CET Submission to SA Royal Commission on Nuclear Power

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1. Key requirements for future utility scale, grid-connected generating plant are anticipated to be flexibility and capacity to provide firm supply.

There is a growing demand for new power generation with capacity to provide both low net CO_2 emissions and firm supply. Firm supply is increasingly sought in OECD nations because the growth in intermittent renewables is leading to the increased curtailment of their output, while the strong growth in total demand in non-OECD nations is making it too expensive to install new plant that cannot provide firm supply (Crespo, 2015). Flexibility is also needed to accommodate the increasing penetration in intermittent renewable energy supply, together with the inherent variability in demand. The requirement for flexibility is particularly true in the SA context owing to the high penetration of intermittent wind power. For example, this penetration has now reached the point where the entire grid has been supplied by wind power for short periods. Furthermore, presently the State's load factor (i.e. the ratio of peak demand to average demand) is the highest in Australia (AEMO, 2015). This implies that SA has an even greater requirement than most other regions for flexibility in its generators and is poorly suited to accommodate additional inflexible supply.

Nuclear power is well placed to provide firm supply, but presently available nuclear power has relatively poor flexibility (Ruth et al., 2015). In contrast combustion has the greatest flexibility of any commercially available technology, owing to its utilisation of stored chemical energy in fuels, which are also widely distributed. While combustion of fossil fuels with current commercial technology has high CO_2 emissions, in combination with solar thermal as a hybrid, they offer commercially-available technology with relatively low CO_2 emissions together with flexibility and firm supply. Incorporating the combustion option also allows the use of renewable fuels from sources like biomass or solar fuels (e.g. hydrogen or its derived fuels such as ammonia), which are expected to become increasingly widely available in the future and offer both flexibility and a substantial reduction in CO_2 emissions. This suggests that the potential for nuclear power penetration within SA will be relatively small and less than that of hybrids.

Hybrids between concentrating solar thermal (CST) and combustion offer the lowest cost way to provide the storage of renewable energy for which there is growing global demand for energy storage (IEA World Energy Outlook, 2012). This is because it is very much cheaper to store heat than electricity, which has been identified as a key driver for the ongoing development of CST technology despite the rapidly reducing costs of solar PV (IEA Roadmap, 2014). However, hybrids are necessary both to ensure firm supply and to enable the maximum economic utilisation of thermal energy storage (TES). That is, the economically optimal amount of storage is somewhere between 4 and 12 hours, which is sufficient to load-shift from the period of strong solar resource into the load peak later in the evening and/or to cover the diurnal variation. However, to provide sufficient storage for periods of extended cloud requires 4 to 10 times more storage capacity, which is much more expensive and also provides additional capacity that is increasingly rarely used, resulting in low capital utilisation (Kueh et al., 2015).

Combustion is expected to remain as an important component of a network for the foreseeable future to ensure firm supply, even in the event of growing penetration of storage. This is because the inclusion of some combustion is expected to be very much cheaper than relying solely on storage. This is illustrated by Figure 1, which presents the dependence of the calculated probability of an unscheduled reduction in output due to solar resource as a function of storage capacity for a single solar thermal plant at six sites of excellent solar resource. This shows that the capacity of the storage required to provide firm supply is unlikely to ever be economic, at least for the case in which constant output is needed. For example, for the case that the probability of an unscheduled reduction is 0.3% (i.e. 1 day in 3 years), not only would the storage capacity need to be between 50 and 300 hours, depending on the site, but the capacity of the heliostat field relative to that of the thermal conversion unit (e.g. power block) is a factor of ten (Kueh et al, 2015). Furthermore, this study also showed that increasing the capacity of the storage facility above a capacity of about 12 hours (depending on the site), results in a decrease in the utilisation of the facility. That is, the progressive increase in the oversizing of the storage facility and the heliostat field to reduce the probability of an unscheduled shut-down, reduces the extent to which the facility is utilised. Hence, while many other demand scenarios and turn-down scenarios are possible than that shown here, this assessment is sufficient to illustrate that it is not economically viable to provide the massive oversizing needed to design for “worst-case” scenarios of relatively rare periods of extended cloud cover. Instead, it will inevitably be very much cheaper to design the storage facility to be fully utilised and to provide the capacity for firm supply through a hybrid (Kueh et al, 2015).

In summary, the relatively low flexibility of commercially-available nuclear power will limit the extent to which they are likely to be relevant to the South Australian context, without additional investment in power to fuel and/or network interconnections. Note that the same is not true for off-grid systems from large mines and minerals processing plants, such as in Olympic Dam, which have a very steady demand that is likely to be very compatible with nuclear power.

