

Pathways Call for Evidence Submission

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NSW Government – Net Zero Commission

Decarbonisation Pathways for NSW – Call for Evidence: June-July 2026

Submission by Martin Thomas AM FTSE HonFIEAust HonFAIE

Opening remarks

I have read carefully the briefing paper provided by the Net Zero Commission (the Commission). I clearly cannot respond with authority to each of the thoughtful questions raised on pages 3 and 4. Accordingly, and within my own lived experience, I have contributed only where I believe I have a respected opinion, essentially *Electricity and Energy*.

That said I note that the first dot point under *Opportunities, barriers and timelines*, which alludes to generation assets, refers only to the deployment of renewable energy generation, associated infrastructure and Renewable Energy Zone delivery. No reference is made to other proven low emission generation technologies that could undoubtedly contribute to NSW-specific decarbonisation pathways to 2050.

My understanding, within energy policy development, is that all governments declare themselves technology agnostic. Accordingly, despite noting the exclusion of any reference to uranium or thorium as possible future fuels, or nuclear power to deliver electricity and heat, I assume these options are open for consideration as prospective contributors to decarbonisation pathways.

Accordingly, and based upon my life experience and strongly supporting the aims of the Commission, my submission *inter alia* supports the inclusion of nuclear energy in NSW, and indeed in Australia as a whole, as a viable contributor to decarbonisation pathways.

Introduction

Australia is truly the lucky country, and NSW a most fortunate state, in the extraordinary array of energy options (from resources to delivery systems) to provide its needs economically, reliably and sustainably for transport, mining, manufacturing, residential and commercial use, agriculture and construction.

That NSW targets progressive emission reduction to net zero by 2050, while readily legislated, is extraordinarily ambitious and technologically challenging. Meeting the essential criteria of economy, reliability and sustainability is crucial if NSW is to maintain and enhance its position in an increasingly competitive world economy.

Consumer energy priorities are firstly security (lights, businesses and computers must work); quickly followed by price (poor domestic consumers are particularly sensitive), while businesses must remain internationally competitive (or we lose them); and, finally, freedom from unwanted pollution – gases, particulates and increasingly the destruction of our irreplaceably precious environment.

This submission holds that no one energy source or technology can deliver all the essential answers. All economically viable technologies must play a rational role. Global population growth, the predicted doubling of energy demand (eg AI centres) and compelling economic and environmental concerns are a heady mix. Hard-headed rational policies, grounded in relevant data and practice experience, must be developed soon if heroic 2050 targets are to be met.

Opening comment

Turning to the Commission's Briefing Paper, it is noted that within the *Key Focus Areas* the '*Opportunities, barriers and timelines*' identified for each of eight sectors of relevance, rightly include electrification - in its many manifestations. However subsequent text *inter alia* alludes to the deployment of '*renewable energy generation assets*', and the delivery of '*Renewable Energy Zones*' (REZs).

Reference is also made, *inter alia*, to batteries, rooftop solar, vehicle to grid (ie battery) technologies and the orderly closure of coal fired generation assets. In the Transport sector reference is made to '*renewable and low efficient fuel emission fuels including hydrogen.*' Later reference is made to carbon capture and storage, including from direct air capture. One cannot argue against any of these propositions, but all require evidence and data (including economic data) from experts grounded in relevant data and practice experience.

However, no reference is made to the readily available resources of gas or uranium, both of which are deliverable via well proven technologies for which a wealth of relevant reliable data is available. Nor is oil mentioned, although Australia still relies heavily on diesel fuel for transport, and will do so for many years yet, as well as provision for emergency generation. It is unclear if these omissions are intentional, but it could suggest that essentially 'renewables only' generation policies are for consideration by the Commission. Hopefully this is not the case; such policies are nowhere supported by international experience.

Personal experience relevant to the submission

I read engineering at Cambridge University, graduating with Class 2(1) Honours in 1957. My career commenced with British Petroleum in the UK including an understanding of oil production, refining and delivery.

I migrated in 1967 to Australia, managing the design, construction and commissioning of mainly diesel power generation projects for developing iron ore, nickel and lastly uranium mining companies, but with later experience in both open and combined cycle gas turbine generation and also coal combustion technologies.

My professional career included leading several national and international power generation and industrial energy management projects for the World Bank (IBRD), the Asian Development Bank (ADB) and the Australian Agency for International Development (AusAID).

Following 'retirement' in 1995 I was appointed inaugural managing director of the Australian Cooperative Research Centre (CRC) for Renewable Energy, allowing me to work closely and constructively with renewable energy generation and distribution researchers and emerging enterprises.

