Submission No 186

SUSTAINABILITY OF ENERGY SUPPLY AND RESOURCES IN NSW

Organisation: Medical Association for Prevention of War

Date Received: 15 September 2019

MAPW - Health Professionals Promoting Peace

Legislative Assembly Committee on Environment and Planning

Parliament of New South Wales

15th September 2019

Re: Sustainability of energy supply and resources in NSW

Thank you for the opportunity to provide a submission. In this submission we focus on solely on nuclear power, given that has been proposed by some as an option for energy supply.

The Medical Association for Prevention of War (Australia) works for the elimination of all weapons of mass destruction and the prevention of armed conflict. We promote peace through research, advocacy, peace education and partnerships. Our professional not-for-profit organisation has branches across Australia, and works globally through the International Physicians for the Prevention of Nuclear War.

There are clear historical links between the nuclear industry and nuclear weapons proliferation. Uranium mining is part of the nuclear fuel chain. Radioactive waste is toxic material that can last for millennia.

Summary

Constructing and operating nuclear reactors in Australia would be difficult and slow, with a 15 year time frame very optimistic, even with small modular reactor construction.

Nuclear power plant operations have major health implications for surrounding populations.

Events at Chernobyl and Fukushima reactors demonstrate the potential for catastrophic outcomes involving radionuclide dispersal is not negligible.

Civil nuclear power generation is associated with the acquisition of nuclear weapons capability, and as such any proposal for Australia to acquire nuclear power may fuel regional nuclear weapons proliferation. Deliberate attack of nuclear reactor sites has happened in the past and is possible.

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The past record of the nuclear industry means safety claims need to be viewed with scepticism.

Regulatory capture is prevalent in the nuclear industry and well documented in Australia, with the South Australian Roxby Downs Indenture Acts a clear illustration.

The prohibitive cost demonstrated internationally makes nuclear energy a very expensive electricity generating pathway for Australia.

Nuclear waste also remains a major unsolved problem internationally. Here is Australia it is highly contested issue, and current proposals to deal with our relatively small amount of nuclear waste are deeply flawed and well below international best practice.

Given the urgency of the climate imperative and the perils inherent in failing to meet reduced emissions targets, establishing nuclear power generation is too slow.

Fortunately there are well articulated, affordable and feasible alternatives to nuclear power. Renewable energy with storage measures is able to produce power that is reliable and in a form that is readily dispatchable.

For renewable energy to expand fast enough to displace fossil fuel requires the right policies put in place as soon as possible. In the timeframe required to get to zero carbon in the energy sector, nuclear power is unsuitable, as it cannot be on line in the time available and has significant carbon emissions.

The longer nuclear issues dominate the debate on energy and climate, the longer it will take to make the fundamental change to systems based on renewable energy.

MAPW strongly rejects nuclear power as a suitable energy source for Australia. Nuclear power has inherent health and safety risks, nuclear proliferation risks and produces waste that has no disposal solution anywhere in the world. In addition it is too slow, too expensive and has significant carbon emissions.

We believe Australia needs an energy policy that recognises the urgency of climate change and the known advantages of expanding firmed renewable energy sources.

We would be happy to appear before the committee to discuss this issue further.

Yours sincerely,

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INTRODUCTION

Feasibility

This submission addresses the overall "feasibility", i.e., *the degree of easily or conveniently* establishing and operating facilities to generate electricity from nuclear fuels in Australia. It explores the capacity of nuclear energy to contribute safely, cleanly and quickly to the energy transformation imperative, with emphasis on health implications. In so doing it focuses on the necessary circumstances, disadvantages, risks and measures entailed. Small modular reactors will be specifically addressed.

PREAMBLE

Anthropogenic global warming and its anticipated devastating ecological consequences require urgent and comprehensive transformation of global energy production technologies to zero-carbon emitters. International governmental deliberations about the importance of addressing climate change by reducing fossil fuel use and thus carbon emissions have been conducted since 1988.

In the last few months a number of countries have declared a climate emergency including the UK, Ireland, Canada and France. Impacts of climate change in Australia are well documented.[1] Recent medical and scientific literature attests to the fact that the impacts of global warming are already evident and document extensive current and potential human health outcomes.[2,3,4,5]

Effects on individual and societal health and wellbeing occur directly, indirectly, and via economic and social disruption, including amplification of pre-existing issues:

- increased injuries and deaths from more severe or frequent weather events including heat waves, and storms compounded by sea level rise and population shifts
- indirect effects from ecosystem changes in natural cycles and functions
    - the changed range and timing of infectious diseases
    - changed temperature, rainfall and evaporation effects on plants additional to those from increased atmospheric CO_2 concentrations
    - sequelae from changes in micro-biota influencing soil fertility
    - changed insect ecology that will effect crop fertilisation and pest prevalence and behaviour

All of these are likely to synergistically reduce agricultural output and quality resulting in food insecurity.

