bright new world

Stable Climate. Rich Nature. Prosperous Humanity.

Submission to

Australian Energy Market Operator (AEMO)

Planning and Forecasting consultation

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Table of Contents

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Executive Summary

Bright New World welcomes the Australian Energy Market Operators (AEMO) 2020 planning and forecasting consultation process. Accurately planning and forecasting the National Electricity Market's (NEM) future technology mix is essential to avoid and prevent failures in a vitally important system.

Bright New World is a not-for-profit environmental NGO based in South Australia. We believe that human prosperity and environmental conservation can work together rather than in conflict. Our core ethos is: Stable Climate, Rich Nature, Prosperous Humanity.

A key component is access to affordable plentiful energy that is low carbon and low impact to the environment. Bright New World supports any low carbon generation deployment in Australia that achieves the objectives of reducing emissions, minimising environmental impacts and enables a high quality of life. These have been referred to in prior electricity market reviews as the "energy trilemma"; affordable, reliable and environmentally responsible energy sector.

The consultation paper outlines the Forecasting Best Practice Guidelines that AEMO applies to their forecasting and planning information. These are accuracy, transparency, and effective engagement. Bright New World contends for the case of nuclear energy none of these best practice guidelines were followed. Immediate action needs to be taken to ensure all technologies in the GenCost paper are held to the same standards, especially nuclear.

The accuracy of the nuclear energy figure is not representative of detailed vendor statements or current peer reviewed literature. The $16,000/kW figure is indefensible against current information available to AEMO, CSIRO and GHD (see section 1.2.1-1.2.3). This figure represents a hypothetical reactor (Generation 4 300MWe SMR) that is then generalised to "Nuclear SMR" in the 2019 update.

Upon questioning in the recent inquiry into the prerequisites for nuclear energy in Australia the origin of this figure and its original source are unknown to the authors, CSIRO. There is no reference in the GHD report that defines where or how the $16,000/kW figure was derived. Thus the transparency of the original figure is opaque, and not clear at all to its original source or calculations to arrive at the figure.

We also contend that to engage in effective engagement associations, professionals or organisations with nuclear expertise should have been consulted with during the update to GenCost 2018. Only the Australian Nuclear Science and Technology Organisation was invited. Bright New World and other organisations with nuclear knowledge were only engaged by third parties, and once consultation began were told it was not a priority.

These guidelines are echoed in the GenCost study stating "wide stakeholder engagement and transparency are also built into the project design". Bright New World reviewed the document and its supporting work for the treatment of SMR nuclear technology. The results are not consistent with 'wide stakeholder engagement and transparency' and certainly not presenting results that are a function of 'global technology deployment'.

AEMO and CSIRO with the input of knowledgeable stakeholders need to amend the capital cost figures for nuclear SMR in the GenCost data set to reflect current knowledge on the potential costs. Evidence in this submission points to capital cost figures falling in the range of AU$5,300 to $10,000/kW for "Nuclear SMR".

1. GenCost 2018 & 2019 review

1.1 Capital Expenditure

The main concern, which is by far the most material assumption, lies in the extraordinary capex assumption of $16,000 kW installed. GHD offers a premise that they must look to advanced designs with a strong business case. Given that, a capex of $16,000/kW installed, which is a profoundly weak commercial case, is contradictory to the premise.

No developer would have been able to advance SMR designs as they have done if their data suggested $16,000/kW would be their price point. This simply doesn't make sense. GenCost 2019 chooses to accept the figure as it is "reasonable for a technology at low commercial development"[1]. However there is no further justification to affirm this figure as reasonable for all nuclear SMR technology.

Examining the references for the GHD section on nuclear, they selected a capex without any:

- industry consultation from advanced reactor developers, or
- referencing of independent studies that have put effort into answer this question (see section 1.3)

The capex has a with a vague reference and no link ('World Nuclear Association')[2]. We have perused the page for small modular reactors at the WNA site and spoken to them directly. The $16,000/kW figure <u>does not appear</u> on their website or in their documentation for a 300MWe Gen 4 reactor.

For example the NuScale SMR was presented in evidence to a Commonwealth inquiry of US$3,600 per kW[3]. That price would need to be tripled to yield AU$16,000/kW. While its plausible NuScale is overly optimistic about their product, it's unlikely they would be wrong by a factor of three. That company has received of both extensive government funding through competition and private CAPEX, and they have sold the first 150 MW of their first plant in Idaho.