In energy systems research I was a member of CSIRO's 2002, 2006 and 2018 external Energy Science Reviews, being chairman of the latter two.

In 2006 I served on Prime Minister Howard's Uranium Mining, Processing and Nuclear Energy Review (UMPNER) (aka the Switkowski Review)¹, undertaking in depth research including numerous interviews and the inspection of nuclear facilities of nuclear enabled nations worldwide.

My relevant energy industry external roles have included chairmanship of the NSW Electricity Council; founding chairman of nationally supported export association Austenergy; chairmanship of the Sydney 2000 Olympic Energy Panel; and national chairman of the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADET).

I served for many years as deputy chairman of electricity utility Australian Inland Energy, at that time responsible for electricity generation and distribution throughout far west NSW. AIE was one of the earliest utilities to deploy large scale wind and solar technologies in the public system.

Throughout my career I have contributed professionally to several Commonwealth and State Government energy system inquiries and have delivered over 400 invited presentations on energy management in industry, renewable energy, nuclear power and electricity generating systems. I have also served as chancellor of the Asia Pacific International College and am currently chair of Dulhunty Poles P/L, having held directorships in a number of listed and unlisted energy technology companies.

¹ <https://webarchive.nla.gov.au/tep/66043>

Lastly, I have served my profession in voluntary roles including presidency of Engineers Australia; president of the Australian Institute of Energy; president of the Federation of Engineering Institutions of South-East Asia and the Pacific; vice-president of the Australian Academy of Technology and Engineering and founding chair of its Energy Forum; and a founding member of The Warren Centre Energy Hub at Sydney University. For that service I have received Engineers Australia's Peter Nicol Russell Memorial Medal (its highest award) and its AGM Michell Medal; the Australian Institute of Energy's Institute Medal; the James Kirby Award; the Australian Nuclear Association's Annual Award and the Australian Centenary Medal. I am a Member of the Order of Australia for services to energy and engineering.

I mention the above only to make it clear that what I say below does not derive from any sense of bias whatsoever, but simply from life experience closely associated with the economics and real world applications of Australia's energy resources, their transformations including electricity and heat generation, their efficient use in a wealth of applications, and finally dealing with end of life disposal, including pollution and wastes along the way.

I acknowledge that the basic renewables building blocks (viz - solar panels, windmills and batteries) have fallen significantly in price, being largely imported from China. However, the associated infrastructure costs of renewable energy systems have certainly not fallen, witness Snowy 2.0 and extensive additional HV transmission lines, some having significant difficulties in rural acceptance crossing the landscape. Indeed, commenting on past Chief Scientist Dr Alan Finkel's exceptionally lucid and comprehensive book *Powering Up, The Australian* quotes, albeit somewhat excessively, "*Forests of wind farms carpeting hills and cliffs from sea to sky.*"

Unfortunately, many renewable system enthusiasts appear unaware of, and at times prepared to ignore, the extensive and costly additional infrastructure needed, essential for 'firming' electricity supply whenever demanded, not to mention concerns for Australia's existing social, visual and climatological environment - too precious to trade away for unproven predictions of climatological disaster unless net zero is achieved. To this end it is crucial that '*all the tools in the toolbox*' are given full consideration.

Brief comment on renewable technologies and alternative low carbon technologies

Renewables, solar and wind, while certainly essential contributors to decarbonisation pathways, do exhibit certain constraints, not always acknowledged in the literature and the media. These include:

- 'Whole of system costs' including transmission and distribution, land use and 'firming', while often omitted in simple economic comparisons, remain high and increasing, with growing public resistance on environmental grounds. While basic component costs are certainly reducing (solar panels, windmills and batteries), overall system costs, requiring new costly infrastructure, are increasing, but are often obscured by a significant range of taxpayer funded subsidies, not all of which are well understood by the public at large.
- Electricity is time and weather dependent: capacity factors for solar and wind are at best respectively 25% and 40%. In other words, they cannot consistently meet their nameplate output or meet electricity demand without significant 'firming' via pumped storage, batteries and occasionally gas turbines.
- Solar panels and wind turbines are relatively short lived – 25 to 30 years at most – while employing far more material resources per lifetime MWh delivered compared to certain alternatives. End of life disposal can leave a substantial non-recyclable legacy.
- Provision for charging 'firming' low capacity factor wind and solar technologies (see above) to replace retiring baseload technologies with 80-90% capacity factors, requires installation of up to three times the installed nameplate capacity.

