Simulating ISP's 2050 NEM Grid

Using 2024 AEMO Data

February 2025

"AEMO's Integrated System Plan (ISP) is a roadmap for the transition
of the National Electricity Market (NEM) power system."
– aemo.com.au

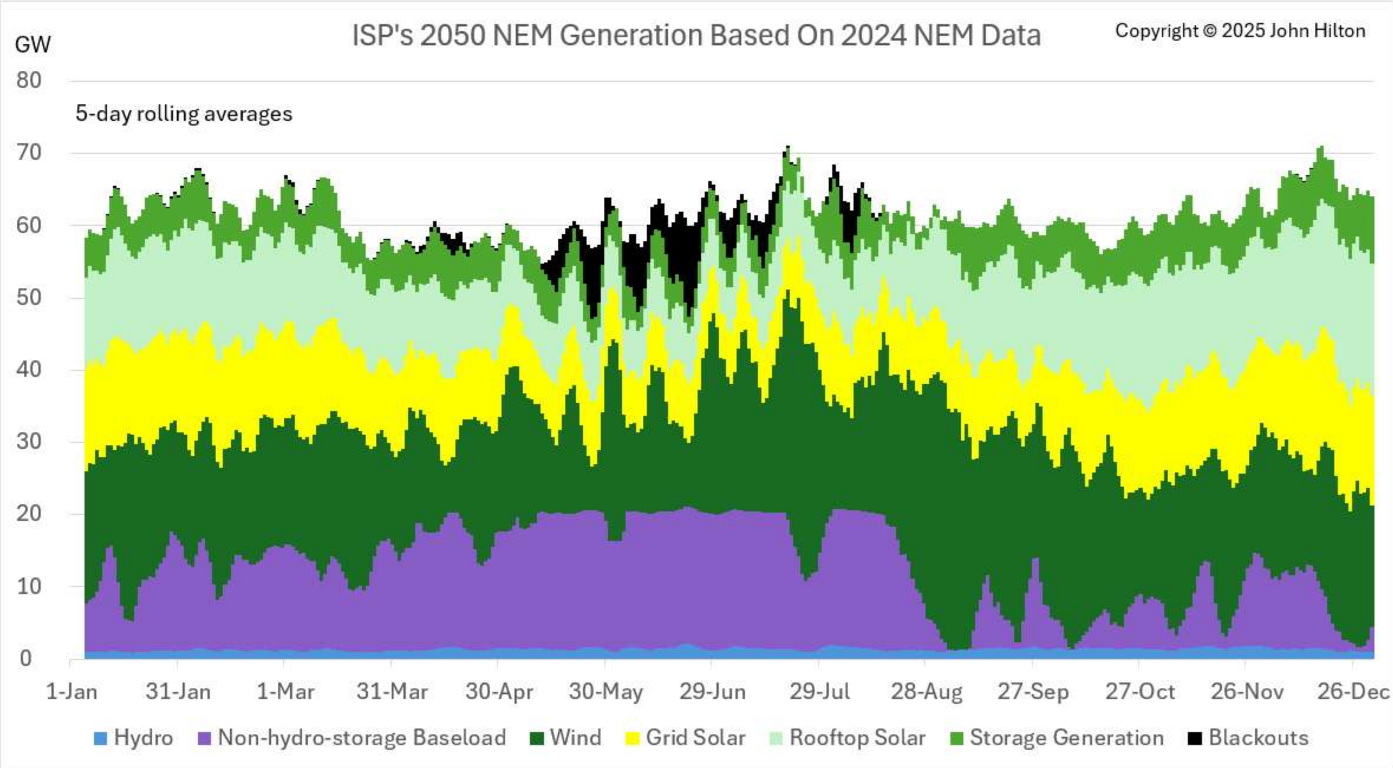
Accountants have methods to double check calculations to uncover potential errors. Likewise, engineers have methods to do the same. AEMO's ISP is a large and complex simulation of Australia's electricity grid. The power flow simulation used here is far simpler as it takes a high-level view of the overall system.