This is certainly the biggest concern. The capex appears to be taken from nowhere, for a hypothetical reactor, with no relevant references. The figure is contradicted by studies that are following these developments and figures from SMR developers that look likely to deploy in the 2020s (see section 1.1-1.3).

1.2 Overnight capital cost figures

Bright New World undertook a review of current peer reviewed literature to assess whether the capital cost the GenCost papers outline ($16,000/kW) are within the bounds of current knowledge. The following is a representation of both large giga-watt scale nuclear and SMR capital costs from studies undertaking extensive literature reviews.

1.2.1 Large scale nuclear

A study by Lovering, Yip and Nordhouse in 2016[4] undertook an analysis of overnight capital costs (OCC) of nuclear to understand trends in the capital of nuclear. Of their analysis of 349 nuclear reactors across several countries there are key differences in the jurisdictional cost escalation and learning rates across the countries assessed.

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1 (Graham, 2019)
2 (GHD, 2018)
3 (NuScale, 2019)
4 (Lovering, 2016)

Figure 1 highlights the historical trends in nuclear deployment across several countries. The full study has detailed datasets on historical OCC figures. This data demonstrates there are maximum OCC figures of up to $11,000/kW (2010 USD), with the majority of data points between $1,000 to $6,000/kW.

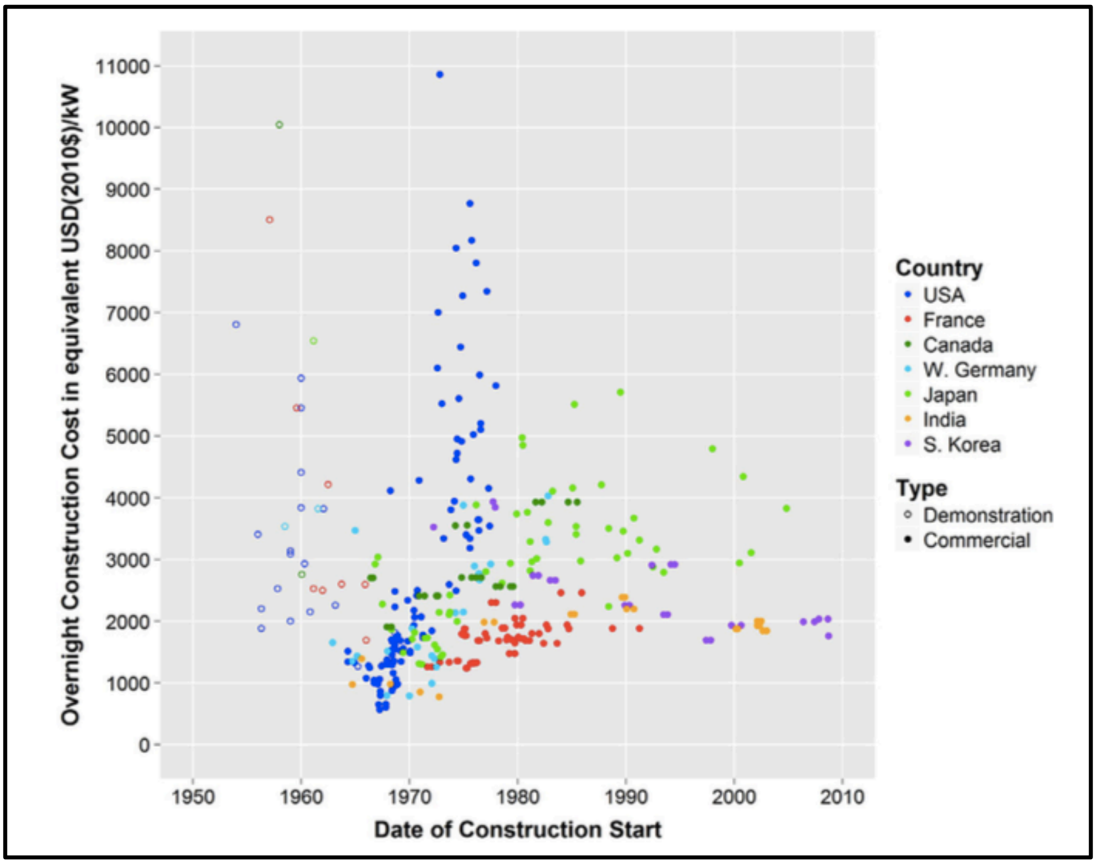

Figure 1 - Overnight Capital Costs of nuclear from Lovering, Yip and Nordhouse (2016)

1.2.2 Small Modular Reactors

The attractiveness of SMRs is in their modularity and lower capital cost per unit compared to large nuclear plants. As below discussed, the majority of the financial risk for nuclear is in the upfront costs. To be able to deploy nuclear in smaller amounts helps to reduce financial risk, and flexibility to add capacity as the grid requires.