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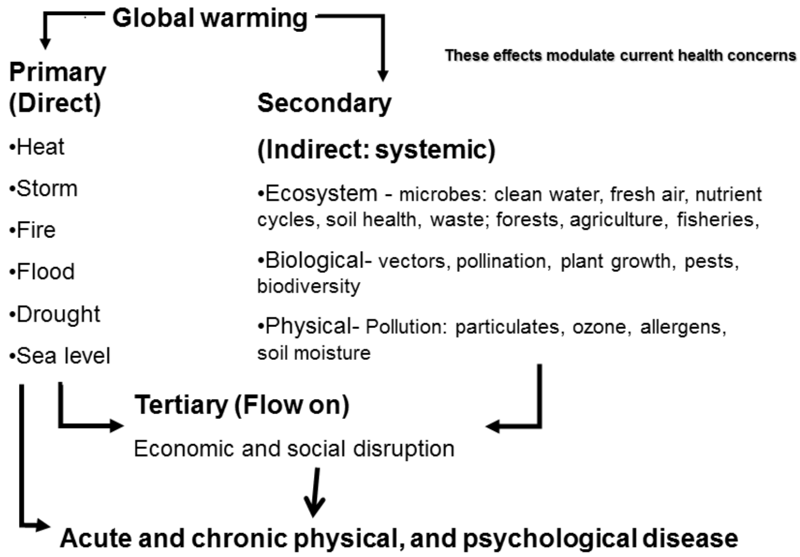
[1] The Frontline: Australia and the Climate Emergency https://www.theguardian.com/environment/series/the-frontline

[2] McMichael AJ. Climate Change in Australia: Risks to Human Wellbeing and Health, Austral Special Report 09-03S. Melbourne, Australia: The Nautilus Institute, RMIT2009.

[3] Butler C, Harley D. Primary, secondary and tertiary effects of eco-climatic change: the medical response. Postgraduate Medical Journal. 2010;86:230-4.

[4] *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* August 2019 https://www.ipcc.ch/report/srccl/

[5] The 2018 report of the *Lancet:* Countdown on health and climate change: shaping the health of nations for centuries to come. *Lancet.* 2018; 392: 2479-2514



Summary of health consequences of greenhouse gas emissions[6]

The economic and social consequences of these and other systemic effects will reduce both capacity to respond, including health system capacity, and psychosocial wellbeing.

Mass extinction of species is already occurring and will worsen if action is delayed.

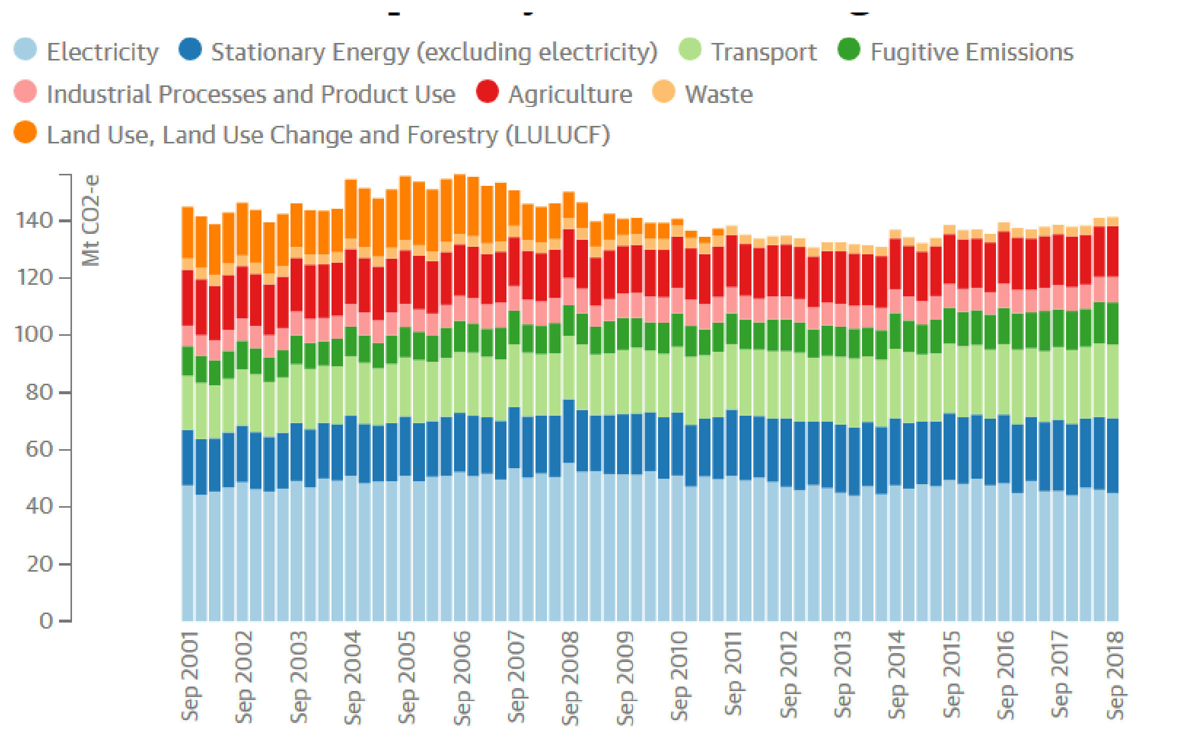
The essential inference from this evidence is the requirement to replace fossil fuel-reliant systems with alternative energy systems which are:

1. Non-polluting
2. Rapidly deliverable
3. Currently or on the verge of commercial viability
4. Affordable

Australia has to date made marginal progress in addressing these scenarios, making the need all the more urgent. When excluding land use data (due to unreliable collection), Australia's emissions for the 2018 year to September reached 558.3m tonnes of carbon dioxide equivalent, an all-time high[9].