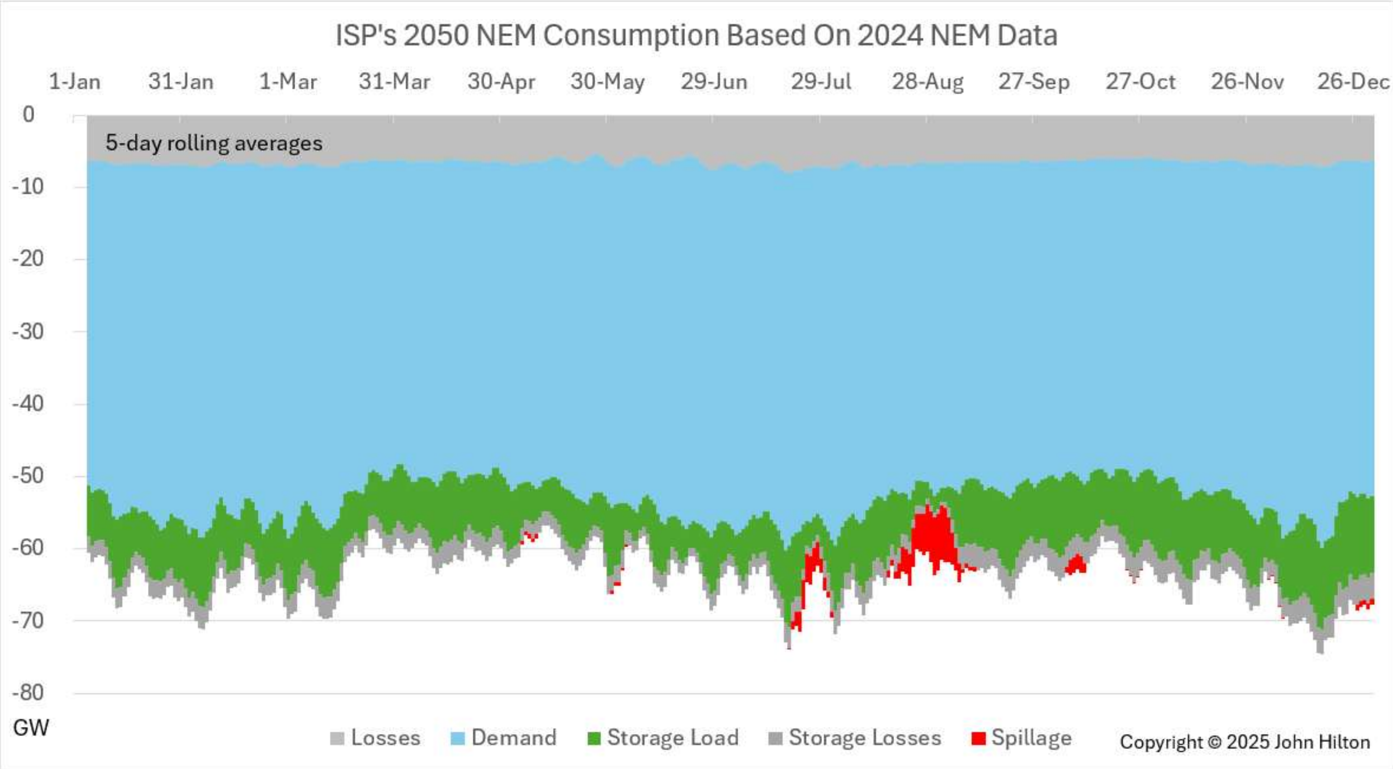
Valid input is key to any simulation. Weather-wise 2024 was an unremarkable year so scaling 2024's factual data provides highly credible input for a 2050 simulation. The ISP itself describes transitional changes to 2024's grid. The weather, the performance of wind and solar generators and Australia's electricity demand is already baked into 2024's factual data. The fine-grained simulation calculates at 5-minute intervals and typically takes less than a minute to run. This simulation is fully open source at github.com/jhilton00/NEMWeb. Any engineer can download and experiment with it.

The 2024 ISP specifies a transition roadmap based on 2024...

