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November 3rd, 2024

Written submission: Inquiry into the consideration of nuclear power generation in Australia

Thank you for the opportunity to provide a submission to the House Select Committee on Nuclear Energy.

My response to the terms of reference will concentrate on details relating to

a) deployment timeframes;

h) risk management for natural disasters or other any safety concerns;

i) potential share of total energy system mix;

k) costs of deploying, operating and maintaining nuclear power stations; and

l) the impact of the deployment, operation and maintenance of nuclear power stations on electricity affordability,

as public understanding of these issues has suffered from slanted claims in the media – the text of this post[1] on X being a prime example:

Experts have told us that Peter Dutton's nuclear scheme could cost $600bn, take 20 years, only secure 4% of the energy grid and push up your power bills hundreds of dollars.

Whether or not it eventually contributes to the energy mix, nuclear power generation in Australia can only be maturely and legitimately considered through reliable information which withstands scrutiny.

[1] x.com/Bowenchris/status/1844252726253002885

a) deployment timeframes

Claims made against inclusion of nuclear energy on a timeframe basis are that it will “take 20 years” (or even longer), but they are not made by experts in the subject matter.

A reasonable upper limit for a concerted Australian nuclear power program was determined to be fifteen years in the previous parliamentary committee process.[2]

A commitment to adopt nuclear energy necessarily includes several years of preparation prior to “first concrete” of the first power power station. As with the duration of construction, this need not be protracted, however. The guidance from the IAEA Milestones Approach, which is being implemented in around 30 newcomer countries, is a 10–15 year phased timeframe. An expert in the subject matter has concluded that international experience, alongside Australia's current nuclear capabilities, legal stability and economic capacity makes it likely that this timeframe can be compressed once nuclear energy is officially considered as an option.[3] Note that this doesn't necessarily require the immediate lifting of the federal prohibition.

Staying on schedule will be critical for a compressed Milestones Approach timeframe (or any equivalent). Chapter 3 of Pathways to Commercial Liftoff: Advanced Nuclear, recently published by the US DOE,[4] explores what to consider for a successful schedule effort, including consortium approaches to financing, completed reactor design, and various known delay factors for the recent Vogtle expansion. Significant work has recently been completed to understand where improvements can be achieved, some of which is illustrated here.

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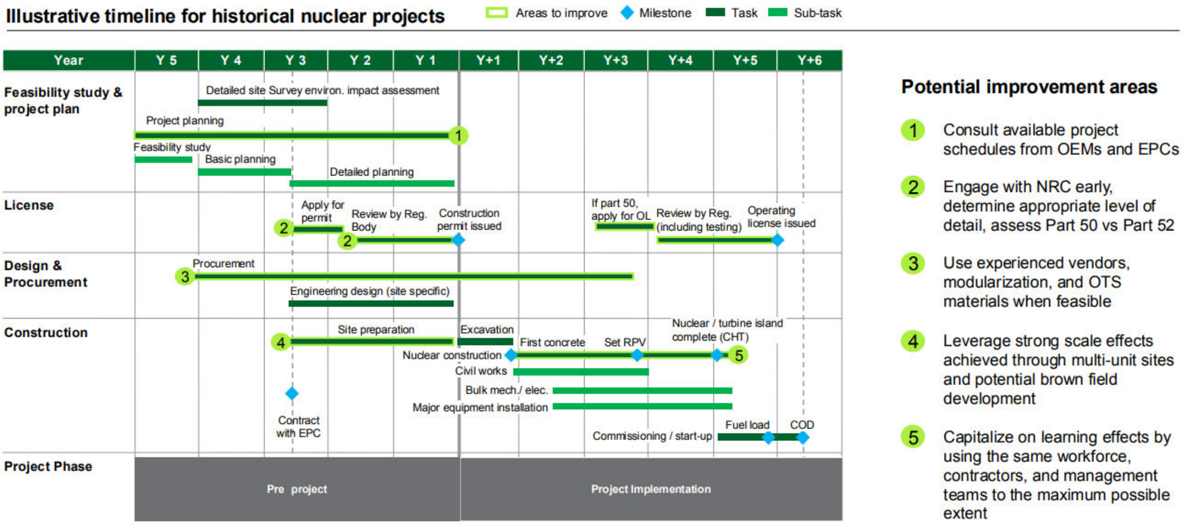
[2] www.csiro.au/en/research/technology-space/energy/GenCost page 35
[3] www.nuclearaustralia.org.au/wp-content/uploads/2022/04/P14_Cook_ANA2022.pdf
[4] liftoff.energy.gov/advanced-nuclear/

