Seasonal Hydrogen Storage for Solar Renewable Energy

Executive Summary

Sophie Burgess, Dr Fiona J Beck

Research School of Electrical, Energy and Materials Engineering

u6702942@anu.edu.au, fiona.beck@anu.edu.au

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Hydrogen fuels could be a potential solution to many of the challenges associated with the transition to renewable energy technologies, including grid firming to account for renewable seasonal intermittency. Of the main renewable energy alternatives, solar photovoltaic energy has the largest seasonal intermittency. Solving the challenge of seasonal intermittency for renewable energy is critical for the future of grid stability, and this is especially crucial for solar energy due to its expected major role in the reduction of carbon emissions. One potential storage solution is to use the excess solar electricity produced to generate hydrogen in times of high solar exposure. Hydrogen could then be produced over the course of several months and stored in high volumes as a compressed gas in salt caverns and retrieved in months of high solar exposure to be utilised in a fuel cell.

This report investigates seasonal hydrogen storage for solar energy around Australia. We considered a simple scenario: a fixed daily output is required from a solar power plant all year round. The two options for meeting this required output are to either oversize the solar system to ensure sufficient power all year round, or have a smaller solar system with hydrogen storage.

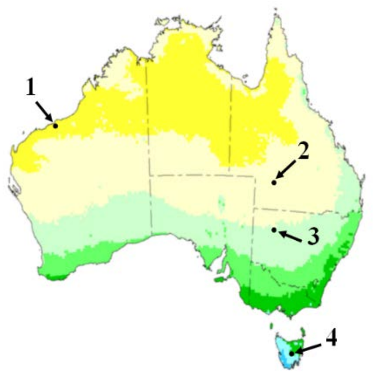

Figure 1 Location placement on BOM data map for average annual solar exposure (2017).

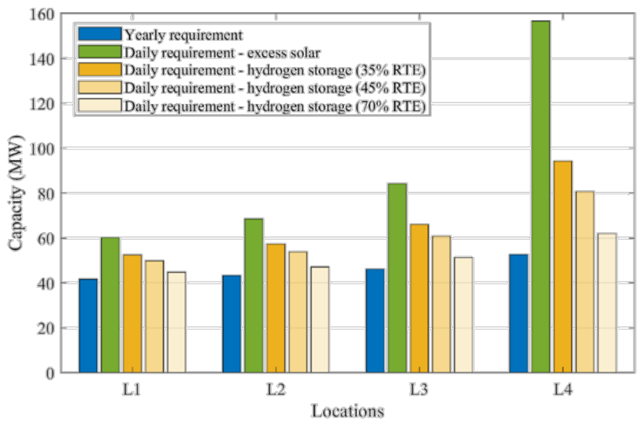

Figure 2. Bar graph showing capacity of hypothetical solar farms, including forecast improvements to round-trip efficiency (RTE).

We choose to locate our power plant in 4 regions of Australia, shown in Figure 1. The solar irradiance data from the Bureau of Meteorology (BOM) showed that peak in irradiance in the summer months was approximately uniform for all locations, however the minimum value reduced significantly with the reduction in average annual solar exposure indicated by the colours in Figure 1. This means that from locations 1-4, the amplitude of seasonal intermittency increases.

Figure 2 shows the capacity of solar plants in each region, for a plant sized to provide a fixed yearly power requirement (blue), a fixed daily power requirement with no storage (green), and a fixed daily power requirement with seasonal hydrogen storage (orange). Data is shown for different round trip efficiencies (RTE) of hydrogen generation, storage and conversion back into electricity. The results indicate that hydrogen storage will only significantly reduce the required solar plant capacity for locations 3 and 4, with lower average annual solar exposure.

For the hydrogen storage to be utilised in any location, the costs associated with installing and maintaining the hydrogen system must be less than or equal to the cost difference in solar cells. This means that the financial capital saved as solar cell area is reduced from the oversized solar scenario to the smaller solar scenario becomes the budget limit for a hydrogen system. From this it can be surmised that hydrogen storage will be most feasible for locations with larger amplitudes of seasonal intermittency (Figure 2). With improvements to round-trip efficiency, it is observed that this budget will increase for all locations but most significantly for locations with larger seasonal variations.

While it can be concluded that hydrogen storage is most effective in areas of high seasonal amplitude, harvesting solar energy is more practical in locations with the smallest seasonal amplitude. This contradiction creates a spectrum of potential options for utilisation; at one end of the spectrum, solar energy for grid supply could be harvested in large volumes in areas of high average annual solar exposure and low seasonal amplitude, such as L1. In this case, networks of high voltage power lines would be required to transport the electricity from these regions to the areas of high population, which may incur large installation and maintenance costs. Alternatively, solar farms could be installed closer to areas of high population towards the south-east Australian coast and the larger seasonal variation could be managed through use of hydrogen storage. Both of these options could potentially solve the challenge of renewable seasonal variation; however, the option or combination thereof selected will largely depend on additional feasibility factors.