System-Level Effects of 24/7 Matching in the NEM

George Furrer
UNSW Sydney, NSW, Australia

The National Electricity Market (NEM) is currently undergoing a rapid transition from fossil-fuel based generators to variable renewable energy (VRE) as the world looks to mitigate the impacts of climate change. Corporate entities are part of a wide array of stakeholders that look to play their part in the efforts to decarbonise, and they usually do this through a Power Purchase Agreement (PPA). Typically, a corporate's consumption and energy purchased are usually matched over the calendar year through a PPA to make claims such as that they use "100% renewable energy". However, when analysed over a day, there are often times when generation is less than demand and these corporates have to import energy from the grid, often at emissions-intensive times. Figure 1 demonstrates a typical commercial and industrial (C&I) load, typical generation of a solar project, and hence the mismatch in generation and demand.

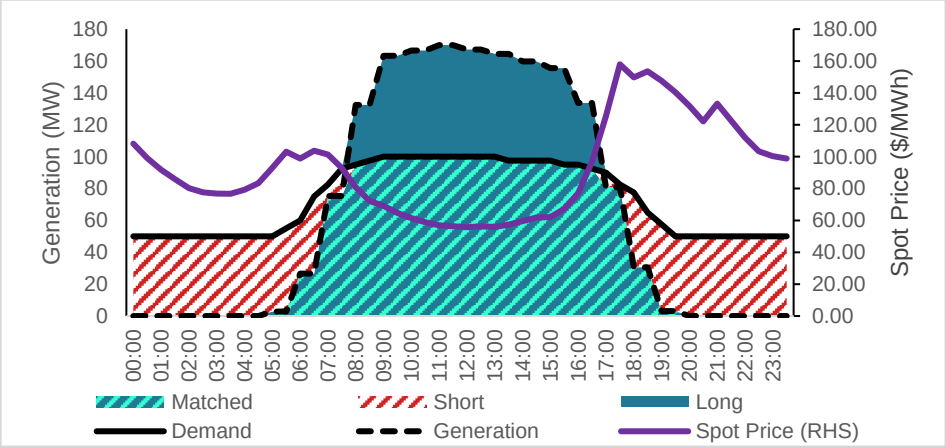

Figure 1 - Annual Matching of C&I and Solar asset over typical day

There is a growing trend, led by the tech sector, for corporates to match their energy consumption with renewable energy generation on an hourly basis. "24/7 matching" aims at ensuring deeper decarbonisation and promoting additional renewable energy investment. Figure 2 depicts a portfolio of wind and solar meeting demand of the same C&I profile in all time periods.

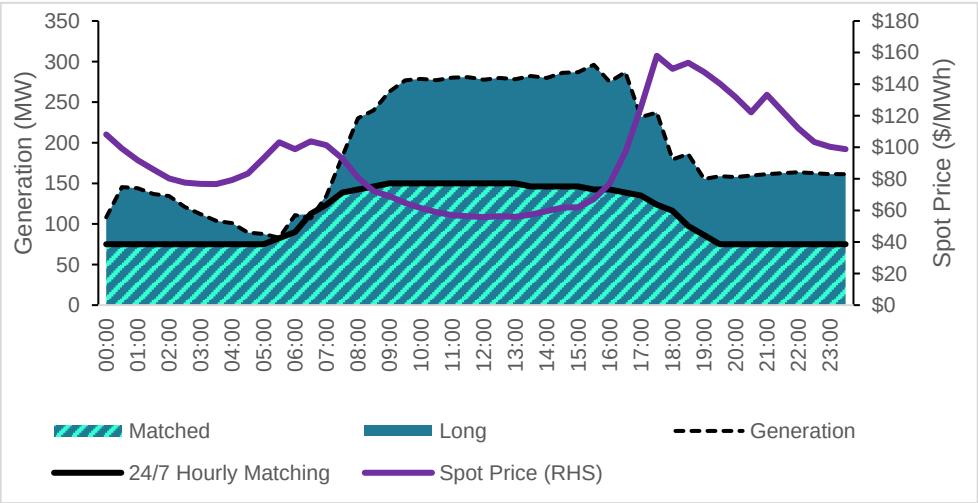

Figure 2 - 24/7 Matching of C&I load

Before this thesis, no research had been completed on what effect corporates matching consumption and generation on a 24/7 basis would look like in the NEM. There was also no open-source tool available to investigate this topic.
Given that no research had been performed on the implications of 24/7 matching in the NEM, this thesis investigated the following scenarios:

1. Business As Usual (BAU) scenario. When there is no corporate RE procurement beyond legislated obligations at all, corporates do nothing and rely on policy makers to implement change.
2. Annual 100% RE: Broad adoption of 100% RE procurement, accounted for on an annual basis. This paper looked at effects when 25%, 50%, 75% and 100% of C&Is procure 100% RE on an annual basis.
3. 24/7 Matching: Large-scale adoption of C&I 24/7 matching. Corporates match their consumption with generation for every hour of the year. This paper looked at effects when 10%, 25%, 50% 75% and 100% of C&Is match consumption with generation on an hourly basis.

The following research questions were proposed for these scenarios:

1. Given no appropriate tool exists, can an open-source capacity expansion model of the NEM be built to investigate research questions 2 and 3?
2. What is the change to the build out in capacity in the NEM pending the behaviour of corporate RE procurement (varying portion of C&Is that annually or hourly match).
3. Does large-scale C&I procurement of RE on an annual or hourly basis reduce the overall emissions in the NEM?

PyPSA model
First, an open-source model of the NEM was built using the python package PyPSA (Python for Power System Analysis). The model consisted of a 10-node network, consistent with the ISP subregions. It took inputs from the 2022 ISP Step Change scenario, namely demand, RE trace data, all generators and storage units, interconnectors and build costs amongst other parameters. The model then performed a capacity expansion over the years 2030, 2035 and 2040, finding the least cost way to build new capacity and meet demand at all times. This presents a significant milestone, as this tool is open-source and hence available to be utilised by anyone to perform their own research and build on the findings of this thesis. Figure 3 compares the capacity build out of the PyPSA model and the ISP – validating that the model is accurate.