[6] http://www.phaa.net.au/documents/item/327

Where are Australia's quarterly emissions coming from?



Source: NGGI, NDEVR Environmental[7].

A crucial element in the discussion is the cost of a continuing delayed response to global warming: any technology that cannot be installed rapidly now, with a steady increase in output starting now, carries major costs of exacerbating existing climate hazards with all the attendant risks**.**

Diverting resources – financial, environmental and social - into such delayed (often referred to as 'emerging') technologies will cause major additional and unnecessary detriment.

As noted in the Independent Review into the Future Security of the National Electricity Market – Blueprint for the Future[8]

"We are at a critical turning point. Managed well, Australia will benefit from a secure and reliable energy future. Managed poorly, our energy future will be less secure, more unreliable and potentially very costly. Governments have made commitments to a lower emissions future but the pathway is blocked by uncertainty about how to get there. If we don't take immediate action, or even if we continue as we have been, Australia risks being left behind."

[7] https://www.theguardian.com/australia-news/2018/dec/13/australias-carbon-emissions-highest-on-record-data-shows

[8] https://www.energy.gov.au/publications/independent-review-future-security-national-electricity-market-blueprint-future

Of critical import, the longer the delay, the greater will be the environmental damage and higher the likelihood of catastrophic and unpredictable development.

THE NUCLEAR OPTION GLOBALLY

The proposition that nuclear fission should play a role in replacing the fossil fuel sector gained prominence in the 1990s and the catch-cry of a 'nuclear renaissance' was oft repeated throughout the following decade.

Current industry status

According to the *World Nuclear Agency* (the principal international organization that promotes nuclear energy) globally the share of nuclear in world electricity has showed decline from about 17% to 11% since the mid-1980s…'[9] This assessment was confirmed by the *World Nuclear Industry Status Report 2019*[10] which documents additional indifferent nuclear capacity projections, including:

- The number of nuclear reactors under construction in the world has been steadily decreasing for the last five years (including this year), and the annual increase in power generation by wind and solar sources has by far surpassed that of nuclear energy
- The actual number of units under construction globally declined from 68 reactors at the end of 2013 to 50 by mid-2018, of which 16 are in China.
- The nuclear share of global electricity generation remained roughly stable over the past five years (–0.5 percentage points), with a long-term declining trend, from 17.5 percent in 1996 to 10.3 in 2017.
- At least 33 of the 50 units under construction are behind schedule, mostly by several years. China is no exception, with at least half of 16 units under construction are delayed.
- Of the 33 delayed construction projects, 15 have reported *increased* delays over the past year.
- Auctions resulted in record low prices for onshore wind (<US$20/MWh) offshore wind (<US$45/MWh) and solar (<US$25/MWh). This compares with the "strike price" for the Hinkley Point C Project in the U.K. (US$120/MWh).

Nuclear power projections took a major hit in 2011 when the reactors at Fukushima melted down, triggering a profound global reconsideration of the safety of the reactor fleet and existential questioning about the industry. Germany and Switzerland committed to phasing out their nuclear reactor programs, many countries elected to abandon plans and even the most enthusiastic nuclear builders, eg China, pulled back and have reduced their projected nuclear output. While it is of course *conceivable* that nuclear energy *can* make a substantial comeback, circumstances are clearly militating against that prospect. Despite concerted efforts to label nuclear technologies as 'clean and green' many communities remain suspicious of, if not hostile to, its safety and health profile.

[9] https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx
[10] https://www.worldnuclearreport.org/-World-Nuclear-Industry-Status-Report-2018-

In addition nuclear fission is rapidly being outstripped by renewables in terms of costs and propagation: Globally, wind power output grew by 17% in 2017, solar by 35%, nuclear by 1%. Non-hydro renewables generate over 3,000 TWh more power than a decade ago, while nuclear produces less[9].

Over the last decade, China's investment in renewable energy and natural gas has surged.[11] In 2017, almost half of global renewable energy investment came from China, totalling $125.9 billion. This is more than double the $53.3 billion that China invested in renewables in 2013. China is becoming the largest market in the world for renewable energy. It is estimated that 1 in every 4 gigawatts of global renewable energy will be generated by China through 2040.

China's wind power capacity in 2017 surged to 16,367 megawatts (MW), a 10.5 percent increase from the previous year.

From 2000 to 2015, China increased its hydroelectric energy-generation capacity by an impressive 408 percent. As a result of the Three Gorges Dam and other projects, China became the world leader in hydropower in 2014.

China is now home to two-thirds of the world's solar-production capacity.

Nine of the 31 nuclear countries—Brazil, China, Germany, India, Japan, Mexico, Netherlands, Spain and United Kingdom (U.K.)—generated more electricity in 2017 from non-hydro renewables than from nuclear power[10]. In 2015 Spain generated more power from wind than from *any* other source, outpacing nuclear for the first time. It was also the first time that wind became the largest electricity generating source over an entire year in any country.

