CSIRO-AEMO GenCost 2023-24 Consultation Draft

Stakeholder Submission

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Executive Summary
This personal submission addresses, alone, the treatment of nuclear energy in the *CSIRO-AEMO GenCost 2023-24 Consultation Draft,* commenting upon its potential role in Australia's energy policy.

The key issues raised in this submission are:

- A review of nuclear power generation worldwide **(refer Section 1.0 – Nuclear power generation today)** unequivocally demonstrates the growing adoption and deployment of advanced nuclear technology by leading industrial nations. Thus its effective dismissal by GenCost for consideration in the Australian generation technology mix, based upon arguably limited (and some would suggest biased) analysis, is questionable. Its omission, if continuing to be persisted with, could, and very likely would, deny Australia the ability to reach Net Zero Emissions (NZE – the Australian government's declared bipartisan policy) by 2050.

- Despite urging in previous GenCost submission debates, CSIRO has extraordinarily continued to forego any recorded consultation with reliable respected national and international authorities **(refer Section 2.0 - Reliable sources of nuclear energy expertise)**, notably ANSTO, but also other significant organisations prepared to contribute with authority and knowledge.

- Although perhaps beyond CSIRO's body of knowledge (although very much part of AEMO's) are several issues that should at least be considered in reaching GenCost's findings and recommendations, given the high-level use to which GenCost's recommendations will be applied. Essentially **(refer Section 3.0 – Issues for further consideration by CSIRO and AEMO)**, these cover vital aspects of overall electricity system construction, operation, maintenance and eventual disposal.

1.0 - Nuclear power generation today
Nuclear technology now delivers some 10% of the world's primary emissions free electricity, in significant part derived from Australian uranium. Today nuclear energy is gaining increasing interest world-wide as a contributor to responding to the acknowledged challenges of global warming, climate change, and the need for clean air and water in a fast-increasing world population, many without such resources.

Worldwide some 390GWe of nuclear power generation is operable, 68GW is under construction, 113GWe is planned and 365GWe proposed[1]. Interest in small modular reactors (SMRs) and is fast gaining significant commercial interest, as are very small reactors suited to remote mines and other needs for both power and heat. International commitment to nuclear energy cannot, in good conscience, realistically continue to be presented as of limited relevance to Australia.

Based upon reliable international evidence and widespread practice, or emerging practice, in over 30 advanced economies, nuclear energy is one proven element, amongst others, in the mix of proven low emissions generation technologies available to Australia needed to assist in meeting the longer term bipartisan political commitment to Net Zero Emissions (NZE) by

[1] https://world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requireme.aspx

2050. Without nuclear energy in the generation mix it is considered by many unlikely this target can be met, or even approached in an economically acceptable manner.

In this paper I offer opinions that I know are shared by other Fellows and many specialists in the nuclear energy field. Overall I am concerned that GenCost data relating to nuclear energy technology, its economics, its operating characteristics and its projected resource usage and plant life spans is not adequately consistent with the data used and experience of those 30 or so advanced sovereign nations who have chosen to deploy nuclear energy in their power systems, in some cases for over 50 years. Nuclear technologies have of course advanced very significantly over those years, and of course the well-publicised disasters of Three Mile Island (1979), Chernobyl (1986) and Fukushima-Daiichi (2011) have all contributed to the development of very high levels of reactor safety. Today nuclear power technology is arguably proven and reliable.

I further believe that certain cost data derivations used in the consultation draft, both capital and operating, are in my opinion (and that of many nuclear experts) seriously misleading. For example the use of one of the first SMR project deployment capital costs, although that project has been discontinued, chooses to ignore many other examples of reactor costs, at both known GW and SMR scales, in a field where competition is now intense, is arguably biased. It is certainly inconsistent with the cost data and longer-term projections used for renewable technologies, essentially solar and wind, in the consultation draft.

In offering my personal comments I limit myself to matters upon which I am respected as knowledgeable. My arguments are based upon internationally peer reviewed evidence, proven experience, sound engineering and rational economics. I decline to comment upon other technologies covered in the *Consultation Draft*, noting CSIRO's disclaimer that it *'comprises general statements based on scientific research'*.