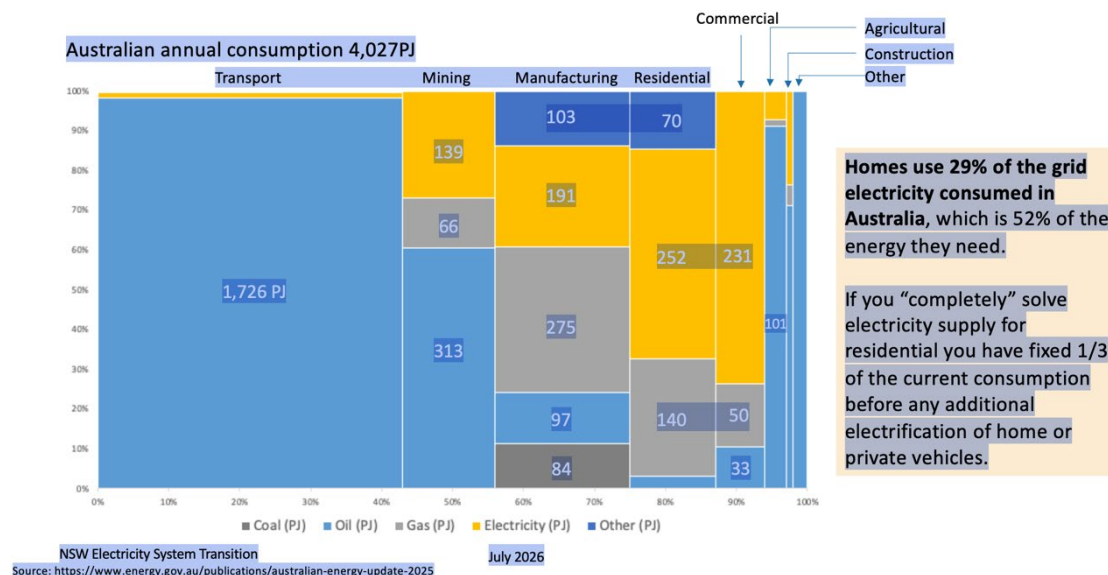
What are the credible low emission baseload options?

- Gas: plentiful, proven, readily deployable but with 'lawfare' increasingly expensive. While inevitably remaining part of the generation mix in near to medium term decarbonisation pathways, gas is not a long-term contributor to full decarbonisation.

However gas remains a critical input for agricultural fertilisers, via ammonia, and for certain accepted pesticides.

- 'Clean coal' with carbon capture and storage (CCS): plentiful, expensive, complex with CCS yet to be proven as a commercial option. As with natural gas, coal inevitably has to remain part of the generation mix in near to medium term decarbonisation pathways if electricity demand is to be reliably met, but clearly cannot be considered a long-term contributor to full decarbonisation.
- Geothermal: plentiful, remote, yet to be proven, expensive and technically complex, currently making a minimal contribution to national electricity generation, but a potentially valuable low emissions contributor to future decarbonisation pathways.
- Nuclear: plentiful low-cost fuel, clean proven ever advancing technologies, high first cost but with high capacity factors and long reactor lives, potentially utilising existing transmission infrastructure, retiring coal plant sites and trained operating staff. Currently illegal in Australia. A strong low emissions candidate that cannot be left out of consideration as a proven and established contributor, both to decarbonisation pathways and importantly to reliable system control and stability.

The above comments focus essentially on low emission electricity generation. However the overall use of energy in NSW is not limited to electricity generation and use alone. Referencing the image below, provided by courtesy of Sydney University's Energy Hub (aka The Warren Centre) shows that transport remains predominantly diesel oil (shown in blue) with electricity generation and use (shown in yellow) less than one third of the total.



While yet to be installed low emission electricity generation will in time increasingly take up a significantly greater share of the transport and mining demands, such considerations are not taken up in this submission, although the writer was an early adopter of electric vehicles. Nevertheless, dealing with overall state decarbonisation pathways will require a significant emphasis on transitioning today's road transport fleet from well-established but far from carbon free diesel fuelled trucks to electric battery powered heavy vehicles. The writer doubts, despite the best of intentions, that such a transition is fully achievable by 2050, although significant progress will surely be made.

The remainder of this submission thus focuses solely upon the prospective adoption of nuclear power within the electricity generation technology mix in achieving any decarbonisation pathway envisaged by the NSW Government's Net Zero Commission. What is presented in support of this argument is believed to be grounded upon relevant proven data, a considerable number of peer reviewed papers, and the lifetime experience of the writer. Peer reviewed papers are referred to in the text and listed under **References**.

Nuclear energy

Introduction

In Australia nuclear energy has been politically regarded until recently as a pariah technology, remaining illegal for over 20 years. Yet nuclear power has reliably served over 30 industrialised countries for over 60 years, with a combined capacity of some 400GWe, as confirmed by the authoritative and fact rich World Nuclear Association². The WNA further confirms that some 440 or more civilian power reactors are currently operable, 79 are under construction, 120 more are planned and a further 326 reactors proposed.