ENVIRONMENTAL IMPACTS OF NUCLEAR POWER- MYTH vs REALITY

A critical consideration are the actual emissions generated by nuclear power plants. In addition to the significant and long lived radioactive waste generated, there are significant carbon emissions, repeatedly overlooked by nuclear proponents.

Mark Deisendorf noted in Feb 2014:

"*Unfortunately, the notion that nuclear energy is a low-emission technology doesn't really stack up when the whole nuclear fuel life cycle is considered. In reality, the only CO_2-free link in the chain is the reactor's operation. All of the other steps – mining, milling, fuel fabrication, enrichment, reactor construction, decommissioning and waste management – use fossil fuels and hence emit carbon dioxide."*

Several analyses by researchers who are independent of the nuclear industry have found that total CO_2 emissions depend sensitively on the grade of uranium ore mined and milled. The lower the grade, the more fossil fuels are used, and so the higher the resulting emissions.

In one such study, the nuclear physicist (and nuclear energy advocate) Manfred Lenzen found that CO_2 emissions from the nuclear fuel cycle increase from 80 grams per kilowatt-

[11] https://chinapower.csis.org/energy-footprint/

hour (g/kWh) where uranium ore is high-grade at 0.15%, to 131 g/kWh where the ore grade declines to low-grade at 0.01%.

Other experts, such as nuclear energy critics Jan Willem Storm van Leeuwen and Philip Smith, using assumptions less favourable to nuclear energy, have reported an increase in emissions from 117 g/kWh for high-grade ore to 437 g/kWh for low-grade ore.[12]

For comparison, the life-cycle emissions from wind power are 10–20 g/kWh, depending upon location, and from gas-fired power stations 500–600 g/kWh. So depending on your choice of analysis, nuclear power can be viewed as almost as emissions-intensive as gas."[13]

This analysis is reinforced by a report that came out in early 2019 from the Climate Council[14]. They noted "Unlike coal and gas, no greenhouse gas pollution is created in the operation of the nuclear reactor. However, all other steps involved in producing nuclear power (from mining, to construction, decommissioning and waste management) result in greenhouse gas pollution. Greenhouse gas pollution associated with nuclear power could be similar to a gas power station, with estimates ranging from 80 – 437 kg/MWh.

Considering the pattern of growth followed by decline in the industry it is improbable that nuclear can compete with renewables in the medium to longer term. And while nuclear proponents are voluble in ridiculing the capability of renewables to replace fossil fuels - raising concerns about geography, intermittency and capacity - many nations have concluded that debate some time ago, have now moved on and are busy implementing a non-nuclear energy-transformation.

There is increasing availability and affordability of storage options, enabling firmed dispatchable power from renewable sources. In October 2018 Deisendorf and Elliston rebutted many of the myths regarding use of renewables. They noted:

"*Large-scale electricity systems that are 100% renewable, including those whose renewable sources are predominantly variable (e.g. wind and solar PV), can be readily designed to meet the key requirements of reliability, security and affordability. The transition to 100% renewable electricity could occur much more rapidly than suggested by historical energy transitions."*[15,16,17]

NUCLEAR REACTOR PROJECT TIME FRAMES

[12] https://www.stormsmith.nl/reports.html

[13] Diesendorf, M. Sure, let's debate nuclear power – just don't call it "low-emission" The Conversation February 2014 http://theconversation.com/sure-lets-debate-nuclear-power-just-dont-call-it-low-emission-21566

[14] https://www.climatecouncil.org.au/nuclear-power-stations-are-not-appropriate-for-australia-and-probably-never-will-be/

[15] The feasibility of 100% renewable electricity systems: A response to critics

[16] https://www.sciencedirect.com/topics/engineering/security

[17] https://www.sciencedirect.com/topics/engineering/affordability

The urgency of the requisite energy-transformation is clear.

The prospects for a speedy transition to nuclear electricity generation and dramatic carbon-emission abatement of a 'virgin' nuclear power nation like Australia can be framed via the IAEA document 'Establishing the safety infrastructure for a NPP'.

This paper provides a timeline chart which serves as a (typically buoyant) guide to anticipated timing of such a venture.[18] The guidelines propose that between 11 and 20 years are required to establish appropriate safety infrastructure for a nuclear power program, from *initial site survey* to *commissioning* of a reactor.

The chart assumes several optimistic timeframes, given recent experience of reactor-builds in nations with similar safety cultures as ours, such as France, Finland and the United States. Faster processing has been achieved in China, but the existence of a one-party state, with very low transparency and multiple build safety concerns makes for a poor comparator for a start-up nuclear power nation like Australia.

Given the lack of experience, expertise, technology and materials in Australia for a *de novo* program, even the more conservative IAEA time-frames must be greeted with a degree of skepticism.

The IAEA describes phases 1, 2 and 3 in establishing a new reactor.

According to the IAEA, by the end of *Phase 1*, an initial site survey and an environmental impact statement will have been completed over a period of 1 to 3 years and then a nation should be 'ready to make a decision whether to introduce nuclear power'. The first step articulated here is 'Site survey'.