2.0 - Reliable sources of nuclear energy expertise

2.1 – Introduction

The *Consultation Draft*, as with previous GenCost editions, is undoubtedly a significant work of scholarship, backed by advanced computer modelling. It is a valuable tool for helping assess electricity generation options available to meet Australia's commitments to providing affordable, reliable and sustainable electricity and heat to the nation's growing economy, while helping to define the technological and economic pathway towards minimising unwanted emissions and other negative externalities. *Prima facie* it therefore depends on the validity of its whole of system input data, not simply the useful but limited Levelised Cost of Electricity (LCOE) metric, itself derived from very many variables.

Given the deservedly high esteem in which CSIRO is held, its opinions are understandably regarded by politicians, the media and the public as highly authoritative. However, CSIRO would be first to acknowledge that nuclear energy science and technology lies well outside its undoubted core competencies and expertise.

I therefore respectfully submit that CSIRO, in respect of its opinions on nuclear energy, would be wise to seek acknowledged reliable and up to date source data from established knowledgeable authorities. I set out in the sub sections below those authorities (and supporting references) believed to meet the criteria of providing evidence based, peer reviewed data and enjoying national and international industry confidence, principally the highly respected Australian Nuclear Science and Technology Organisation (ANSTO).

2.2 - The Australian Nuclear Science and Technology Organisation (ANSTO)[2]
Several submissions to previous *GenCost Consultation Drafts* stakeholder feedback have included the strong recommendation that CSIRO draw upon the national and international experience of the taxpayer funded Australian Nuclear Science and Technology Organisation (ANSTO). It appears this opportunity to be appraised of reliable technical, developmental and cost data continues to be ignored.

ANSTO's senior staff include contributing members of well-informed national agencies (notably ARPANSA and ASNO), and of highly authoritative international agencies, especially in the current context its representative membership within the Generation IV International Forum (GIF).[3]

The GIF is an active co-operative international endeavour. It seeks to develop the research necessary to test the feasibility and performance of fourth generation nuclear systems**,** aiming to make them available for industrial deployment by 2030**.**

The GIF brings together 13 countries (Argentina, Australia, Brazil, Canada, China, France, Japan, Korea, Russia, South Africa, Switzerland, the United Kingdom and the United States), as well as Euratom **–** representing the 27 European Union members − to co-ordinate research and development on these systems**.**

The GIF has short-listed six reactor technologies for further research and development: the gas-cooled fast reactor (**GFR**), the lead-cooled fast reactor (**LFR**), the molten salt reactor (**MSR**), the sodium-cooled fast reactor (**SFR**), the supercritical-water-cooled reactor (**SCWR**) and the very high-temperature reactor (**VHTR**).

The GIF is undoubtedly the best-informed independent agency on advanced nuclear generation technologies and related cost and performance projections relevant to potential deployment in the 2030s. Its world class current knowledge, together with the highly relevant independent knowledge of ANSTO, could be available to CSIRO for the purposes of GenCost. To appear wilfully to forego this opportunity and its related expert resources, while relying upon commercial consulting services for information on nuclear technology and developments, is of some concern.

2.3 – The Australian Nuclear Association (ANA)[4]
The Australian Nuclear Association Inc (ANA) is an independent scientific institution with individual members from the professions, business, government and universities having knowledge of, or an interest in, nuclear technologies. The ANA accesses and promotes international knowledge and the practice of the peaceful, safe and effective use of nuclear science and technology. It also provides an open forum for the presentation, exchange and dissemination of information in the field of nuclear science and technology.

The ANA's respected annual conference, invited papers, occasional special events and quarterly newsletters are sources of well-informed information on nuclear energy, including electricity system analyses in which nuclear plays a critical part, some of which are included

[2] See https://www.ansto.gov.au/
[3] See https://www.gen-4.org/gif/
[4] See https://www.nuclearaustralia.org.au/

in **Appendix A - References**. CSIRO's sustainable energy researchers could be well advised to take part in such events to build useful inter agency relationships.