Operating reactors provide safely about 9% of the world's clean carbon emission free electricity. Australia's known uranium resources are the world's largest at around 30% of the world's total and has the world's largest economically recoverable reserves. With three operating uranium mines Australia exports some 4,500t/a of uranium oxide (U₃O₈ and known as yellowcake) to many of the world's reactors for electricity generation. The recent trade agreement with India foreshadows significant new uranium sales. Clearly nuclear power is valued by industrialised nations worldwide, most of whom are adding or planning to add to their present installed capacity.

So why no nuclear power in Australia? Because nuclear power leads to bombs? No! Nuclear bombs preceded peaceful power generation, not the other way round.

The reasons are essentially political. Australia, the lucky country in nearly all its energy resources, has plentiful low-cost easily won coal near its load centres, against which nuclear cannot compete - so long as carbon emissions are not costed. The electricity cost is still some 20-50% higher. Coal mining and power generation support major investments and thousands of jobs. Industry disruption in the short to medium term is politically and commercially inconceivable. Moreover the lights would go out.

However, with a price on carbon and still unknown economics for carbon capture and storage, base load power cost relativities will change. Nuclear power could well become Australia's future low emission generation choice as power costs inexorably continue to rise. Indeed it is inconceivable that nuclear energy can continue to be excluded from the nation's available technologies.

Australia was nuclear ready and capable in the late 1970s with two 500MWe reactors contracted to the Jervis Bay power station, with the Australian Atomic Energy Commission then among world leaders in nuclear technology development. They were disappointingly cancelled, victim to the politics of the day. Synroc, a brilliant Australian innovation, offered – and still does - a route to safe permanent waste disposal. UNSW had a world class graduate school of nuclear engineering - fortunately now revived, strong and well led³. Uranium conversion and enrichment, attracted by Australia's then low-cost electricity, promised a burgeoning international industry in which our nation would have been highly competitive. Has Australia missed world class opportunities? In my view it most certainly has. Surely this mindset must change if decarbonisation is to remain a genuine objective.

The Nuclear Fuel Cycle

Australia today mines and exports concentrated uranium oxide – 'yellowcake' - to a uranium hungry world. We do it very well; Australia reliably supplies a fast-growing world demand for nuclear power generation. Overseas conversion and fuel assembly plants feed power reactors. Cooling and decay of spent fuel in deep ponds adjacent to those reactors is followed by permanent encapsulation and deep burial in engineered repositories some 500m or more underground; effectively the reverse of hard rock mining in which Australians are first class. Finland, a tiny nation with one quarter Australia's population, has found the answer in Posiva OY.⁴ Enlightened nations are following in Finland's footsteps.

² <https://world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requirements> – July 2026

³ <https://www.unsw.edu.au/engineering/study-with-us/study-areas/nuclear-engineering>

⁴ <https://www.posiva.fi/en/>

Reactor Technologies

A detailed overview is provided via the World Nuclear Association website, referenced below⁵.

In brief Generation I gas cooled reactors of the 1950s are now all closed down – already heritage items! Generation II from the mid 1960s, which included the Soviet Chernobyl reactor, delivered huge nuclear capacity growth in the USA, Russia, China and notably France, with most still in operation. The Three Mile Island accident in 1979 and the Chernobyl disaster of 1986 occurred 47 and 40 years ago respectively. To cite these now distant events as proof of the ongoing dangers of nuclear power is disingenuous. Indeed, the opposite is the case; modern advanced, safer and reliable Generation III light water reactors, emerging in the mid '90s, and incorporating the lessons learned from these disasters, are now operating or being installed throughout the world.

Generation III+, with yet better fuel utilisation and further enhanced safety, entered service from 2010 and could well become a base load technology of choice for Australia. Capacity factors over 90% and plant lives of over 60 years, and possibly 80 or more, can be expected.

Generation IV, in final development and likely to come into service in the 2030s, are the so-called fast reactors, once called fast breeders, able to extract some 50-60 times more energy from the uranium fuel by using both the U235 and the more plentiful unused U238.

There is negligible risk of uranium 'running out.' As sometimes claimed by detractors. Uranium, and probably thorium to follow, are abundant in the earth's crust and reactors use very little to do their job. 1kg of coal could light a 100W incandescent light bulb (a bright bedside light) for 3.6 days with 2.6kg of GHG emissions. But 1kg of low-enriched uranium, enriched from naturally occurring 0.7% to 3.5 - 4.5% concentration for conventional power reactors, could do so for over 1,100 years.