This would presumably require:

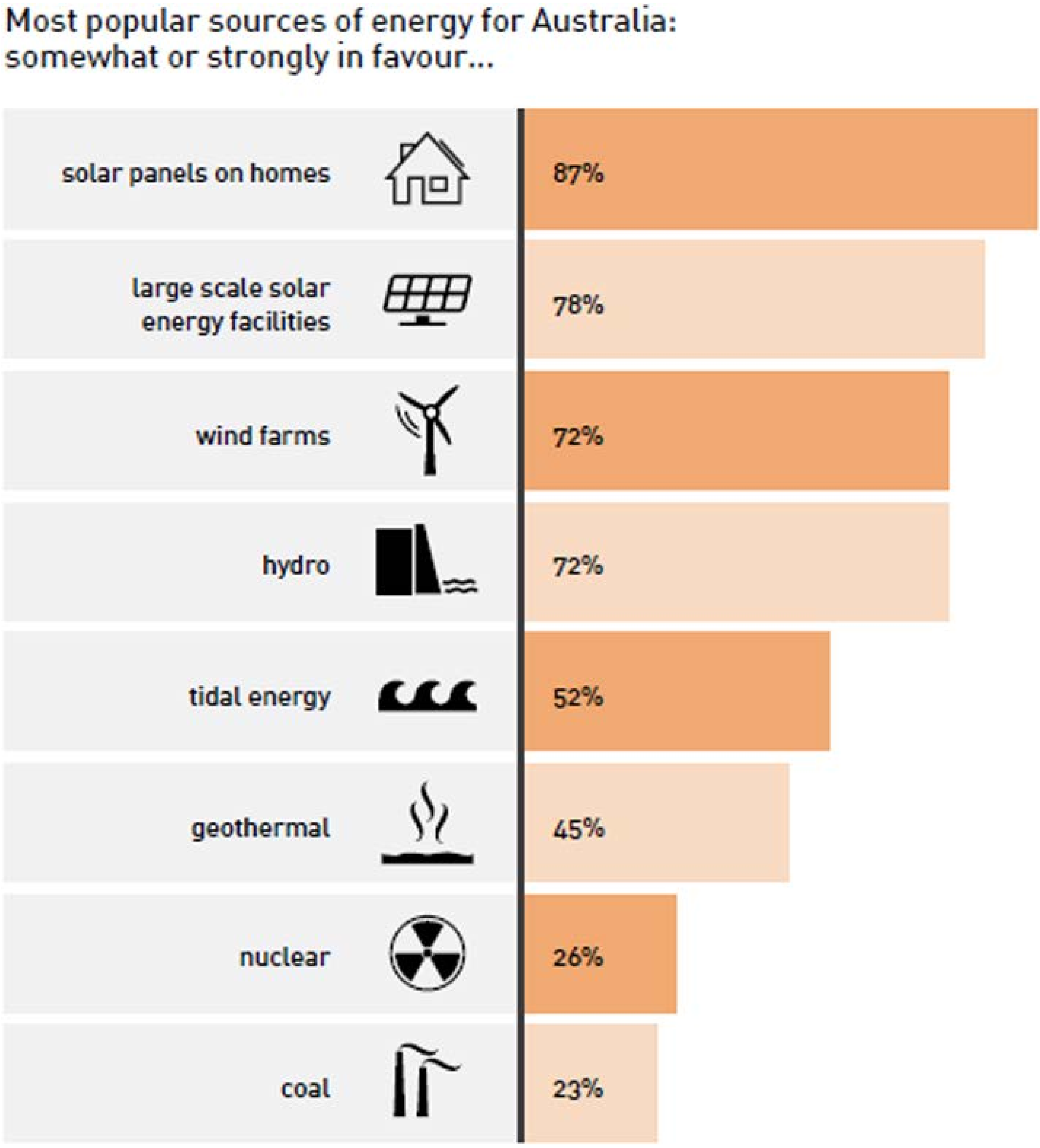
- all major *State* political parties have reached bipartisan agreement on developing a nuclear power program
- attainment of a sufficient State parliamentary majority which can pass enabling legislation
- all major *Commonwealth* political parties have adopted pro-nuclear power policies
- Commonwealth parliamentary majorities have been attained
- Commonwealth legislative changes have been made
- legal challenges have been successfully rebuffed
- community opposition from civil society has been sufficiently suppressed

At present there is no political consensus about nuclear power in Australia, nothing approaching a bipartisan acceptance at the state or federal level and opinion polls repeatedly suggest the electorate is likely to be resistant in the short to medium term at the very least.