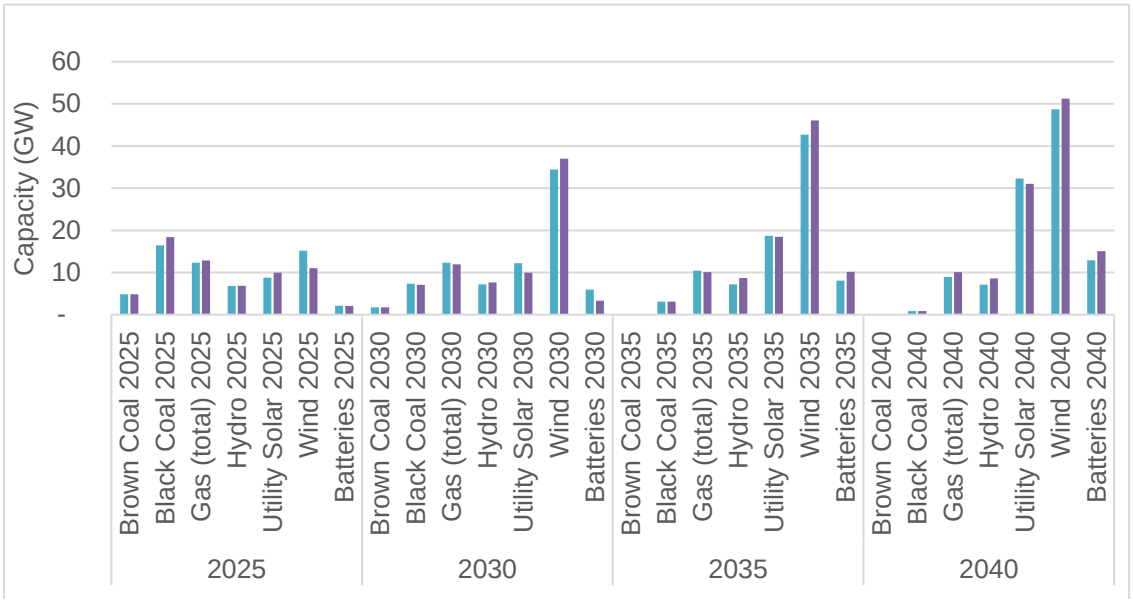

Figure 3 - Validation of PyPSA model vs ISP

Annual Matching

Analysis using the PyPSA model found that corporates that procure 100% Renewable Energy on an annual basis do not induce additional renewable energy (RE) investment. Annually matching does not reduce emissions at all and does not affect the curtailment of wind and solar in the NEM. Figure 4 compares the capacity build out of the BAU and the scenario where 100% of corporates match RE generation with consumption on an annual basis, noting that the capacity of each technology was identical at each time step. The rationale for this finding being that if coal closures are treated as fixed dates, new RE capacity will be built regardless, providing enough renewable energy over the year to completely cover the consumption of corporates.

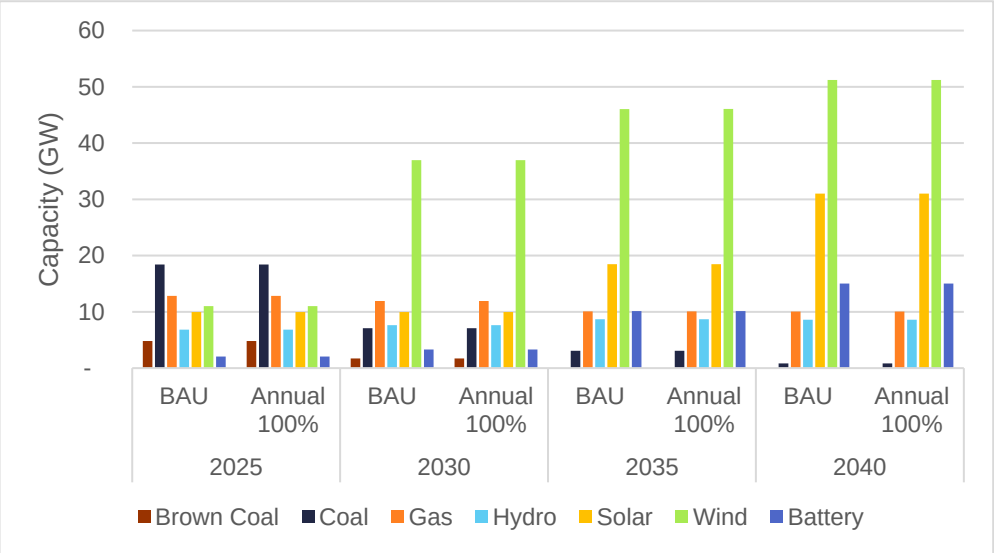

Figure 4 - BAU vs 100% of C&Is Annual Matching

Hourly Matching

For the third scenario, where corporates match demand and generation on an hourly basis, the following constraint was applied to the model:

$$\sum_{g \in p} Renewable\ Generation_h + \sum_{s \in p} Dispatch\ from\ Batteries - \sum_{s \in p} Storage\ from\ Batteries > \sum_{l \in NEM} Matching\ C\&I\ consumption_h$$

Where g = generator, s = storage unit, l = load, and p = portfolio of RE generators and storage units that C&Is can match with, h = specific hour in the year. This scenario led to additional renewable energy investment, however this trend only really emerged once 50% or more of C&Is match on a 24/7 basis. Specifically, 10% of C&Is 24/7 matching did not induce any additional RE investment, and 25% only induced ~1GW of additional capacity. Interestingly, almost all of the additional capacity was solar and batteries, there was no additional wind capacity built. Similar trends were seen on the emissions front, as emissions were significantly reduced once 50% or more of C&Is match on a 24/7 basis. The differences for both capacity and emissions compared to the BAU were greatest in 2030, when there were greater portions of thermal generation still expected to be online. Further, increasing RE capacity in the 24/7 scenario led to increased curtailment as well. Figure 5 highlights the RE capacity for the hourly matching scenarios at each

step and Figure 6 outlines the associated emissions in each investment period for the same scenarios.