Large base load reactors of 1,000MWe, for example the Westinghouse designed AP1000, could readily over time replace Australia's dispatchable base-load generation, today predominantly coal fired but being progressively closed as they reach the end of their commercial lives. Where appropriate such reactors could readily utilise their vacated sites and serviceable infrastructure, especially the well maintained HV and MV transmission and distribution lines already in place, connecting cities and major load centres, not to mention teams of qualified operators and their long-standing social infrastructure.

Of particular interest AP means Advanced Passive, referring to the reactor's safety systems which, in the event of any conceivable accident scenario, would safely shut down the reactor and maintain its cooling for 72 hours, with no operator intervention.

Meantime a new generation is emerging, some already reaching commercial operation, of compact factory built self-contained reactors known as small modular reactors (SMRs⁶). SMRs can be deployed regionally, individually or in multi reactor assemblies, with very little additional infrastructure beyond connection to their load. Some can be fitted into modified shipping containers for transport to sites via road, rail and ship.

Lastly a yet newer family of microreactors (MMRs⁷) are under development, with four designs already reaching criticality. Of particular interest is the Australian technology of Deployable Energy⁸, developed under the leadership of CEO Bobby Gallagher. Called the Unity Nuclear Battery it is rated at 1MWe. Using standard reactor fuel, non-exotic proven materials and to

⁵ **World Nuclear Association.** Review of reactor technologies. <https://world-nuclear.org/information-library/nuclear-power-reactors/overview/nuclear-power-reactors>

⁶ **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

⁷ **SMR Nuclear Technology Pty Ltd.** Mr Tony Irwin. *The Status of Microreactor Development.* July 2026 Update – 4 new microreactors achieve criticality. <https://www.smrnuclear.com.au/>

⁸ **Deployable Energy.** Unity Nuclear Battery. <https://www.deployable.energy>

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be factory built, it is claimed that it will be deployable by the 2030s. SMRs and MMRs are potential contributors to decarbonisation, certainly well before 2050. They cannot be ignored.

Nuclear fusion may yet become a sustainable baseload technology of the future, but is not here discussed further.

Nuclear Power for Australia?

The 2006 Uranium Mining Processing and Nuclear Energy Review (UMPNER) (see Reference 1) suggested the soonest nuclear electricity could support the Australian grid would be 10 to 15 years – say around 2020 to 2025 – with permanent high level waste disposal not needed before 2050. Transferring that finding, which is still supported, some 20 years forward suggests 2040 to 2045 for Australia's first nuclear power stations, with deep high level waste disposal, probably following Finland's Posiva model, not required until nearer 2070. By then many deep disposal repositories, now under construction worldwide, will be operational and no doubt offering safety enhancements and improved operational systems.

But first Australia needs a national regulator and a cadre of trained nuclear scientists, engineers and technologists. In recent years the UNSW Nuclear Engineering program has been re-established, while the ANU maintains a Department of Nuclear Physics; both have international partnerships. Other Australian universities are considering nuclear energy options. Australian graduates will find ready employment worldwide to service the 'nuclear renaissance', and at home to support the AUKUS submarine program.

The challenge is huge; Australia needs to respond. To this end a team of researchers, guided by knowledgeable mentors and a significant host of experts, including the writer and under the inspired leadership of Adjunct Professor Stephen Wilson of the University of Queensland, funded wholly by Mr Barry Murphy FTSE, in 2022 delivered a superbly bound and presented document⁹ entitled: *Preliminary Concept Study – What would be required for nuclear energy plants to be operating in Australia from the 2030s*. Fully expert peer-reviewed, it has been widely circulated, *inter alia*, to most serving federal (and several state) MPs for their attention and hopefully – in time – appropriate political action. The Study has been openly presented and discussed in Parliament House Canberra and in many other venues. Importantly it takes the reader through all the steps needed to establish nuclear power generation in Australia. It is strongly commended that it be referenced in ATSE's submission to the NSW Government's Net Zero Commission.

Most importantly of all, it needs to be accompanied by the recommendation to support the legalisation of nuclear power in Australia. Although the final political decision rests with the federal government, it must be realised that the interconnected National Electricity Market (aka the NEM) covers all of the eastern states, not only NSW. It is a single system and can only be considered as such.

Finally, under this heading, must be mentioned the recent well circulated 2025 bound study, entitled *What will it take? Nuclear Power in Australia's Energy Transition*, from Macquarie University's School of Law¹⁰. The enterprise was conceived and led by Professor Tina Soliman-Hunter, Professor of Energy and Resources Law, and prepared by a team of well credentialled experts in the nuclear engineering, operational, research, educational and related legal fields.