Community Engagement

[18] http://www-pub.iaea.org/books/IAEABooks/8636/Establishing-the-Safety-Infrastructure-for-a-Nuclear-Power-Programme-Specific-Safety-Guide

A survey funded by the federal Australian Renewable Energy Agency found that solar panels on roof tops were supported by 87 per cent of respondents, with large-scale solar farms "strongly" or "somewhat" backed by 78 per cent. Wind farms and hydro, at 72 per cent, also far eclipsed the backing of just 23 per cent for coal and 26 per cent for nuclear energy.[19]



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Although community opinions about nuclear energy continue to evolve, research by Newspoll and the Australia Institute suggests that a significant proportion of the population who support nuclear power plants being built in Australia are likely to oppose plans to build them *in their local area*. For example, a Newspoll survey published in The Australian in December 2006 found that 35 per cent of people support nuclear power plants being built in

[19] http://www.ipsos.com.au/Ipsos_docs/Solar-Report_2015/Ipsos-ARENA_SolarReport.pdf
[20] http://www.ipsos.com.au/Ipsos_docs/Solar-Report_2015/Ipsos-ARENA_SolarReport.pdf

Australia[21]. However, a survey conducted by Newspoll on behalf of the Australia Institute found that only 25 per cent of Australians support a nuclear power plant in their local area.[22]

It is worth noting the actual difficulties the Federal government has faced for over two decades (and continues to face) in finding a location for our relatively small amount of long lived Intermediate Nuclear Waste (ILW).

The process has divided communities and created enormous distress. The misinformation provided by the government has been highly problematic, and the promises made to these communities about ongoing employment opportunities clearly unrealistic when compared with facilities operating overseas.

The proposal of a 100 year “nuclear waste storage facility” for long lived, highly radioactive intermediate level waste (that stays toxic for around 10,000 years) clearly does not meet international best practice.

The community that ends up “storing” this waste is likely to be left stranded with it in the long term, without any true disposal option.

Opposition to any nuclear reactor is likely to be much greater, given the higher risks associated with both traditional and small modular reactors.

There will also be much greater quantities of High Level Waste (HLW) and ILW. There are no HLW disposal facilities operating anywhere in the world. Despite 70 years of research and many optimistic promises, nuclear waste remains an unsolved problem. This is a significant proliferation risk, given nuclear waste can be used to make nuclear weapons.

Locations in Australia that have reasonable compliance with the IAEA guidelines are few. One comprehensive effort to apply the guidelines of regulators was attempted in the wake of the UMPNER review[23] in 2006, by researchers at the Australia Institute. In siting a nuclear power plant, there are two main objectives:

- ensuring the technical and economic feasibility of the plant; and
- minimising potential adverse impacts on the community and environment.[24]

There are four primary criteria for the siting of nuclear power plants in Australia:

- proximity to appropriate existing electricity infrastructure;
- proximity to major load centres (i.e. large centres of demand);
- proximity to transport infrastructure to facilitate the movement of nuclear fuel, waste and other relevant materials; and
- access to large quantities of water for cooling. [25],[26]

[21] Newspoll 2006, ‘Opinion Polls’, (30 November 2006, 2007).
[22] Macintosh, A. 2007, Who Wants a Nuclear Power Plant? Support for nuclear power in Australia, Research Paper No. 38, January, The Australia Institute, Canberra.
[23] http://www.ansto.gov.au/__data/assets/pdf_file/0005/38975/Umpner_report_2006.pdf
[24] http://www.tai.org.au/documents/downloads/WP96.pdf

Other important siting criteria include demographic, economic, ecological, heritage, security, atmospheric and geological a parameters.

Given recent experience with resistance to Coal Seam Gas and wind power in Australian neighbourhoods, it would seem judicious to assume there would be substantial resistance to nuclear reactor proposals in local communities and more broadly.

International experience suggests that siting new reactors is much easier in locations where there are pre-existing facilities – it is safe to assume that developing a greenfield site would focus pre-existing powerful civil society forces and facilitate recruitment of previously uncommitted citizens to the cause.

Whatever disparaging attitudes proponents of such a project might have about 'NIMBY-ism', the reality would surely translate to arduous, drawn-out, divisive and socially disruptive struggles.

As noted, the Federal government has failed to site a relatively small amount of low and intermediate level radioactive waste after several decades, with bipartisan political party support, even in perceived 'remote', low-population zones because of community opposition. This gives some indication of the potential for community resistance and provides a caution to would-be promoters of the technology.

It is unlikely that a nuclear power program where sites have been identified could achieve State and Commonwealth parliamentary majorities within the next 2 parliamentary cycles. Realistically, given the multiple political impediments, the IAEA time-frame – which begins with site surveys - is not likely to proceed in the next decade.

The IAEA proposes that Phase 3 can be completed within 7 to 10 years, with up to 5 years required to enable appropriate safety and regulatory frameworks to be enabled. A reactor could then be built and ready to install fuel within 3 to 4 years.

Assuming the more conservative time frame and ten years to achieve political consensus, the reactor would then begin fission by 2045. But a survey of the past decade of reactor projects in the western world gives cause for considerable caution in accepting even the more conservative estimate of 4 years from concrete to fuelling.

The world leader in nuclear power production is a case in point. The French EPR (Evolutionary Power Reactor) was the first Generation III design to win orders, first in 2003 when the order for Olkiluoto 3 (in Finland) was the first for a nuclear reactor in Western Europe in 15 years. This was followed by the 2006 order for an EPR at Flamanville in France, and two EPRs at Taishan in China in 2007.