A study released in February 2020 undertook a systemic review of the economics and finance of small modular reactors. The study by Mignacca and Locatelli is a literature review of current economic data on SMRs and is a source of references that would greatly inform the GenCost report. Their review demonstrates for a range of OCC SMR costs based on the current literature, these are replicated in figure 3[5].

Another review of SMR costs was undertaken in 2013 by asking 16 experts "who are involved in, or have access to, engineering-economic assessments of SMR projects"[6]. The data from this study was incorporated into Mignacca and Locatelli. This assessment arrived at a range of $4,000-$16,300/kW for a 45MWe SMR, and $3,200-$7,100/kW for a 225MWe SMR (2013 USD). Given the GHD SMR was at a size comparable to the latter multiple expert assessment

[5] (Mignacca, 2020)
[6] (Abdulla, 2013)

the $16,000/kW (AUD) figure is well beyond the upper bound. Additionally the GHD study relied on one nuclear expert[7], compared to the above 16.

The Canadian SMR roadmap[8] assessed 47 different SMR capital cost estimates and 17 large scale nuclear reactors (>1GWe). Figure 8 demonstrates a wide array of capital cost estimates for different SMR types (presented in Canadian Dollars; 1CDN = 1.11AUD).

It should be noted that there are only a handful (n=3) of references in the SMR roadmap where the SMR capital cost is close to the GenCost 2018 and 2019 figures but none are referenced in the GenCost 2018 or 2019 reports.