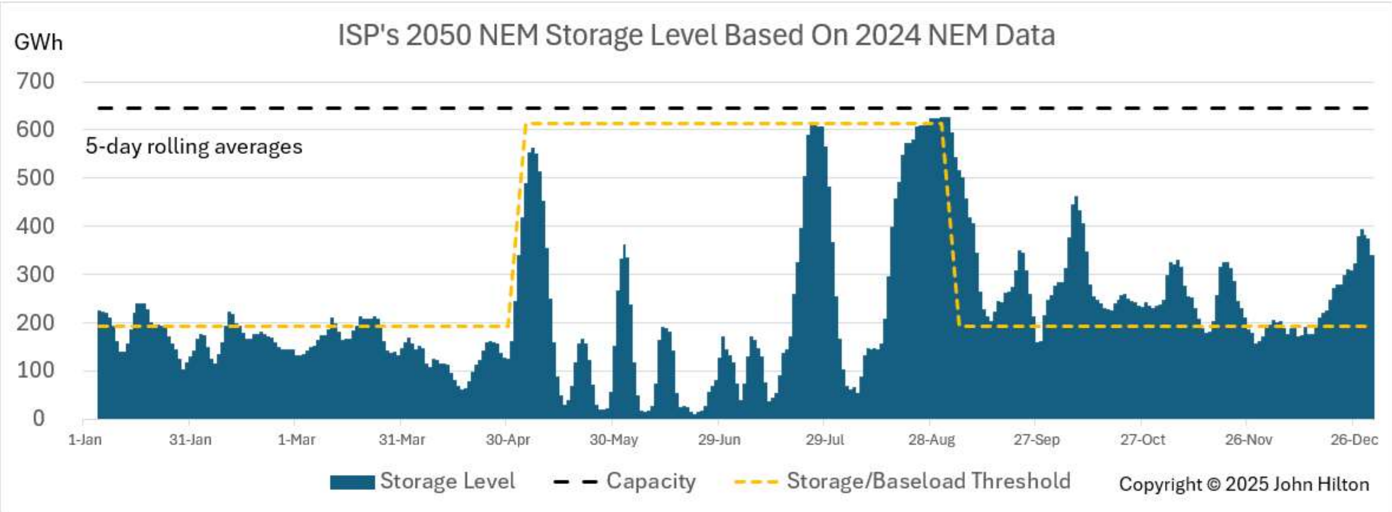
- Scale Wind and Grid Solar by six
- Scale Rooftop Solar by four
- Scale Hydropower by 83%
- Scale Electricity Demand by 208%
- Provide 49 GW / 646 GWh of dispatchable storage
- Provide 15 GW of gas power and 4GW of other baseload power
- Include additional power system security services

The following diagrams and graphs tell the story and it doesn't look good! Note the 78 days with partial blackouts (in black of course) as the transitioned grid doesn't cope, especially during the colder months.