2.4 – The Australian Academy of Technology and Engineering's Energy Forum. (ATSE)[5]
ATSE is a national body of professional engineers and technological scientists who, through their education, career backgrounds, lifetime research contributions and national and international associations, have been elected to Academy Fellowship by their peers. Fellows *inter alia* seek to appraise the Australian government, its relevant agencies and the wider community with unbiased authority on matters of technological sciences and engineering.

Such matters include Australia's energy policy and the potential roles and associated technological and economic issues associated with the provision of affordable, secure and sustainable electrical power and heat throughout Australian industry, commerce and domestic consumption, mindful of the emerging body of science associated with global warming and climate change. ATSE's Energy Forum holds itself ready for constructive consultation and input to the *Consultation Draft*.

2.5 – Engineers Australia's Nuclear Energy Panel (EA NEP)[6]
Fellows and Members of The Institution of Engineers Australia (Engineers Australia) are fully qualified professional engineers, with skills ranging over the full range of accredited engineering expertise. Strictly applied sanctions apply to any member practising outside his or her qualifications and experience.

Fellows included highly respected individuals, a number with hands-on nuclear reactor construction, commissioning and operating experience of land-based generation and marine propulsion. A number of these serve in its Nuclear Engineering Panel. Several, over many years, have contributed reliable cost data to CSIRO in response to requests for such inputs, and hold themselves ready for further constructive consultation to the *Consultation Draft*.

2.6 – The International Energy Agency (IEA)[7]
Arguably the most reliable international source of generating cost data is the IEA. Established in 1974, with Australia becoming a member in 1979, the IEA provides policy recommendations, analysis and data on the entire global energy sector. Its recent focus is on curbing carbon emissions and reaching global climate targets, including the Paris Agreement to which Australia is a signatory. The IEA's member and associate countries represent around 75% of global energy demand.

The IEA's report[8] *Projected Costs of Generating Electricity 2023* is an exhaustive study based on detailed up-to-date analysis of virtually all available worldwide sources of all proven generation technologies in all nations. *Inter alia* the Executive Summary includes the statement:

"***The energy crisis has renewed interest in the role of nuclear power*** *in contributing to energy security and reducing the* CO_2 *intensity of power generation. In Europe and the United States****, discussions on the future role of nuclear in the energy mix have resurfaced****. At the same time, other parts of the world are already seeing an accelerated deployment of*

[5] See https://atse.org.au/
[6] See https://www.engineersaustralia.org.au/
[7] See https://www.iea.org/
[8] See https://www.iea.org/reports/electricity-market-report-2023/

nuclear plants. As a result, ***global nuclear power generation is set to grow on average by almost 4% over 2023-2025****, a significantly higher growth rate than the 2% over 2015-2019. This means that in every year to 2025, about 100 TWh of additional electricity is set to be produced by nuclear power, the equivalent of about one-eighth of US nuclear power generation today.”* ***(Author's emphases in bold text).***

This well-informed opinion cannot realistically be ignored by CSIRO. Nor can it realistically be accepted that capital costs for the projected international growth of nuclear power will likely be anywhere near the costs forecast in Tables B.1 and B.2 of the *Consultation Draft.* Indeed, it has been reported internationally that, unless Australia takes the first steps necessary to deploy nuclear power generation relatively soon (extraordinarily it currently remains illegal), it risks missing out when the time comes to be placing orders for by then proven plant reactors well suited to the Australian system.

2.7 – The Nuclear Energy Agency (NEA)[9]

The IEA works closely with the Nuclear Energy Agency (NEA). Established in 1958 Australia is one of 33 country members. The NEA in turn works closely with the European Commission and the International Atomic Energy Agency. NEA's mission is to help maintain develop the scientific, technological and legal bases for the safe, environmentally sound and economical use of nuclear energy for peaceful purposes. Importantly it aims to forge common understandings on key issues as input to government decisions on nuclear energy policy.