While the 22-page document inevitably covers most of the issues raised in this submission, it does so in considerably greater depth and with wider insights, given the wider authorship. It is certainly a further peer reviewed reference of quality, believed essential reading for the Commission in reaching an understanding of the many aspects of introducing nuclear power generation into Australia, and thus into NSW.

Economics of Nuclear Electricity

⁹ **University of Queensland.** <https://energy.uq.edu.au/research/social-economic-environmental-research>

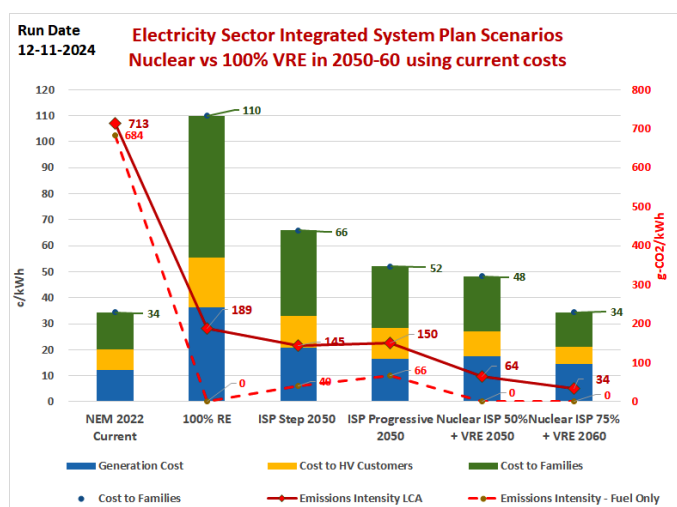
¹⁰ **Macquarie University School of Law - Transforming Energy Markets Research Centre.** *What will it take? Integrating Nuclear Power into Australia's Energy Transition 2025.* <https://www.mq.edu.au/research>

Nuclear power economics depend primarily upon the cost of capital and the management of financial risk. Fuel costs, with uranium currently around \$US65-75/lb, are a small portion of sent out power costs – typically some 0.5 to 0.7 US c/kWh – to which is can be added a small levy of 0.1-0.2 US c/kWh to a sinking fund to cover safe waste disposal and final decommissioning some 50 to 60 years or more later. Capital costs are indeed significant although, as with all evolving technologies, including renewables, these will fall with the efficiencies of growing production, international competition, market scale, factory production and design standardisation.

Electricity costs to end use consumers must be considered on a case-by-case basis for all viable source options - including coal, gas, wind and solar - ensuring that all costs along the source to consumer supply chain, both direct and indirect, are properly included. Nuclear reactors, albeit with acknowledged high capital costs, nevertheless with their modest footprint and ready location on retiring coal power station sites, can utilise not only existing infrastructure (ie road and rail access, cooling water and HV transmission connections), but also, most importantly, experienced local human skills and supporting social infrastructure. Nuclear power largely avoids the needs of renewables to occupy significant tracts of arable land or wayleaves through protected forests.

A particularly interesting member of the family of computer or mobile phone applications dealing with electricity pricing is *Electricity Maps*. It provides at finger touch, *inter alia*, the cost of electricity in every nation, the current carbon intensity in gCO₂ eq/kWh, the installed generating capacity in MWe and the mix of generation technologies. Importantly, and in broad terms, it makes clear that those nations with higher percentages of nuclear in the generating mix, such as Finland, France and S Korea, not only have the lowest carbon emission intensities but are among the lower end of consumer costs on a per MWh delivered basis. This again suggests that consideration of nuclear power cannot, despite the negative legislation, rationally be excluded from consideration of the planning of NSW's decarbonisation pathways.

Dr Robert Barr AM, a respected consultant well acquainted with Australia's electricity systems, has delivered several well-researched peer reviewed systems modelling studies. While too numerous to cover in this submission, the selected graphic¹¹ below clearly shows the significant impact of costs to families of excessive renewable energy penetration as compared with the NEM's 2022 system costs, albeit now well exceeded. The RHS of the graph then indicates clearly the reducing system costs using AEMO's own Integrated System Plans (ISPs) with increasing percentages of nuclear power in the mix going out to 2050, the NSW Commission's net zero target date, and thence to 2060 with increasing nuclear (75%) in the generation mix. Importantly emissions intensity falls to the desired net zero by 2050, at least in the production of electricity. Even if Dr Barr's modelling is only partially correct it is inconceivable that nuclear power can be omitted from any realistic decarbonisation pathway.



¹¹ Dr Robert Barr AM <https://nuclearforclimate.com.au/wp-content/uploads/2024/11/Scenario-Comparison.png>
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A further useful reference for this submission is the widely published and well researched paper of Dr Robert Idel PhD, published in *Science Direct*, entitled *Levelized System Costs of Electricity*¹².