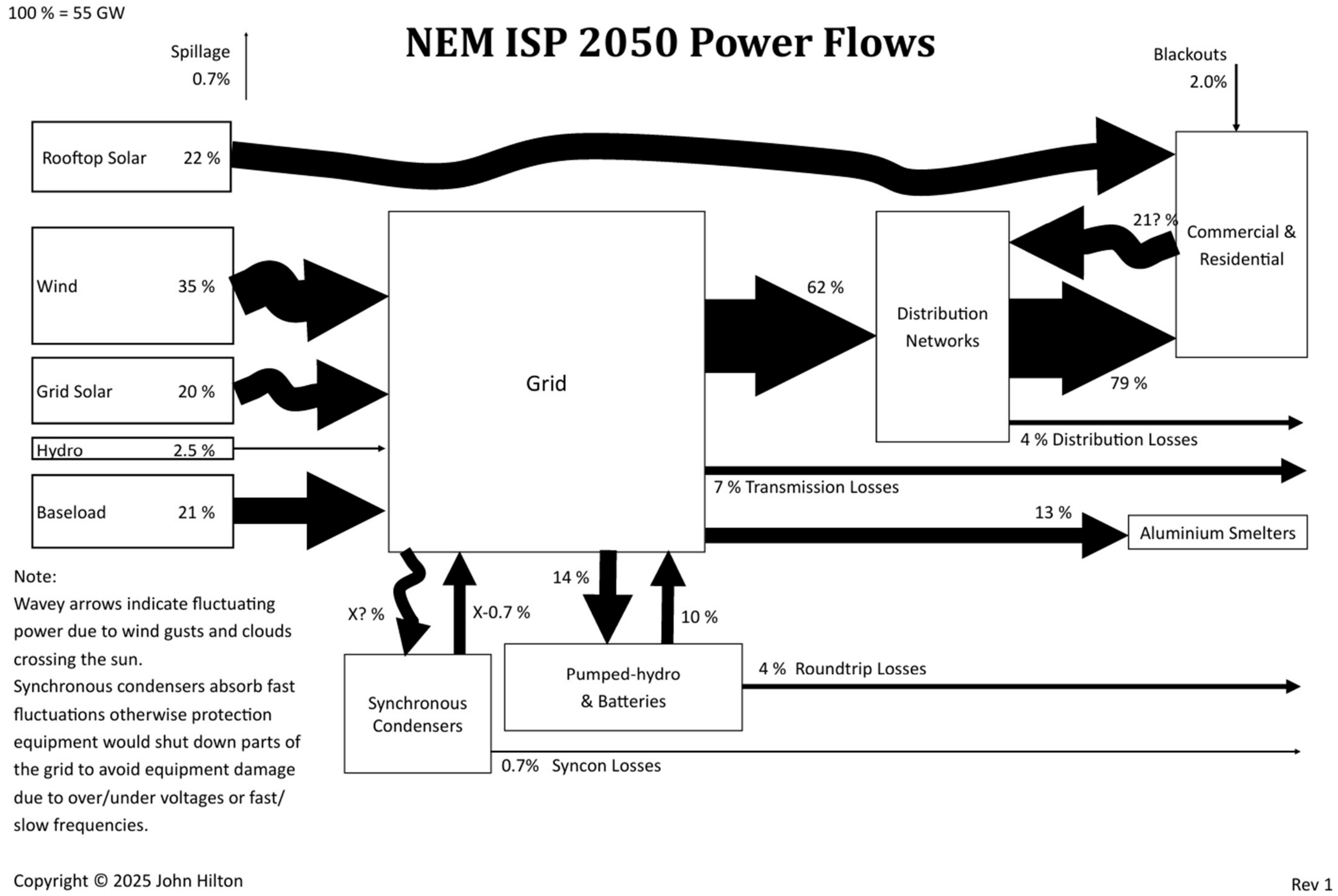




Note: Spillage is power that can't be stored.



Note how the top two-thirds of the expensive storage is hardly used. It's likely significant cost could be saved by halving storage and increasing baseload with only a small increase in CO_2 emissions for any added fossil fuel baseload.



According to the simulation…

Blackouts

From May through August, when there is less sun and when winds may be low, the grid fails to meet demand 8% of the time. Rolling blackouts, for example where some suburbs are turned off, will occur when the grid falls short.

Over the whole year blackouts occur in 78 days (24%). Massive blackouts occur during the worst time in the simulation at 7:50 PM on 13th June when the NEM is 36 GW (64%) short of the 57 GW demand as storage is empty and the 2.3 GW wind power doesn't even cover transmission losses. Clearly far more than 19 GW of dispatchable non-hydro-storage generation will in fact be required!

CO_2

Fossil fuel generators provided **132 TWh** of electricity in **2024**. Non-hydro-storage baseload, having 15GW of fossil fuel gas and 4GW of unspecified generation, will produce **103 TWh** of electricity in **2050**. The large number of blackouts will not be tolerated so more wind, solar and storage and/or non-hydro-storage baseload will be added. Adding non-hydro-storage baseload will only increase the 103 TWh generation number along with CO_2 if gas is used. Not much of a transition given the massive investment.

Storage and Spillage

Storage is particularly relied upon to absorb daytime solar power and return it at night. The storage graph shows how longer-term storage is consumed when really needed, typically over a week or so.

There is some spillage (wasted oversupply) particularly as the storage fills in late August.

Background - 2024 Generation Data

AEMO's nemweb.com.au website provides the power output for all NEM-connected generators every five minutes and rooftop solar generation is reported every thirty minutes. All up, over 24 million data points provide an accurate history for the previous 12 months. The NEMWeb project at github.com/jhilton00/NEMWeb is an open-source analysis of this data.

From the 2024 analysis 5-minute interval data for five categories is copied over.