2.8 – The World Nuclear Association (WNA)[10]

The World Nuclear Association represents the global nuclear industry. Its mission is to promote a wider understanding of nuclear energy by producing authoritative information and contributing to the energy debate. One of its useful data sources is the table[11] *World Nuclear Power Reactors and Uranium Requirements.* Most recently updated to January 2024, this table sets out the reactor inventories, power ratings and future nuclear investment plans for the 31 sovereign nations which rely upon nuclear power. Australia is notably absent. By contrast France, with some 62% of its electricity generated from nuclear energy in 2022, enjoys one of the most reliable, stable and lowest cost electricity systems in the world.

3.0 – Issues for further consideration by CSIRO and AEMO

3.1 - National and international support for nuclear power

Outside the zealot fringe there is growing public support and willingness in Australia (see Section 5.12 below – Legal and social acceptance in Australia) for consideration of nuclear energy in the rigorous whole-of-system long-term analysis of all low emission technologies, some yet unproven at scale (such as solar thermal), and others (such as nuclear) supporting long standing proven low-electricity-cost economies like France.

Data available to CSIRO shows that France, with around 62% of its electricity in 2022 sourced from nuclear energy, has at 65g carbon intensity[12] (gCO_2 eq/kWh) – (cf NSW at 431g!), amongst the least carbon polluting electricity systems of any advanced industrial nation.

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[9] See https://www.oecd-nea.org/

[10] See https://world-nuclear.org/

[11] See https://world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requireme.aspx

[12] See Electricity Maps application

Conversely Germany, with a massive policy driven conversion to renewables and closure of its coal and nuclear power plants, has achieved little if any reduction in emissions, currently 641g carbon intensity (gCO_2 eq/kWh) – near 10 time the carbon pollution levels of adjacent France – as well as massive increases in electricity costs: far from an example of rational long-term decision making. Many informed German people, all consumers of increasingly costly electricity, believe Germany's near obsessive move to variable renewables has cost them dearly.

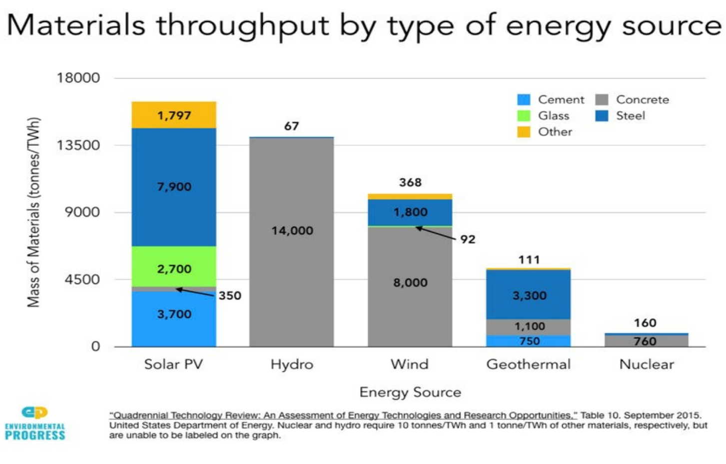
Australia's informed citizens certainly do not wish to see their nation follow this path and, say by 2030, realise that the excessively high VRE penetration associated with massive new support infrastructure, with hugely costly batteries carrying significant end-of-life disposal costs and related environmental challenges, has been ill considered – as many foreshadow.

I for one certainly do not wish to see a proud and capable CSIRO possibly carry some burden of blame for high level advice to governments, notwithstanding international experience, leading to poor decision making based on inadequately researched input data.

3.2 – Raw materials requirements for clean technologies

The US Department of Energy's 2015 Quadrennial Technology Review[13] includes *Table 10 – Materials throughput by type of energy source.* Of relevance to GenCost are the significantly higher raw material requirements for solar and wind technologies as compared with nuclear energy, estimated on the metric of tonnes/TWh of energy delivered (presumably over plant lifetime) rather than tonnes/GW of nameplate capacity.