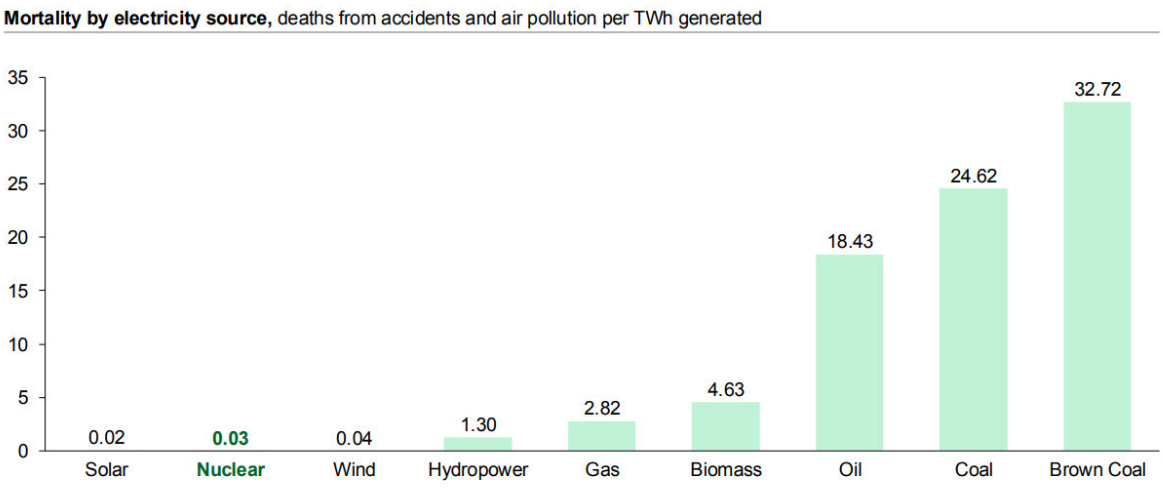
Figure 35: Illustrative major steps for building a nuclear power plant from historical LWR projects[129]



h) risk management for natural disasters or other any safety concerns

Commercial nuclear energy has been operated for seventy years, and under widely varying national regulatory arrangements for most of that time. Even accounting for the famous accidents, actual human mortality is as minor as it is for solar and wind energy, normalised for energy production.

Figure 17: Nuclear is one of the safest sources of energy, in line with solar and wind[71]



Thus, safety concerns are usually not based on factual information but instead on perception. Anti-nuclear campaigners have sought to influence this perception for many decades, often successfully, to stop or shut nuclear projects. Terms like "risky" trade on this perception and do not assist the public's understanding.

While each nuclear project needs to incorporate adequate protection against site-specific natural disaster risks, the global track record of nuclear energy in general indicates long-term success, and informs improvements in guidance and regulatory expectations through organisations such as the IAEA, INPO, and EPRI, and national regulators (NRC, CNSC, ONR).[5]

Engagement with genuine safety concerns – held by people who legitimately wish to gain knowledge about an aspect of nuclear power operation, fuel cycle management, reactor protection designs, etc, which they haven't previously had the chance to understand, or want to know for sure whether or not it will affect them – is vital as part of any nuclear project.

i) potential share of total energy system mix

Nuclear energy generally comprises a substantial share alongside other firm and intermittent energy sources in nuclear-inclusive nation-scale grids. It is not 100% of any such grid, and is either the major share, or a very minor share, in only a few grids.