- Hydropower
- Wind
- Grid solar
- Rooftop solar (interpolated from 30-minute data)
- Electricity demand used by factories, businesses and residences

Methodology

The five categories are scaled to form the corresponding 2050 categories then the power-flow analysis, as presented in the Average NEM Power Flows 2024.pdf[1] where system losses are calculated, baseload generation is determined and storage responses are included. The 5-minute interval simulation is then summarized in a daily table that is used to derive the results and graphs.

The simulation is driven by only 20 parameters with almost half of those being specified by the ISP. See the appendix.

The algorithm is described in the open source project at github.com/jhilton00/NEMWeb.

[1] https://github.com/jhilton00/NEMWeb/blob/master/Average%20NEM%20Power%20Flows%202024.pdf

APPENDIX

The following table is copied from the *Parameters and Results* tab in NEM ISP 2050 Simulation.xlsx. Anyone can download and adjust these parameters (in orange cells) as they see fit to revise the simulation.

Name	Value	Notes
Hydro Factor	83%	ISP Page 11 graph, 7.5/9 - as read from graph
Grid Solar Factor	600%	ISP Page 11, bottom dot point, "Triple grid-scale variable renewable energy (VRE) by 2030, and increase it six-fold by 2050"
Wind Factor	600%	Ditto
Rooftop Solar Factor	400%	ISP Page 12 third dot point, "Support a forecast four-fold increase in rooftop solar capacity"
ISP 2050 Firming Capacity	75 GW	ISP Page 73 2nd paragraph: "75 GW of firming technology" ISP Page 65 4th paragraph: "Firming technologies include storage, hydro, gas and other fuelled generation."
Hydropower 2024	8.5 GW	ISP Page 6 "8.5 GW of hydropower assets in operation across Australia today"
Demand Factor	208%	ISP Bottom of page 23, "Future energy consumption from the NEM will rise by approximately 108% by 2050"
Storage Capacity	646 GWh	ISP Page 12 second dot point, "This includes 49 GW/ 646 gigawatt hours (GWh) of dispatchable storage"
Storage Generation Capacity	49 GW	Ditto
Non-hydro-storage Baseload	19 GW	From ISP values above
UK Average Generation 2024	37 GW	The UK grid is highly renewable
UK Grid Inertia 2024	220 GWs	
Average NEM Generation 2024	24.7 GW	From nemweb.com.au - see github.com/jhilton00/NEMWeb
Average Non-stabilised generation	47.4 GW	Just solar, wind and storage generation as hydro and baseload self-stabilise
Average NEM Generation 2050	47 GW	Manually copy the value from the cell above to avoid circular references
NEM Grid Inertia 2050	282 GWs	Use the UK's ratio to estimate the NEM's requirement
SynCon Power Consumption Factor	2.9 MW/GWs	From some research - needs further investigation
SynCon Power Consumption	818 MW	
Average Transmission Loss Factor	8%	
Average Dist Network Loss Factor	5%	
Aluminium Smelters Consumption	2,118	github.com/jhilton00/NEMWeb, Tomago's 960MW has been removed from 2024's consumption
Rooftop to Dist Network Factor	95%	The percentage of rooftop solar power put into the distribution network
Rooftop Local Consumption Factor	5%	
Baseload Threshhold May to Aug	95%	Turn on baseload to try and maintain this amount of storage
Baseload Threshhold Sep to Apr	30%	
Storage Threshhold May to Aug	614 GWh	
Storage Threshhold Sep to Apr	194 GWh	
Average Storage Charging 2024	182	github.com/jhilton00/NEMWeb
Average Storage Discharging 2024	121	github.com/jhilton00/NEMWeb
Storage Turnaround Loss Factor	34%	
Storage Charging Efficiency	82%	
Storage Discharging Efficiency	82%	
Starting Storage	323 GWh	Say 50% of capacity.

Name	Value	Notes
Average NEM Power Generation	55 GW	
Average Demand	47 GW	100%
Average Non-hydro-storage Baseload	12 GW	26%
Blackouts	8%	
Non-hydro-storage Baseload Capacity Factor	63%	
Commercial and Residential Factor	95%	The percentage of non-aluminium-smelter demand