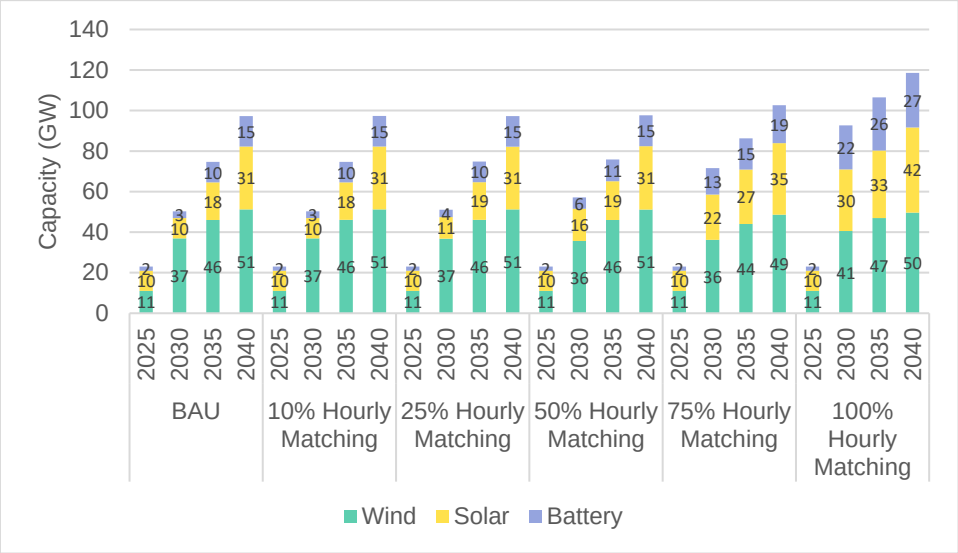

Figure 5 - RE Capacity of Hourly matching scenarios

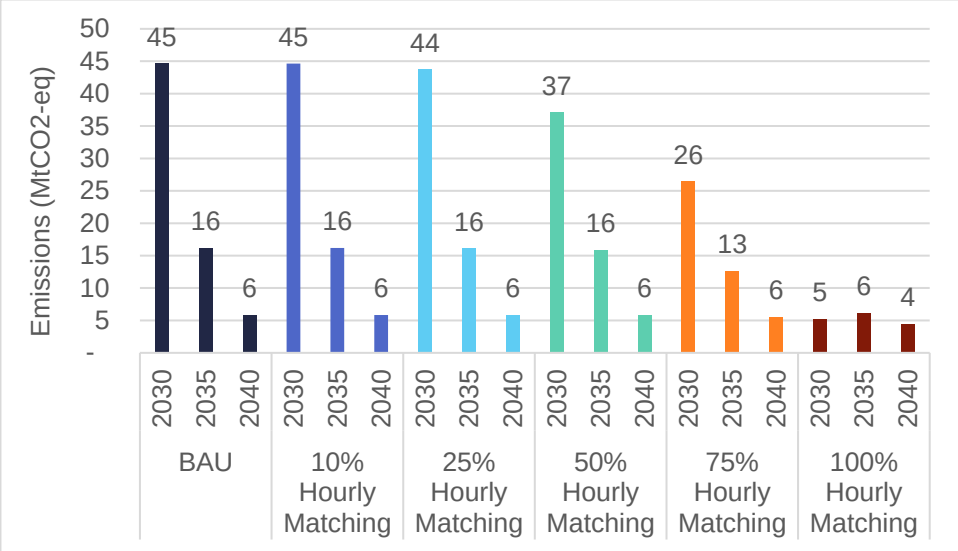

Figure 6 - Emissions of Hourly matching scenarios

Acknowledgement

This project was made possible due to the support from Racefor2030. Thank you for the funding linked to the 24/7 TRUEZERO project.