The environmental damage created by some built and proposed wind farms, notably very recently in Queensland's diminishing native forests, can be considerable. However some 25 years after commissioning these wind farms become scrap for disposal, leaving behind massive concrete foundations and access roads, with native forests, habitat for so many species, gone forever. Dr Alan Finkel's recent book - *Powering Up: Unleashing the clean energy supply chain* - makes clear the quantum of materials used, some rare, some toxic and some plentiful like cement and steel, used in the construction of wind farms per kWh delivered. The amounts are huge, in line with the US DoE findings. Safe and permanent disposal costs do need to be included in CSIRO's overall economic analysis for both renewable and nuclear technologies.



[13] See https://www.energy.gov/quadrennial-technology-review

3.3 – Comparative energy density

Amongst the key benefits of nuclear power are its ‘energy density’; its minimal footprint per TWh compared with solar and wind farms; its near zero GHG emissions and its very high prospective capacity factor (90% plus) when deployed for baseload generation.

By way of illustration, the energy in 1kg of coal could light a 100W light bulb for 3.6 days with 2.6kg of GHG emissions. The energy in 1kg of low-enriched uranium (LEU) could do the same for 1142 years with no GHG emissions.

3.4 – Comparative plant footprints

It is claimed that the real estate ‘footprint’ of a windfarm, based on ha/TWh delivered, is some 400 times that of an equivalent nuclear power plant. While no universal ratio can be attributed, all sites being unique, a reliable example is available for the Diablo Canyon Nuclear Plant in California, compared with the Alta Wind Energy Centre, a substantial wind farm, also in California. In 2017 Diablo Canyon generated 17.9TWh on 84ha while Alta wind generated 3.2TWh on 6,040ha.

The costs of land use (purchase or leasing) and the potential sequestration of agricultural produce (by both wind and solar farms) may not be included in the GenCost LCOE modelling. However it is again a significant economic issue that needs to be considered as well as LCOE.

3.5 – Reactor siting

While wind and solar farms both require significant land use, SMRs, where appropriate, can readily be located on the sites vacated by retiring coal plants. In such cases the existing plant infrastructure, including road and rail access, construction power, cooling water if needed as SMRs can if necessary be air cooled, and most importantly existing high voltage (HV) powerline interconnection with the grid (in Australia the NEM or the SWIS) can all be repurposed rather than built from scratch on new and possibly costly sites. Environmental impacts, significant for fossil fuels and especially coal mines, are minimised.

Particularly important is that existing power station staff, with the addition only of some nuclear training or new specialist staff, can readily be re-employed. Dependent communities can continue to thrive. Social costs are minimised.

3.6 – Plant lifetimes and total GWh delivery per GW of nameplate rating

Firstly, worldwide operating experience shows that nuclear reactors have lives of 60 years plus, compared with solar panels and wind turbines, together with associated batteries for capacity firming, of 25 years.

Secondly, plant capacity factors are typically 85%-90% for nuclear reactors but only 25%-30% for solar panels and wind turbines, although it is acknowledged that offshore wind turbines may achieve 40% or more, depending on location.

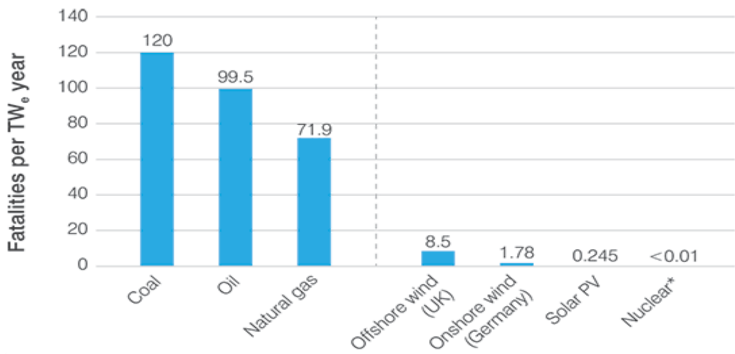
Thus equivalent GWh delivery per installed GW of nameplate rating would require at least four or more complete VRE replacements, including batteries and their round-trip losses, for lifetime delivery equivalence compared to a single reactor of the same nameplate rating.