A proposed capacity of 11 GW for brownfield Australian power station sites has faced an objection on the basis of the claim that it would contribute approximately 4% of annual supply by 2050. It is incorrect.

According to the source of this estimate,[6] 4% would be the instantaneous power contribution if solar, wind, storage and gas capacity modelled by AEMO in its Integrated System Plan Step Change Scenario ("around 300

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[5] www.iaea.org/topics/siting
www.wano.info/wp-content/uploads/2024/07/WANO-White-Paper-Nuclear-Industry-New-Build-New-Entrants-1219_1.pdf
www.epri.com/research/products/000000003002023910
www.federalregister.gov/documents/2024/02/29/2024-04223/regulatory-guide-general-site-suitability-for-nuclear-power-stations
www.cnsc-ccsn.gc.ca/eng/acts-and-regulations/regulatory-documents/published/html/regdoc1-1-1-v1-1
www.onr.org.uk/our-work/how-we-regulate/nuclear-site-licensing
[6] smartenergy.org.au/articles/nuclear-fallout-116-600-billion-to-build-7-nuclear-reactors

gigawatts") was all operating at 100% across the National Electricity Market – a complete impossibility for every energy technology in this calculation ***except*** for nuclear power.

Considering instead total annual energy generation in the modelled 2050-51 financial year[7] (approximately 531 terawatt hours) compared to the sum of 'baseload' nuclear generation, as specified by the proposal,[8] for the NEM (WA excluded), the share would be about 14%. If storage is recognised as not being generation, the share of nuclear generation is about 16%.

However, this is merely correcting part of an erroneous analysis effort. Determining the potential share of nuclear energy across Australia's major grids by 2050 or earlier will be better served by impartial system level modelling with a range of sensitivities. Note that AEMO *"does not model nuclear power as it is not permitted by Australia's current laws and rules"*, i.e. insights into the Australian situation cannot be determined through its established procedures. This is in stark contrast to the relevant work by the US DOE:

"Despite the low capital and operating costs of variable renewables, system decarbonization with only variable renewables and storage results in higher system costs because of the volume of generation capacity required for adequacy and reliability (and subsequent decrease in marginal value and utilization rates). Additionally, firm technologies can produce electricity during the most expensive hours when wind and solar are unavailable. Even when priced at a premium per unit of energy, the inclusion of clean firm resources reduces overall system costs."

The "clean firm" capacity share illustrated by the Department of Energy – in the context of potential gigawatts of nuclear power in 2050 – was a range from 19% to 37% (reduced system costs). Also crucially of note, this is in operational partnership with variable renewable sources, i.e. the US Department of Energy considers variable renewable energy and nuclear

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[7] aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2024-integrated-system-plan-isp
[8] www.australianeedsnuclear.org.au

energy to not only be entirely compatible, but to be major components of the future least cost supply system.

k) costs of deploying, operating and maintaining nuclear power stations

I will address point k) with reference to the basic details of these four nuclear reactor designs:

1. European Pressurised Reactor (EPR), 1.6 GWe, owned by Framatome, France

2. Advanced Pressurised Reactor 1400 (APR1400), 1.4 GWe, owned by KEPCO, South Korea

3. Advanced Passive 1000 (AP1000), 1.1 GWe, owned by Westinghouse, USA

4. Boiling Water Reactor 10 (BWRX-300), 0.3 GWe, owned by GEHitachi, USA

Of these four models, only 2, 3 and 4 have been suggested for use in Australia by proponents.

Deploying

Reporting informatively on the costs to deploy nuclear power facilities in Australia currently faces major barriers, with the main barrier being the federal prohibition.