All three EPR construction projects have suffered cost blowouts or delays or both.
The estimated cost of the Flamanville EPR in France has increased from €3.3 billion (US$3.7b) to at least €9 billion (US$10.1b). The first concrete was poured in 2007 and commercial operation was expected in 2012. It is a technical and construction failure; and

[25] Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) 1999, Draft Criteria for the Siting of Controlled Facilities, ARPANSA, Commonwealth of Australia, Canberra.
[26] International Atomic Energy Agency (IAEA) 2003, Site Evaluation for Nuclear Installations: Safety Requirements, Safety Standards Series No. NS-R-3, IAEA, Vienna, Austria

also at least 3.5 time more expensive than originally planned. Current estimates are 10 years behind schedule with operation planned for 2022[27].

There is no credible scenario where more EPRs will be built in Europe, yet they were hailed by France as the basis for its global exports. In 2014 French company Areva recorded massive losses amounting to some €5 billion euros on account of costs linked to delays to its flagship EPR reactor, and is now reported as bankrupt. Finland has cancelled its contract for a second EPR.

In the US, the bankruptcy of nuclear behemoth Westinghouse largely occurred due to massive cost overruns and delays.[28] Their experience is very relevant to the claims made by proponents of the small modular reactors.

> "*Even though Westinghouse's approach of pre-fabricated plants was untested, the company offered aggressive estimates of the cost and time it would take to build its AP1000 plants in order to win future business from U.S. utility companies. It also misjudged regulatory hurdles and used a construction company that lacked experience with the rigor and demands of nuclear work, according to state and federal regulators' reports, bankruptcy filings and interviews with current and former employees."*

The nuclear power industry has a long history of highly optimistic projections not meeting promised outcomes.

Given the urgent need to transition to low/zero carbon by mid-century, it would be sensible to measure our prospects against the international experience.

If we experience the same degree of retardation in construction as witnessed in other more prepared countries (cost blow-outs, material and expertise and labour bottlenecks, unexpected developments) – then we should estimate more like 10 years to get from concrete to fission. Even if we assume novice Australian reactor program management can outstrip the French and the Americans, it is hard to see an Australian reactor producing electricity – and thus abating greenhouse gas emissions - much before 2040.

Way too late.

Rapidly evolving storage technologies are also likely to have major impacts both on centralised grid demand and need for baseload generation.

Experiences with rapid and successful expansion of renewables is well-documented in places including Germany, Spain, Denmark and California and even China.

An authoritative study from Stanford University published in May 2015, examined the prospects in the USA for a similar energy transformation and concludes:

[27] http://world-nuclear-news.org/Articles/Weld-repairs-to-delay-Flamanville-EPR-start-up
[28] https://www.reuters.com/article/us-toshiba-accounting-westinghouse-nucle-idUSKBN17Y0CQ

"The plans contemplate 80–85% of existing energy replaced by 2030 and 100% replaced by 2050. Year 2050 end-use U.S. all-purpose load would be met with 30.9% onshore wind, 19.1% offshore wind, 30.7% utility-scale photovoltaics (PV), 7.2% rooftop PV, 7.3% concentrated solar power (CSP) with storage, 1.25% geothermal power, 0.37% wave power, 0.14% tidal power, and 3.01% hydroelectric power. Based on a parallel grid integration study, an additional 4.4% and 7.2% of power beyond that needed for annual loads would be supplied by CSP with storage and solar thermal for heat, respectively, for peaking and grid stability.

Converting would also eliminate 62 000 (19 000–115000) U.S. air pollution premature mortalities per year today and 46 000 (12000–104 000) in 2050, avoiding $600 ($85–$2400) bil. per year (2013 dollars) in 2050, equivalent to 3.6 (0.5–14.3) percent of the 2014 U.S. gross domestic product. Converting would further eliminate $3.3 (1.9–7.1) tril. per year in 2050 global warming costs to the world due to U.S. emissions.

These plans will result in each person in the U.S. in 2050 saving $260 (190–320) per year in energy costs ($2013 dollars) and U.S. health and global climate costs per person decreasing by $1500 (210–6000) per year and $8300 (4700–17 600) per year, respectively.

The new footprint over land required will be 0.42% of U.S. land. The spacing area between wind turbines, which can be used for multiple purposes, will be 1.6% of U.S. land.

100% conversions are technically and economically feasible with little downside".[29]

The issue of timeliness is not just academic.

Even with the optimistic timeframes laid out in the IAEA "*Establishing the safety infrastructure for a NPP*" guideline and those proposed by other promoters of nuclear electricity generation, nuclear power (including from small modular reactors) would result in major delays in emissions reduction, resulting in greater climate disruption.

Whilst there are vociferous opponents of the principle that our electricity can be powered in the medium term by 80-100% renewables, there is strong evidence to support the proposition and more importantly many nations are already well on the way to achieving this. There are clearly significant hurdles and barriers to this, but it is a genuine alternative.

SMALL MODULAR REACTORS

There is very clear evidence from nuclear reactor construction globally (the French and US as cases in point) that nuclear power plants have a high risk of cost overruns and major delays. While cost of renewable energy has fallen over time, nuclear power has consistently become more expensive.