It does not appear that CSIRO's modelling, based upon initial installed capex including associated system costs of firming capacity and transmission, adequately includes for the associated economics of plant replacement for equivalent lifetime energy delivery.

3.7 – Comparative safety of generation technologies

Notwithstanding the well-publicised disasters of Three Mile Island (1979), Chernobyl (1986) and Fukushima-Daiichi (2011), nuclear technologies have advanced very significantly over the intervening years. All have contributed to the development of very high levels of reactor safety. Today nuclear technology is proven and reliable, arguably safer than it has ever been.

Compared with other generation technologies, it is unexpected but true that nuclear power is the safest of all electricity generation technologies. Chapter 6 – Health and Safety - of the 2006 Uranium Mining, Processing and Nuclear Energy Review – Opportunities for Australia (UMPNER)[14] (aka the Switkowski Report of which the writer was a member) examined this issue in depth. A more recent analysis is summarised in the table below.



3.8 – Technology maturity

Successive editions of GenCost, including the current *Consultation Draft,* have inclined to infer that nuclear energy remains an evolving technology, while giving a degree of prominence to certain renewable technologies, for example high temperature solar, tidal and wave energy which, while potentially exciting, have yet to be economically proven at scale.

By contrast nuclear power became proven commercially in the 1960s, since moving from the obsolete and now decommissioned Generation I, through Generation II – many of which are in mid to late operational life. Then followed Generations III and III+, currently being deployed, with Generation IV in its several emerging variants not far away. Fusion, while hugely exciting, is too far away even for early commercial consideration.

Notwithstanding now long past technology disasters; the nuclear industry today offers an extraordinary level of maturity. The regulatory environment is exceptional; indeed with very significant contributions from Australia's well established ASNO and ARPANSA agencies.

3.9 – Comparative generation technology emissions

The Intergovernmental Panel on Climate Change (IPCC) 2014 reported (See Appendix III Table A III.2t) that the whole of life production of emissions (gCO2eq/kWh) are four times less for a nuclear power plant than for a solar farm. While the value of such emissions in a

[14] https://catalogue.nla.gov.au/catalog/3808099

notional carbon market may be quite modest, it is a factor that should be considered by GenCost in what is essentially an economic analysis.

3.10 – Electricity dispatchability

The GenCost Consultation Draft makes little reference to the relevance of dispatchability. It is important to recognise, and ascribe appropriate commercial and operational value to, technologies (including nuclear) that are 100% dispatchable and most renewable technologies (such as solar and wind) that are not. While much is attributed to the importance of batteries in electricity systems for 'firming' renewables, the received wisdom is that they remain hugely expensive and have limited lives.

While useful for a very great variety of applications (for example electric cars and bikes – both owned and enjoyed by the writer), their massive deployment needs for full electricity system security, their relatively short lives, their demand for valuable scarce resources, their diminishing performance over time and their eventual disposal are issues that must be considered, if not by CSIRO, then certainly by AEMO in long term system planning.

3.11 - Electricity system stability

Much has been researched and is being developed in the digital electronics domain of 'artificial inertia'. As is well known, current electricity systems worldwide with significant rotational inertia (from large turbogenerators) have little problem in maintaining stable system frequency. While artificial inertia may well be the way ahead, it certainly is not yet. While such considerations may not impact GenCost assessments of LCOE, its primary operational metric, the assumption that artificial inertia will manage system stability with the hastened retirement of coal fired steam generation is optimistic. AEMO will undoubtedly be evaluating how best to manage the commercial consequences, no doubt including consideration of the rotational inertia offered by the more conventional steam cycles of nuclear power plants.

3.12 – Skills availability

Undoubtedly new skills will be called for when nuclear power is eventually deployed in Australia. To this end the University of NSW, also the Australian National University and the University of Queensland, offer courses in nuclear engineering and nuclear physics.