In the country's recent political context, the absence of legitimate project cost estimates has left an information vacuum. Exploitation of this vacuum has included suggestions of exorbitant price tags, with one claim[9] that a "nuclear scheme could cost $600bn". $600 billion AUD corresponds to a rudimentary calculation assuming 11 GW worth of capacity at the same cost as the Hinkley Point C twin EPR 3.2 GW plant in Somerset, UK, at AUD$87 billion (11 ÷ 3.2 =4.4375, 87 x 4.4375 = 299), and doubled.

The "nuclear scheme" in question, proposed by the federal opposition, has, so far, specified reactor models 2 and 3 of those listed above. The

[9] smartenergy.org.au/articles/nuclear-fallout-116-600-billion-to-build-7-nuclear-reactors

significant differences this presents to the UK situation go beyond the choice of reactor model:

- Initial nuclear construction in the UK was "private investment only",[10] resulting in high costs of capital, whereas the proposal in Australia features government ownership
- The UK embarked on projects involving true First-of-a-Kind[11] designs, but multiple AP1000 and APR1400 units now operate in multiple countries. At the official completion of the twin AP1000 Vogtle Expansion Project, Secretary Jennifer Granholm announced, "two down, one hundred and ninety-eight to go!"[12]
- Canadan utility OPG anticipates operation of the first BWRX-300 before 2030[13]
- Australia is capable of running competitive tenders, similar to the successful approach by the UAE, and several European countries more recently.

Operating & Maintaining

The "O&M" costs for nuclear plants are well, and authoritatively, documented, for example by the IEA and OECD-NEA in a 2020 publication.[14] Adjusted for inflation, this component is approximately $14.13 (USD) per MWh in the US. For perspective, this reference lists a range of O&M cost for Australian coal power stations of $10.59 to $23.56 (USD) per MWh.

l) the impact of the deployment, operation and maintenance of nuclear power stations on electricity affordability

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[10] www.oecd-nea.org/upload/docs/application/pdf/2024-06/university_of_cambridge_presentation_taylor.pdf
[11] www.nao.org.uk/wp-content/uploads/2017/06/Hinkley-Point-C.pdf page 42
[12] www.energy.gov/articles/remarks-delivered-secretary-jennifer-m-granholm-startup-vogtle-unit-4-and-growth-us
[13] www.opg.com/releases/opgs-smrs-will-generate-jobs-and-lasting-economic-benefits-for-ontario
[14] www.iea.org/reports/projected-costs-of-generating-electricity-2020 page 57-59

Largely as a consequence of the information vacuum defined in k), there is much speculation around what impact nuclear power operation would have on consumer electricity prices. Since these prices directly influence the cost of living and have a significant political component, opponents reliably predict that inclusion of nuclear energy will "push up your power bills hundreds of dollars."

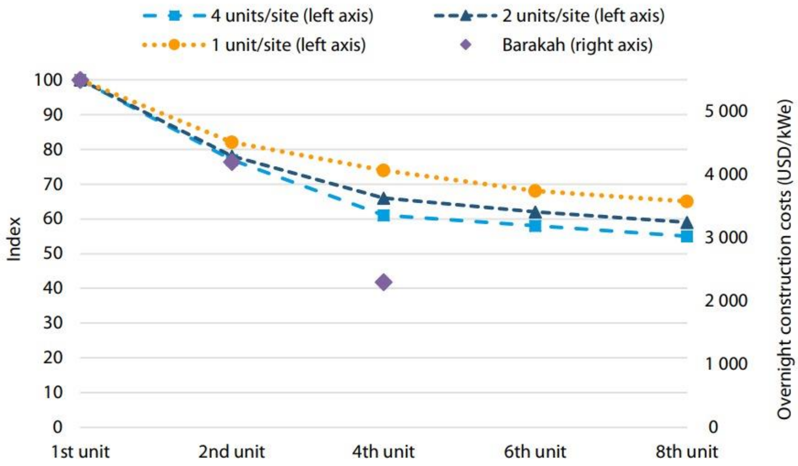
The source of this claim is analysis by an anti-nuclear organisation. It sets several ungenerous assumptions, including heavy emphasis on the UK EPR design (as described previously), a higher cost of capital than strictly required, and an overall unconventional usage of the levelised cost of electricity calculation.[15]

