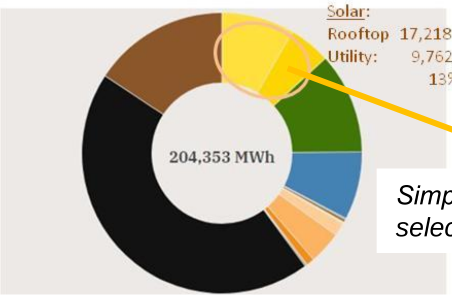
A Discussion Paper on Solar Power with Battery Storage to Smooth Out Variability in Supply

In Australia we are fortunate to have a 'National Energy Market' website (OpenNEM: NEM) that accumulates detailed records for all forms of electric power generation connected to our national grid. It provides detailed time-based operating data showing the overall demand for electric power, together with the contribution by each mode of power generation to meeting that demand. A summary 'pie-chart' illustrates the relative proportions of power contributed by each mode of operation over a selected time, and for each mode of operation, it provides a map showing location and performance details for each installation. The diagram below illustrates the general content of the NEM Website:

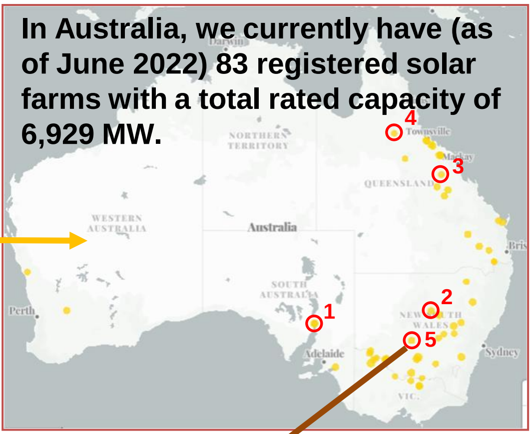
Australia – NEM – Generation by Power Source:
31May21 thru' 05Jun22



Map of Australia – Showing Names, Locations and Specifications of all Solar Farms contributing power to the NEM grid

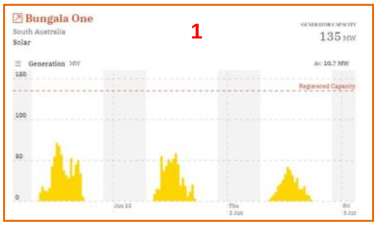
Simply 'Click' on the colour to select the generation mode

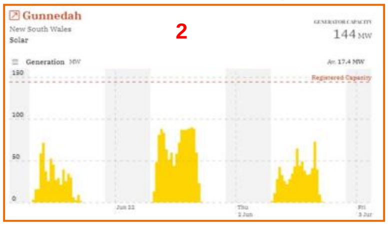
The 'Summarised Pie-Chart' where hour to hour variability is hidden

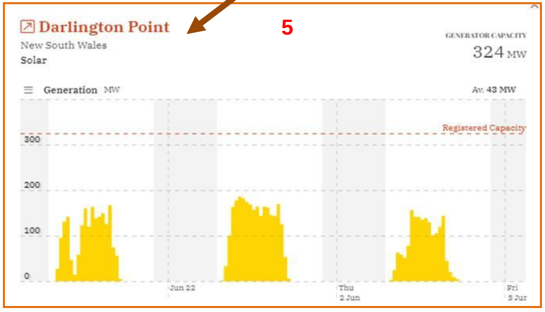


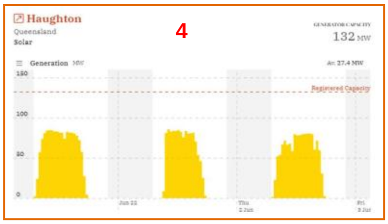
In Australia, we currently have (as of June 2022) 83 registered solar farms with a total rated capacity of 6,929 MW.

'Click' on the individual location to view the specifications and performance data









The five solar farms shown here are taken randomly to facilitate review and discussion of their performance as grid power supplies.

As most of us are aware, solar power comes in an 8 to 10 hour 'daily hit' providing the panels are clean and the sky is not too cloudy. That is a simple fact of life driven by the weather, and by the daily rotation of planet Earth. Most certainly NOT things that humans can 'control'.