However, as noted in ***Section 3.5 – Reactor Siting*** above, if the opportunity is taken to deploy new nuclear generation on the sites of retiring coal generators there will likely be a strong cadre of existing skills available, with potentially profound social consequences. While clearly outside CSIRO's modelling skills, the issue of long-term staff availability and training will certainly be an issue for AEMO's consideration.

3.13 – Technology development and competition

Australia's entry to nuclear power generation will probably be via Small Modular Reactors (SMRs) for which the nuclear industry worldwide is currently well provided with lively well-funded competitors. Candidate SMR technologies of interest to Australia could include:

- NuScale 12 x 77MWe modules totaling 884MWe capacity.
- GE-Hitachi BWRX 300 x 2 modules totaling 600MWe capacity.
- Rolls Royce 1 x 470MWe module totaling 470MWe capacity.
- Terrapower-GE-Hitachi Natrium 1 x 345MWe and up to 500MWe
- GE-Hitachi Integrated Fast Reactor (longer term).

All the above are Western technologies, but it should be noted that Russia, China and India all have advanced and even operating SMRs. All claim to be commercially operational by 2030, or soon after, but all still dealing with a range of legal, developmental and financing steps, all of which will be overcome in time. Government subsidies will likely play a part in early SMR deployment in all jurisdictions, as has been and still is the case for renewables.

While strictly not of relevance to GenCost, the above information is given to show that, should Australia repeal its legal constraints, lively private sector interest, currently in waiting, would rapidly eventuate. Indeed leading SMR proponents have already been evaluating potential supply chains for potential Australian deployment. Canada, which in some ways can be seen as a proxy for Australia, offers a good example of a rational approach to nuclear energy and the adoption of SMRs within its existing system. It is therefore unlikely that Australia's interest will fade with GenCost's harsh LCOE projections for SMRs.

3.14 – End-of-life plant disposal
The associated intractable waste disposal challenges of solar panels and huge wind turbine blades, together with associated batteries, all of which included both precious metals and non-recyclable materials, have been barely considered to date by its passionate enthusiasts, not to mention the destruction of the environmental quality of our land, witness the recent prescient phrase: *"Think of forests of wind farms carpeting hills and cliffs from sea to sky. Think of endless arrays of solar panels, disappearing like a mirage into the desert."*

Given maximum lifetimes for large scale solar and wind farms, the emerging end-of-life disposal problem is becoming increasingly significant; indeed far more significant than the disposal of radioactive nuclear reactor wastes, a problem that will not arise at the earliest until the 2070s. Again, while this may not seem a direct issue for the GenCost analysis, it most certainly has significant economic and social consequences which must be evaluated.

3.15 – Legal and social acceptance in Australia
A recent public survey conducted by the NSW Minerals Council showed strong support, in three key Sydney federal electorates, averaging around 68%, for lifting the ban on nuclear power and for nuclear power to be considered as part of Australia's future energy mix. A June 2023 ABC's Q&A TV program asked on-line the question *"Should Australia invest in nuclear power?"* 61% responded *Yes*, 32% *No* and 7% *Unsure.*

Previous surveys have also shown a majority for the consideration of nuclear power in Australia's generation mix, of course requiring first the repeal of its legal prohibition, with a notable positive shift of opinion in the last year as the populace at large begin to realise first that 'renewables only' policies are failing to deliver cheaper more reliable energy and that nuclear power, for which Australian exports uranium oxide to the world, is now safe, advanced, clean and broadly out of sight.

Nevertheless it is recognised that this is not a direct issue for GenCost, beyond observing that Australia's current energy policies, like GenCost recommendations, effectively exclude any full and proper analysis of whole of life and whole of system nuclear power. Future generations will be dismayed. The writer of this submission is deeply concerned.