The report neglects sensitivity analyses to explore cost ranges under its limited methodology, in favour of preferred results to justify its title and conclusion. It is also contradicted by the US Department of Energy's report which emphasises the value of design completion and maturity.[16]

Firstly, the conventional large reactor designs (1-3) all have operating reference plants as of 2024, obviating the well-defined difficulties of true First-of-a-Kind construction. Secondly, a planned national reactor fleet of standard design presents distinct opportunities for achieving substantial learning rates.[17]

[15] Ibid, page 33: "The LCOE is the principal tool for comparing the plant-level unit costs of different baseload technologies over their operating lifetimes. The LCOE indicates the economic costs of a generic technology, not the financial costs of a specific projects in a specific market."
[16] liftoff.energy.gov/advanced-nuclear page 47
[17] www.oecd.org/en/publications/unlocking-reductions-in-the-construction-costs-of-nuclear_33ba86e1-en.html

Figure 24: **Average cost of one unit in a programme of n units**



Sources: Based on NEA (2000), *Reduction of Capital Costs of Nuclear Power Plants*; and Gogan (2019), "The potential for nuclear cost reduction."

Ultimately, the question of nuclear generation on electricity affordability deserves rigorous and impartial exploration at the system cost level. This is yet to be performed in Australia. The OECD-NEA[18] has recently provided updated guidance:

A key challenge in system cost analysis is to relate scenario results to relevant cost metrics and to allocate overall costs to particular elements of the model, such as individual technology options, behavioural patterns or policy objectives under carbon constraints of different stringencies. The starting point for such breakdowns will always be the complete costs of an electricity or an energy system required to satisfy given levels of demand at all times under an exogenous set of policy assumptions. A frequently applied technique is to then compare two least-cost equilibria distinguished only by differences in the numerical value of one single parameter, for instance the relative share of nuclear energy and variable renewables. The cost difference can then be allocated to the changed parameter. NEA system cost analysis is thus particularly useful for comparing the costs of different generation mixes to attain long-term policy objectives in terms of carbon emission reductions. Figure 1 shows results for a given electricity system, whose identical demand and carbon constraint are satisfied by different low-carbon generation mixes with

[18] www.oecd-nea.org/jcms/pl_91154/nea-system-cost-analysis-for-integrated-low-carbon-electricity-systems-a-guide-for-stakeholders-and-policymakers

different shares of nuclear energy and variable renewables such as wind and solar PV.

Working with optimised least-cost equilibria also distinguishes NEA system cost analysis from other assessments of system costs or system contributions such as the IEA VaLCOE metric. The latter, beginning from a non-equilibrium constellation, indicates how different technologies would move the system closer or further away from equilibrium. That said, NEA system cost analysis is not confined to any specific least cost equilibrium. The highly flexible mixed integer linear programming POSY model can adopt any number of conditions and constraints corresponding to real-world electricity systems.

Rapidly changing electricity systems subjected to stringent carbon constraints can pose challenges to stakeholders and policymakers at the conceptual level – even before the necessary societal discussion processes are fully under way. In this context, system cost analysis can help answer a series of relevant questions. Examples of possible questions are given below. Many others can be imagined:

- *What are the economic costs of attaining a given carbon emission target such as net zero with different low-carbon generation mixes?*
- *If carbon emission targets are coupled with targets for the deployment of variable renewables such as wind and solar PV, what is the impact of such targets on the capacity mix, the generation mix and the load factors or remaining dispatchable low-carbon generators?*
- *How does the market value of the electricity produced by wind and solar PV decline as their capacity and share in generation increases?*
- *What are the costs and benefits of deploying additional flexibility resources such as batteries, demand response, flexible back-up or additional interconnections?*
- *What is the level, volatility and structure of electricity prices, including hours with zero or negative prices? What is the likely impact on the cost of capital of such volatility?*