- Levelised costs of electricity ignore the cost of intermittency of renewables,
- Including storage to balance them increases the costs of variable renewables,
- Levelised full system costs of electricity include the cost of balancing, and
- Combining wind and solar with a firm resource reduces costs significantly.

The fourth dot point, while complex and arduous to digest, is of relevance in determining the least cost decarbonisation pathway available to the Commission.

Lastly I draw attention to the highly regarded paper¹³ by Dr Gabriel Rioseco of the University of Queensland entitled *Modelling the Australian National Electricity Market (NEM)*, presented in 2002 to Engineers Australia.

Nuclear Power Plant Siting

Many sane people, apart from the pragmatic French, harbour fears of nuclear power and present NIMBY responses when discussing plant locations. And who wants to live near any power plant, regardless of its primary energy source – be it coal, gas or wind?

The land for a 1000MWe nuclear power station itself – less than 1km² - differs little from its coal equivalent. However, to the coal station area must be added the significant area of its associated coal mines, washeries and conveyors; its chimneys to disperse combustion flue gas and fine particulates; and lastly its modestly radioactive ash dam of ever-increasing area.

Cooling water demands of nuclear plant are slightly higher than for coal due to rather lower steam conditions and hence cycle efficiency. However, the source can be once-through sea or estuarine water, evaporative cooling towers with limited make-up water, or even direct dry cooling using air-cooled condensers where water is particularly scarce such as in inland Australia. Typical suppliers of such systems include Heller of Hungary, SPG of Germany and others. The penalty is slightly increased plant capital cost and slightly reduced thermal efficiency.

Pollution from nuclear plant is extremely low. There are no CO₂ or other airborne pollutants. High level nuclear wastes, while very dangerous if not rigorously contained, are very small in volume and extremely robustly encapsulated. Disposal systems are likewise extremely well engineered and accidents with waste disposal over 60 years are negligible. Indeed, nuclear power safety records, including for Chernobyl, are superior to all generating technologies in terms of deaths and injuries per lifetime units of energy delivered (see below). In short, a nuclear reactor can safely be located anywhere near a power grid given adequate cooling water (or dry cooling), assured security and plans for a long-term future.

Waste Disposal

Nuclear wastes arise in three broad categories – low, intermediate and high. Low and intermediate wastes present no real issues and are disposed of safely at sites worldwide, including at ANSTO's Lucas Heights for the OPAL research reactor, a world class producer of essential medical radioisotopes.

Long term encapsulation and deep disposal of HLW is essential as for many other of society's intractable wastes. Most nuclear nations are well advanced with such facilities, as above noted for Finland where the facilities are now operational. Australia is particularly well placed geologically with vast remote geo-stable regions ideal for deep disposal which, at least for Australia, would not be needed until around 2070.

Spent fuel volumes are no more than 2 to 3 cubic metres per annum for a 1,000MWe base load nuclear power station if reprocessed; and 10 cubic metres if not (a small ensuite bathroom!) Compare this with disposal to the atmosphere of around 7 million tonnes of

¹² <https://doi.org/10.1016/j.energy.2022.124905>

¹³ <https://portal.engineersaustralia.org.au/event/2022/04/modelling-australian-national-electricity-market-nem-42126>

carbon dioxide per annum for the most modern 1,000MWe coal plant, not to mention many tonnes of moderately radioactive ash.

Engineering of a spent fuel repository is well within the skills of Australian hard rock mining engineers. It has been proposed as a commercial opportunity – but has yet to be accepted – that Australia might lease its uranium to approved world users, taking it back as used fuel (aka HLW) after 30 years for permanent encapsulation and burial unless reprocessed. Many support this innovative proposal.

Research and development

The world class Australian Nuclear Science and Technology Organisation (ANSTO) is highly respected and well connected internationally. *Inter alia* it maintains, on behalf of the Australian Government, a watching brief on all nuclear reactor developments. It has been an active member of the Generation IV International Forum assessing advanced reactor designs. It has a cooperating agreement with International Thermonuclear Experimental Reactor (ITER) consortium exploring at scale on Australia's behalf the potential for fusion power generation, quite possibly a proven clean power generation concept well before 2050. It is the builder and operator of Australia's highly successful research reactor OPAL. It contributes in an exceptional way to the manufacture and distribution of medical radiopharmaceuticals to hospitals throughout Australia and overseas. ANSTO's potential to contribute to the Commission's objectives, ideally in collaboration with CSIRO's contributors to the annual CSIRO-AEMO GenCost Report, could prove valuable and is commended.