MH Thomas
9 February 2024

Appendix A – References

1. **Massachusetts Institute of Technology.** *The Future of Nuclear Energy in a Carbon Constrained World* http://energy.mit.edu/wp-content/uploads/2018/09/The-Future-of-Nuclear-Energy-in-a-Carbon-Constrained-World.pdf

2. **SMR Nuclear Technology Pty Ltd**. Mr Tony Irwin, Technical Director. *A Just Transition to Low Emissions Technology Repowering Coal-fired Power Stations in Australia with SMRs - February 2022.* http://www.smrnuclear.com.au/wp-content/uploads/2022/01/A-Just-Transition-to-Low-emissions-Technology-Repowering-Coal-fired-Power-Stations-in-Australia-with-SMRs.pdf This paper provides an informed up to date review of SMR experience worldwide.

3. **SMR Nuclear technology Pty Ltd.** Mr Tony Irwin. *The Case for SMRs in Australia. August 2021.* http://www.smrnuclear.com.au/wp-content/uploads/2021/07/The-case-for-SMRs-in-Australia_Aug2021.pdf

4. **The University of Queensland.** Adjunct Professor Stephen Wilson. *Preliminary Concept Study – What would be required for nuclear energy plants to be operating in Australia from the 2030s***.** January 2022. https://energy.uq.edu.au/research/social-economic-environmental-research

5. **Australian Nuclear Science and Technology Organisation (ANSTO).** Dr Mark Ho has authoritative role in the international Generation IV Forum, in which he is the Australian representative. I feel sure that he would be able to provide reliable international data on current SMR designs appropriate for Australia.

6. **Electric Power Consulting.** Dr Robert Barr. *Reliable and Affordable Electric Power Generation.* https://epc.com.au/wpcontent/uploads/2018/08/ReliableAffordableElectricPowerGeneration_Booklet.pdf. This study importantly deals with the full system costs of the NEM with various technology mixes, rather than simply the limited LCOE metric.

7. **International Energy Agency (IEA).** *Projected Costs of Generating Electricity - 2020 Edition.* https://www.iea.org/reports/projected-costs-of-generating-electricity-2020

8. **Nuclear Energy Agency (NEA) and the Organisation for Economic Co-Operation and Development (OECD).** *Small Modular Reactors: Challenges and Opportunities (2021).* https://www.oecd-nea.org/jcms/pl_57979/small-modular-reactors-challenges-and-opportunities

9. **Nuclear for Climate.** Mr Robert Parker. I draw attention to the Webex presentation by Mr Parker to Engineers Australia on 1 October 2021, focussing on the advanced GE-Hitachi BWRX-300 SMR, a potential candidate for Australian deployment.

10. **Princeton University.** Interim Report December 2020: *Net-Zero America. Potential Pathways, Infrastructure and Impacts.* https://netzeroamerica.princeton.edu/?explorer=year&state=national&table=2020&limit=200

11. **World Nuclear Organisation (WNA).** *Economics of Nuclear Power (2020 update). https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx*

12. **SMR Technologies Pty Ltd.** Mr Tony Irwin. *The Past, Present and Future of Nuclear Energy in Australia.* August 2022. *http://www.smrnuclear.com.au/*

13. **The University of Queensland.** Adjunct Professor Stephen Wilson. *Preliminary Concept Study – What would be required for nuclear energy plants to be operating in Australia from the 2030s*. *January 2022. https://energy.uq.edu.au/research/social-economic-environmental-research*

14. **Australian Nuclear Science and Technology Organisation (ANSTO).** Dr Lyndon Edwards of ANSTO is Australia's representative in the international Generation IV Forum. Dr Edwards would be willing to provide reliable international data on current SMR designs appropriate for Australia.

15. **Frazer Nash Consulting.** Dr Ben Heard. Dr Heard has very many publications to his name. Of relevance in the current context is the report *SMRs – Small Modular Reactors in the Australian context,* prepared for the Minerals Council of Australia. *October 2021. https://www.minerals.org.au/*

16. **Rod Adams paper.** *What makes smaller nuclear power systems so exciting? - 21 September 2021. https://atomicinsights.com/what-makes-smaller-nuclear-power-systems-so-exciting/*