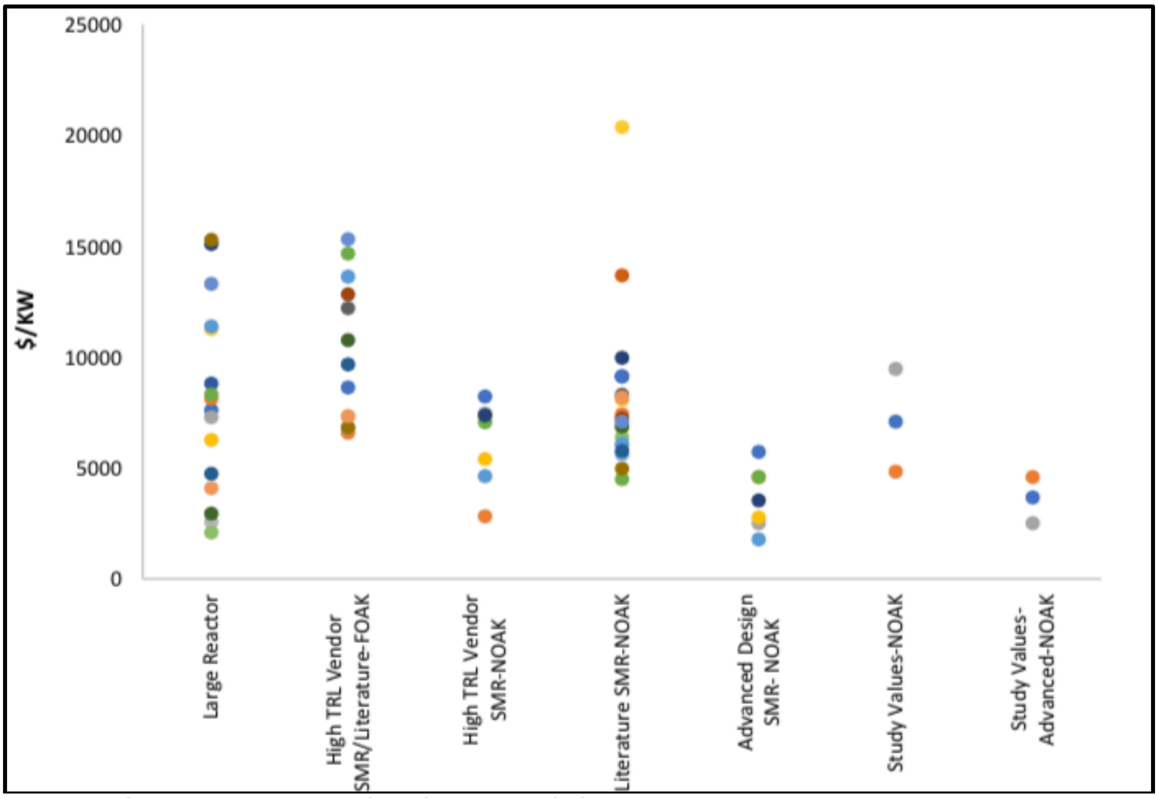

Figure 2 - SMR capital costs in CAD (= 1.11 AUD), SMR Roadmap, 2018

[7] Bright New World has spoken to people familiar with the origin of the GHD $16,000/kW figure and anecdotal evidence suggests the figure was derived from one nuclear expert in the UK.
[8] (SMR Roadmap, 2018)

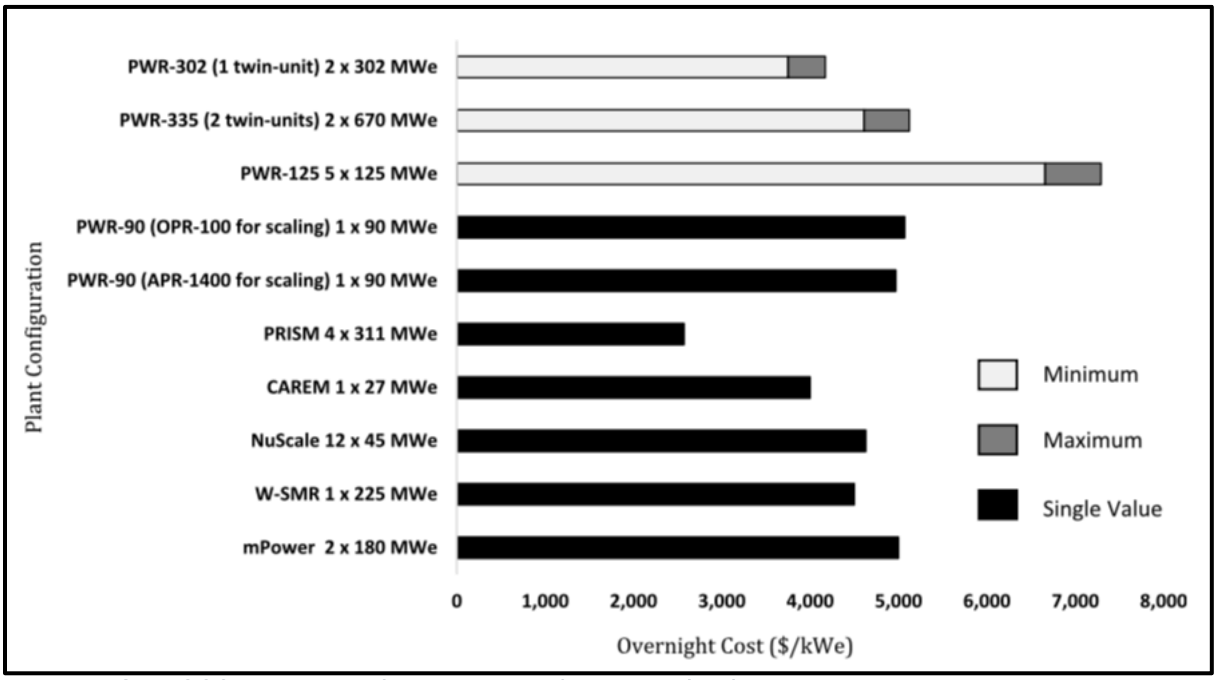

Figure 3 - SMR OCC estimations from Mignacca & Locatelli (p. 8)

1.2.3 Advanced reactor designs (Generation 4 reactors)

The Energy Options Network in 2017 undertook an analysis of advanced reactor designs and had input from several reactor vendors to the costs of their plant. Their analysis determined that the capital costs for all participating companies averaged US$3,782/kW (figure 4 [9]. While these represent vendor assessments, escalating these capital costs to $16,000/kW would require a doubling of estimates.