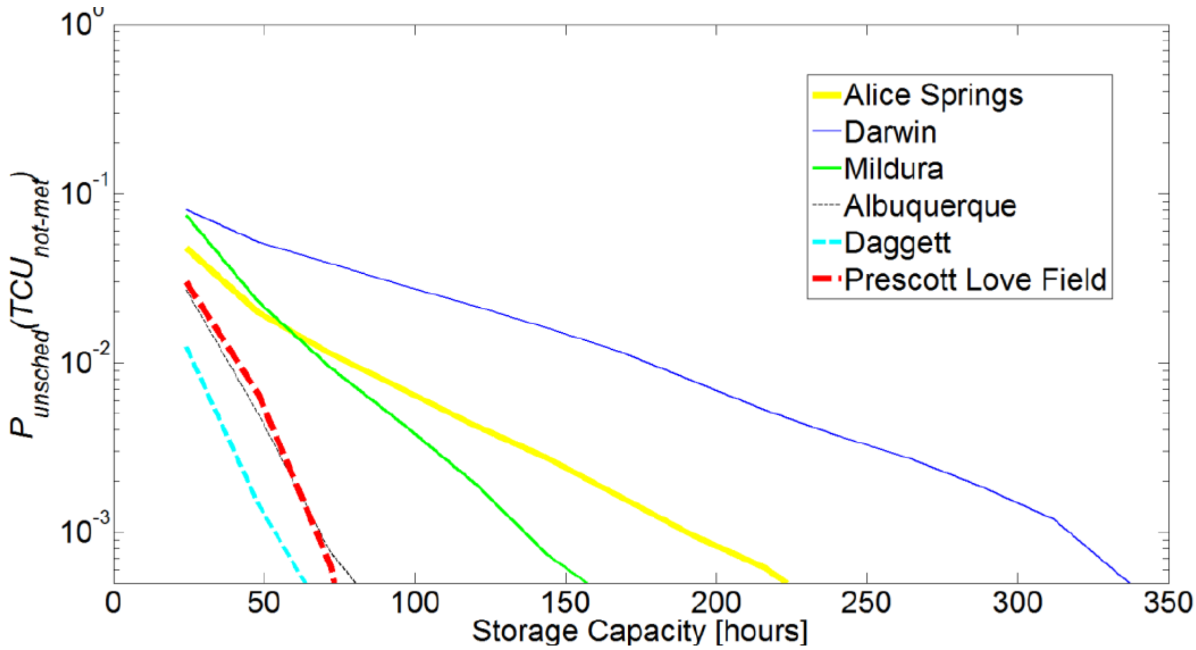

Figure 1: Calculated capacity of thermal storage required to achieve a given probability of unscheduled failure (*P unsched*)to meet the steady demand of a thermal conversion unit (*TCU*), based on a model of a plant that assumes steady state at each half-hour time-step from time series of historical direct normal irradiance at six sites with excellent resource. The peak capacity of the heliostat field is also a factor of 10 larger than that of the TCU (Kueh et al., 2015).

2. To what extent is the potential generation of power in SA linked to the mining of uranium?

In our opinion, the link between the mining of uranium in SA and the potential benefit of using uranium for nuclear power in SA will be weak unless SA were also to perform and/or to control the nuclear fuel processing chain. That is, because:

- The total fuel cost, including processing, contributes only about 10% to the levelised cost of electricity for nuclear power, which is about one quarter of the relative contribution of the price of coal to coal-generated power (Du and Parsons, 2009). Hence, even in the extreme and highly unlikely scenario in which SA were to process all of its uranium and to supply free fuel to our power plant, this would still represent only a 10% reduction in the cost of power, which is far less than the uncertainty in the estimated cost of power. Furthermore, this actual leverage would be even less, given that it would take many years and considerable investment for SA to be able to process its uranium to fuel. Furthermore, the cost of the raw uranium represents only a small fraction of the total cost of the fuel. That is, the majority of the value being in the downstream processing.
- The capacity of any nuclear plants in SA would represent only a relatively small fraction of the energy output of SA's uranium exports. That is, Australia's uranium exports are about 5,000 PJ pa, of which about 50% comes from Olympic Dam. In contrast, SA's entire energy network constitutes about 1 GW average, which is 294 PJ pa. Assuming one third

of SA's supply could be provided from nuclear power (which is likely to be an upper estimate given our existing strong investment in wind power and natural gas generating plant) and a 30% cycle efficiency, SA would still export some 80% of its uranium.
- There is negligible environmental benefit in utilising nuclear fuel near to the point of use over that of transporting it for use elsewhere in the world. This is because nuclear fuels are so energy dense that the loss associated with transport is significantly less than 1% of the total energy content of the fuel.

On this basis, the assessment of whether SA should invest in nuclear power should be undertaken independent from any relationship to of our indigenous supply of the nuclear resource. Other issues, such as social acceptance and lack of regulatory framework, have a far greater influence on the question of whether SA should invest in nuclear power.

3. What type of investment in the nuclear energy chain is likely to offer the best return on investment to establish "value-add" to SA's resources?

While Australia's uranium exports represents 11% of the energy content of Australia energy exports (ABARE 2010), its value is only $620m pa, which is 0.8% of the national value of energy exports. That is, Australia extracts only a small fraction of the potential value of its uranium exports by exporting low-grade uranium. Hence there is great potential for SA to extract greater value from the nuclear power fuel and reprocessing cycle. Given that considerable research is required to identify where in the fuel's cycle SA would be best placed to invest in the value chain, it seems to be logical to invest in the research required to identify such opportunities, such as through the State's higher education sector.

4. Expected costs of nuclear power in Australia relative to the international benchmarks.

There is a high likelihood that the cost of establishing nuclear power in Australia will be significantly higher than the international benchmarks. This is because:

- There are significant risks, costs and potential delays associated with the need to establish a regulatory framework, which is needed for every stage of the process spanning site selection, design, construction, operation and management. Since no regulatory framework exists, its establishment would incur a considerable cost;
- There is a high risk of cost blow-outs that could be incurred from delays associated with social license to operate;
- There is a lack of any real expertise in nuclear power in Australia, spanning all the way from education and training through to construction, operation and safety. It would take many years to establish the pool of expertise needed to avoid cost blow-outs.

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