Health & Safety

Nuclear power has unwarrantedly gained a reputation for dangerous radiation and resulting deaths. The truth is that nuclear power, including the Chernobyl tragedy, is by a significant margin less dangerous (on the somewhat gruesome but factual metric of fatalities per unit of total lifetime energy delivered in MWh), than all fossil fuel, hydro and renewables generation options. For anti-nuclear power proponents this is indeed an inconvenient truth.

Electricity system control with nuclear power in the generation mix

Final reference is made to two papers of significance regarding the progressive inclusion of nuclear power into an electricity system with already significant renewable capacity.

The first, from the Massachusetts Institute of Technology, co-chaired and presented in Australia by Professor Jacopo Buongiorno, takes the long view, looking philosophically and practically at *The Future of Nuclear Energy in a Carbon Constrained World*¹⁴. It makes for compelling and indeed essential reading in identifying and specifying realistic decarbonisation pathways as called for by the NSW. Incidentally it is believed that Professor Buongiorno is currently in Australia and could be contacted through the University of NSW School of Nuclear Engineering.

Essentially this extraordinarily comprehensive paper shows that within the existing electricity sector in countries where nuclear power is operationally deployed - some 31 advanced nations - that the most effective and least costly path towards decarbonisation is a combination of variable renewable energy (VRE) technologies (eg solar and wind), and low-carbon dispatchable sources (eg hydropower and inevitably short term battery storage). However the paper points out, (as has recently been experienced in SA), that batteries are not affordable at the scale needed to balance variable energy demand through long periods of low wind and sun (aka the German word *dunkelflaute*) or through seasonal fluctuations, although that could change in the coming decades.

The paper also emphasises the importance of a mix of technologies in any generating system portfolio. It clearly makes the point that for excessive renewables penetration, say over 50% of system energy (ie with reduced dispatchable baseload generation) system control becomes increasingly problematic; system reliability begins to fall dramatically. This is by no means an argument against renewables - they are a valued part of Australia's NEM – but

¹⁴ <http://energy.mit.edu/wp-content/uploads/2018/09/>

rather a cautionary recommendation that any approach to 100% renewables it's likely to prove extremely problematic, not to mention uneconomic.

Finally the paper emphasises that nuclear energy is one low-carbon dispatchable option that is virtually unlimited. It is available for deployment in nuclear enabled countries now. If nuclear power is ignored it could double or triple the average cost of electricity for deep decarbonisation scenarios, as envisaged by the Commission in seeking pathways to net zero by 2050. The reason is the need for the enormous overcapacity of solar energy, wind energy, and batteries that would be required to meet demand in the absence of any long term dispatchable low-carbon energy source.

This finding strongly emphasises the need for NSW, and for Australia as a whole, at the very least to open the pathway to consideration of nuclear energy in Australia, currently one of the very few OECD nation in which legal bans to nuclear remains in place.

The final reference in this submission is from Tony Irwin of SMR Nuclear Technologies, arguably one of the most highly experienced nuclear power experts in Australia today. He commissioned and operated over 8 nuclear reactors for British Energy before migrating to Australia to take a position with ANSTO in 1999, where he remained for ten years becoming manager of the construction and commissioning of the OPAL research reactor at Lucas Heights. He lectures on nuclear science at ANU (where he is an Honorary Associate Professor) and the University of Sydney. He has a degree in electrical power engineering with reactor and fuel cycle modules and is immediate past chair of Engineers Australia's Nuclear Engineering Panel.

The reference¹⁵ included herein, among many that Irwin could offer, is entitled *A Just Transition to Low Emissions Technology Repowering Coal-fired Power Stations in Australia with SMRs - February 2022*. Importantly it deals with issues of social justice in the technology transition, a crucial issue identified by the NSW Commission.

Conclusion

The need for much increased low emission base-load generating capacity, in parallel with much expanded electrically powered transport systems of all types and, it is forecast, the energy demands of artificial intelligence, makes it abundantly clear that any 'business as usual' approach based solely on firmed (and well subsidised) renewables and storage is unlikely to achieve the NSW Net Zero Commission's target by 2050.

By the time the debate over the impact of atmospheric carbon is resolved – and if it excludes serious consideration of nuclear energy as one of the tools in the decarbonisation kitbag - it may well be too late for Australia to regain the leadership it once had in a technology that promises so much.

Should Australia continue to turn its policy back on the potential of nuclear energy to answer society's insistence on finding and managing a solution could, in time, be seen as irresponsible. Our grandchildren and their children may ask how we could have been so blind.

Martin Thomas

¹⁵ <http://www.smrnuclear.com.au/wp-content/uploads/2022/01/>

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