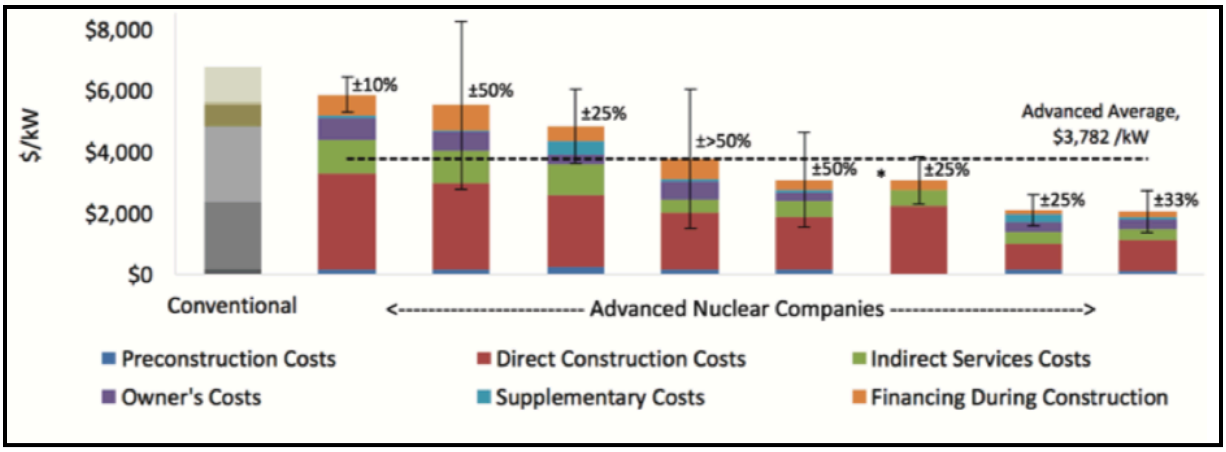

Figure 4 - Energy Options Network: Capital cost (USD)

2. Other concerns

2.1 Reactor type definition

GHD states:

> *Noting that this legislation must be repealed in order to begin the development of a nuclear power plant, it is highly likely that development of Gen III+ reactors will happen not happen before 2030 in Australia, and that*

[9] (Energy Options Network, 2017)

> *Australia will seek to construct a Gen IV reactor which may address safety concerns of the public and have an economical business case[10].*

This statement is unreferenced. We are unclear on what basis GHD makes presumptions about what unknown future investors might or might not seek to develop in the event that nuclear power was relieved of its prohibitions. We suspect the authors are not clear on the distinctions between the generations of nuclear designs and how this might impact investment.

The afore-mentioned small modular reactor from NuScale, for example, is not a Generation IV design (given it uses the well-known light water reactor fuel cycle with solid uranium oxide fuel). However, it has already resulted in profound changes in regulations from the Nuclear Regulatory Commission regarding its safety profile, including that it requires no external back up power supply and no emergency planning zone. It is an entirely plausible choice of design for Australia. The same can be said of the Rolls Royce SMR. While small in size, there is nothing in the fuel cycle to suggest it is Generation 4.

As the technology is generalised as “Nuclear SMR” in the 2019 GenCost update there is serious concerns that adopting a $16,000/kW cost for a narrow reactor technology, when the GenCost data is generalised. Hence capital cost figures for reactor technologies with greater global expertise and knowledge (e.g. light water reactors) will be excluded.

2.2 Unit size constraint

On assumed unit size, GHD references:

> *‘World Nuclear Association - Largest Small Modular Reactor (SMR) size. Smaller sizes likely to be prohibitively expensive to generate a positive IRR’[11].*

This is potentially misleading. There are many smaller unit sizes that will be aggregated into larger power plants – that’s a critical aspect of the commercial model for advanced small modular reactors. Only some have single units of 300 MWe. If GHD applied that as a constraint, this is an error. Referring to NuScale again, that unit size is only 60 MWe, but with initial intentions to deploy in arrays of 12 units for a power plant of 720 MWe. The Terrestrial Energy IMSR is 192 MWe and might be deployed in arrays with multiple such units.

2.3 Erroneous reference for construction time

Construction time is assumed 260 weeks (5 years)[12] based on Moreira, J. M. L., & Carajilescov, P. (2011). That paper is a retrospective review of pressurised water reactors in the established nuclear nations. That is close to irrelevant for the SMR commercial model. The commercial model of advanced small reactors is factory construction of units with high quality control, delivered to site by rail/road, and placed in-situ with balance of plant.

No SMR developer is working on the basis of 5-year construction. This would also raise the LCOE considerably compared with a more probable 3 three years on the basis of what those bringing SMR to market are actually devising.

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[10] (GHD, 2018)

[11] *ibid*

[12] *ibid*

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