Look at the hour by hour time-series data reported for the selected solar farms over a 3-day period as shown on the NEM web-site above. Observe the undeniable and almost constant variation during the day and the expected zero overnight! The hour-by-hour variation and on/off nature of solar power generation is demonstrated in stark and undeniable reality!

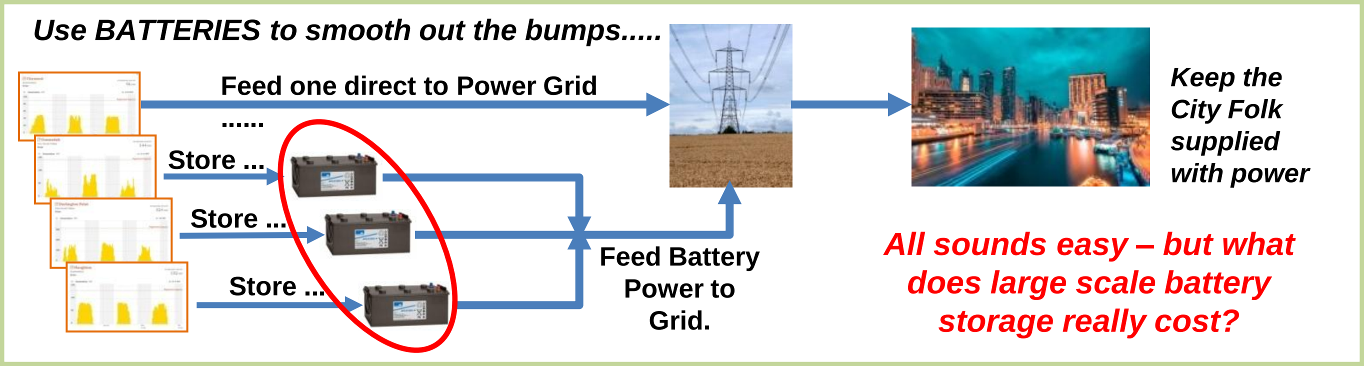
The problem is that most people don't see that variation. That's because they only look at the weekly / monthly summarised 'pie-charts' that give the impression that solar (and wind) currently provides a substantial proportion of our electrical energy. That is a false interpretation because a summated total measured over weeks or months simply hides the detailed (hourly) time-series variation. And that hourly variation is the problem!

Similarly, note that the greater the number of solar farms added together, the greater the difference between the summated 'daily blobs' and the summated 'night-time nothing'.

So while roof-top solar may provide some subsidised benefit to house-holders, the output from commercial solar farms is potentially useless for powering any application that requires 24/7 x 365 uninterrupted grid power supply. There are lots of examples: continuous manufacturing and process industries, supply chains, essential services, the internet, data storage and communications, etc – and what about hospitals, shopping centres and reliable refrigeration to keep our food supplies fresh on the supermarket shelves?

Clearly, solar power is of little use in practical grid based applications unless it's wildly variable performance through each 24 hour period can somehow be smoothed out.

A possible solution could be to provide commercial scale batteries to smooth out the hour by hour power fluctuations delivered by an array of commercial scale solar farms. Could we let one or more solar farms supply the grid directly whilst 'storing' the energy from a suitable number of others to enable constant feed into the grid for 24 hours per day? No doubt there are many options - a simple configuration might look something like as illustrated below:



Use BATTERIES to smooth out the bumps.....

All sounds easy – but what does large scale battery storage really cost?

For the four solar farms selected randomly for this example, the NEM website gives a combined rated capacity of 692MW and measured output of 102.7MW – an apparent 'capacity factor' of just 15%. One farm is chosen to feed directly to the grid while the other three are configured to feed through a bank of batteries to achieve a smooth and dependable supply for each 24 hour period. The NEM total rated capacity (600MW) and measured average output (87.8MW) of those three farms is used to calculate the required power storage capabilities of the batteries. Assuming that that the batteries have to maintain reasonable output for 14 hours to cover over-night plus dawn / dusk transition and cloud cover, etc, that means the storage capacity required of the batteries would be in the order of:

87.8 MW x 1,000 kW per MW x 14 hours = 1,229,200 kW Hrs.

The probable cost of battery storage for this kind of application is given at: Cost Projections for Utility-Scale Battery Storage: 2021 Update (nrel.gov) . That source indicates that commercial scale battery storage will be in the order of $300 to $400 per kW hr. Compare that with the cost of a new, 55 Amp-Hour deep cycle battery for a lawn mower, mobility scooter or electric outboard motor. That too will cost around $300 – but 12 volts x 55 amps is just a measly 660 amp-hours – or 0.66kW Hrs – or $450 per kW Hr!