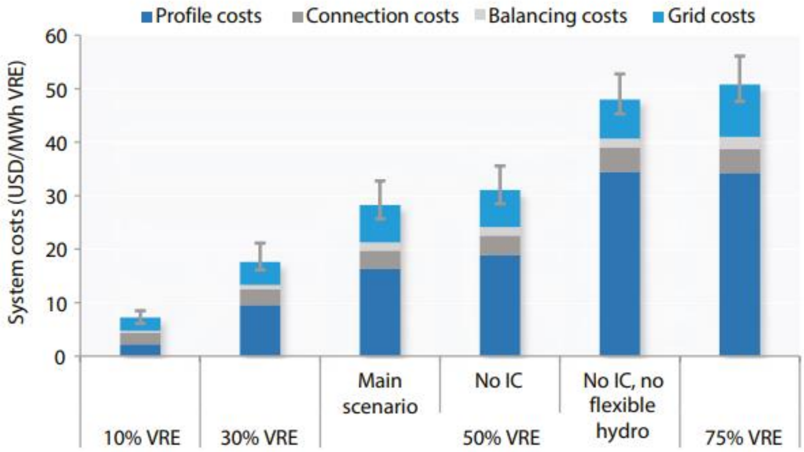
To obtain meaningful results that can help support political decision-making, it is often useful to employ NEA system cost analysis to produce clearly differentiated scenarios that highlight the implications of the strategic policy choices specific to each country. An example of this is provided

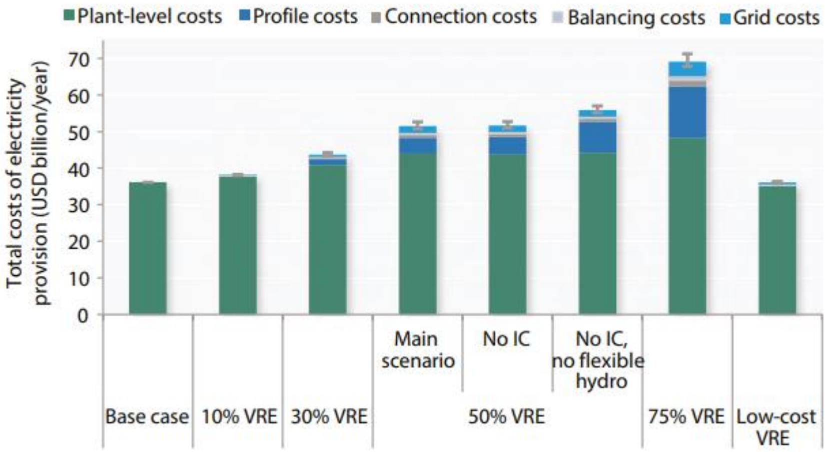
by the results of the 2022 NEA study assessing the system costs of different scenarios to achieve net zero emissions in Switzerland by 2050 (see Figure 2). Each of the fifteen different scenarios combines a specific mix of generation capacity with a given level of interconnection capacity for electricity trading. In this case, results do not come in the form of an additional cost per MWh of solar PV or wind capacity but in the form of a total cost figure for a fully fleshed out scenario, including a careful representation of Switzerland's important hydroelectricity capacity and a series of flexibility options.

NEA system cost analysis thus combines rigour at the methodological level and flexibility at the level of formulating policy-relevant scenarios that aims to provide a useful decision-making tool for decision makers in the energy sector. System cost analysis is also one of the most exciting conceptual advances in energy economics in recent years. It is an effective tool for understanding the costs associated with different strategic choices in the energy field to achieve ambitious carbon targets while maintaining high levels of security of electricity and energy supply.

Figure 1. Total system costs and costs per MWh for different shares of wind and solar PV

(USD/MWh, identical demand and carbon constraint of 50 gCO_2 per MWh)





Source: NEA (2019).

Figure 2. Total system costs of different net zero scenarios in Switzerland

(USD/MWh, identical demand and net zero carbon constraint for all scenarios)