Based on the 'cheap end' $300 per kW Hr, the cost of battery storage to convert the selected array of just four solar farms to (hopefully) achieve 24/7 consistency of grid supply would therefore be in the order of:

1,229,200 kW Hrs x $300 = $368,760,000 !!!

And that's the cheap end of the range of estimates - heaven help us if we have to find the cash to equip all solar farms with battery storage to synchronise generation capacity with demand! In Australia, we currently have (as of June 2022) 83 registered solar farms with a total rated capacity of 6,929 MW. Assuming the same capacity factor of 15%, that would necessitate a cost for battery storage of:

6.929 MW x 1000 kW per MW x 15% Capacity Factor x 14 hours x $300 per kW Hr = $4,365,270,000.

Plus all the costs of grid connections and control gear, etc.!!

Note that there is a critical factor not mentioned so far and apparently, not well defined in the public domain – effective battery life is dictated by the number of charge-discharge cycles that the batteries can withstand during their operating life. Each time a battery is discharged and then re-charged, it loses a tiny fraction of it's energy storage capacity.

Everything You Need to Know About Lithium Battery Charging Cycles - Renogy Australia

It is reported that the average life span for a Lithium-Ion battery is 2 to 3 years or 300 to 500 charge cycles, whichever comes first – but that is for full charge / discharge cycles. If the batteries are only partially discharged and then recharged, their life is extended considerably.

So a key part of the battery sizing calculations must include allowance for optimum life based on partial rather than full discharge-recharge cycles. If that means using an 'oversize' bank of batteries to achieve longer operating life then the initial capital cost of the batteries will be proportionally higher. Either way, replacement batteries must always be costed into the life operating model. Both options incur major costs!

What can we conclude from all this?

Firstly, the overall cost of commercial scale solar power generation supported by battery storage facilities to provide something close to 24/7 x 365 continuity and reliability of supply appears to be cumbersome and very expensive.

Secondly, we know that solar energy is dilute and very demanding of huge areas of land with resultant sprawling extent and complexity of grid connections and support infrastructure when all access roads and maintenance / cleaning requirements are taken into account 'openly and honestly'.

Aren’t there any better ideas?? Of course there are...

For less than the cost of the batteries in our simple example above, we could buy a 600MW natural gas based combined cycle power plant (CCGT) with 24/7 x 365 reliability, high thermal efficiency and low emissions with ZERO measurable impact on our global climate!

GE secures $350m order to develop 600MW power plant in Bangladesh (nsenergybusiness.com)

Plus, the CCGT option would have a significantly lower geographical and ecological footprint, longer operating life and significantly reduced mining and materials requirements in the overall supply chain – and fewer re-cycling problems on decommissioning.

The capital cost for the sub-optimal “solution” of using batteries to smooth out solar power generation on our existing solar power grid of 83 solar farms (if the Greens / Teals get their way it will grow much larger) could currently purchase an installed capacity of 7,480 MW of clean, efficient and reliable 24/7 x 365 combined cycle gas turbine technology with a ‘capacity factor’ closer to 95%.

A sobering thought:

Given the low inherent capacity factor of solar farms (15%) compared to combined cycle gas turbines (95%), how does the total capital cost per “*productive MW Hr*” of generating capacity of the two options compare? Rough calculations indicate very badly, eg: $1,379 per MW Hr for solar plus batteries versus $70 per MW Hr for the turbine – both based on 8,760 hrs per year / replacement batteries and fuel costs not included.

If you don’t like fossil fuels – go nuclear!

We urgently need some politicians (and economists / engineers) brave enough to address the current issues of reliability in our national power grid.

They must explain how spending trillions of dollars importing solar- wind power generation and associated battery storage facilities, plus all the added grid and infrastructure complexity will successfully transform Australia from a declining economic power into an economic powerhouse of the future.

China and other exporters of ‘renewable technology’ will be the absolute winners financially.

We will be paying their bills.

How would we ever recover from the massive debt to be incurred in the currently favoured transition to “renewable energy”? An apparently ill-thought out strategy in which solar power and batteries appear to play such a “big part”?

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