Despite the enthusiastic and optimistic marketing of small modular reactors (SMRs), with new technologies it is well documented that there is even greater likelihood of cost blow outs and delays.

[29] http://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf

Looking at existing experience of SMRs globally is useful, given industry enthusiasm usually gives very optimistic projections.

From the March 2019 report "SMR cost estimates, and costs of SMRs under construction"[30]-

"The CAREM (Central Argentina de Elementos Modulares) SMR under construction in Argentina illustrates the gap between SMR rhetoric and reality. Argentina's Undersecretary of Nuclear Energy, Julián Gadano, said in 2016 that the world market for SMRs is in the tens of billions of dollars and that Argentina could capture 20% of the market with its CAREM technology. But cost estimates have ballooned:

- In 2004, when the CAREM reactor was in the planning stage, Argentina's Bariloche Atomic Center estimated an overnight cost of US$1 billion / GW for an integrated 300-MW plant (while acknowledging that to achieve such a cost would be a "very difficult task").
- When construction began in 2014, the estimated cost was US$17.8 billion / GW (US$446 million for a 25-MW reactor).
- By April 2017, the cost estimate had increased to US$21.9 billion / GW (US$700 million with the capacity uprated from 25 MW to 32 MW).

The CAREM project is years behind schedule and costs will likely increase further. In 2014, first fuel loading was expected in 2017 but completion is now anticipated in November 2021.

In addition the estimated costs of building Russia's floating nuclear power plant have increased more than four-fold (now US$10 billion /gigawatt). In 2016 the OECD NEA report said that electricity produced by the plant is expected to cost about US$200/MWh, with the high cost due to large staffing requirements, high fuel costs, and resources required to maintain the barge and coastal infrastructure.[33]

Similarly a 2016 report said that the estimated construction cost of China's demonstration high-temperature gas-cooled reactor plant (HTGR) is about US$5,000/kW – about twice the initial cost estimates. China's Institute of Nuclear and New Energy Technology at Tsinghua University (according to the World Nuclear Association) expects the cost of a 655 MWe HTGR to be 15-20% more than the cost of a conventional 600 MWe pressurized water reactor (PWR). Cost increases have arisen from higher material and component costs, increases in labor costs, and increased costs associated with project delays. The World Nuclear Association states that the cost of the demonstration HTGR is US$6,000/kW.[33]

This same report analyses authoritative sources for comparable estimates of SMR construction.

In summary it finds:

- **International Energy Agency (IEA) and the OECD Nuclear Energy Agency (NEA):** A 2015 report by the IEA and the OECD NEA predicts that electricity costs

[30] https://wiseinternational.org/nuclear-monitor/872-873/smr-cost-estimates-and-costs-smrs-under-construction

from SMRs will typically be 50−100% higher than for current large reactors, unless there are major identical SMRs being built to give economies of scale. Generation IV reactors would be even more costly.

- **European Commission:** The European Commission 2016 'Communication on a Nuclear Illustrative Programme' notes that claims supporting SMR economics – which emphasize standardization, learning effects, cost sharing and modularization – "are difficult to quantify due to the lack of existing examples". The attached Staff Working Document further states: "Due to the loss of economies of scale, the decommissioning and waste management unit costs of SMR will probably be higher than those of a large reactor (some analyses state that between two and three times higher)."

- **UK Department for Business, Energy and Industrial Strategy - Atkins consultancy report** estimates that the levelized cost of electricity for an SMR based PWR design would be £86–124/MWh with a central estimate of £101/MWh and "recognised that SMR is a new technology and there is a substantial risk that these costs will be higher than this if costs accumulate during development or if financing costs are initially higher than they are for large nuclear."

- **International Atomic Energy Agency:** states that "although SMRs require less upfront capital per unit, their electricity generating cost will probably be higher than that of large reactors"

- **Massachusetts Institute of Technology:** A 2018 MIT report noted *"The industry's problem is not that it has overlooked valuable market segments that need smaller reactors**. The problem is that even its optimally scaled reactors are too expensive on a per-unit-power basis.** A focus on serving the market segments that need smaller reactor sizes will be of no use unless the smaller design first accomplishes the task of radically reducing per-unit capital cost.*

- **Mark Cooper:** senior research fellow for economic analysis at the Institute for Energy and the Environment at Vermont Law School, noted in 2014-"*SMR technology will need massive subsidies in the early stages to get off the ground and take a significant amount of time to achieve the modest economic goal set for it…. Even if the technology could be deployed at scale at the currently projected costs, without undermining safety, it would be an unnecessarily expensive solution to the problem that would waste a great deal of time and resources, given past experience."*

- **Studies published in the *Proceedings of the National Academy of Science*** Carnegie Mellon University's Department of Engineering and Public Policy *"Our results reveal that while one light water SMR module would indeed cost much less than a large LWR, it is highly likely that the cost per unit of power will be higher. In*

> *other words, light water SMRs do make nuclear power more affordable to set up but not necessarily more economically competitive for power generation."*
> For a single 45 MWe reactor, 11 experts in 2013 gave median costs between $4,000 and $7,700/kWe while five experts (four of them working for nuclear technology vendors) provided estimates as much as a factor of two to three higher. The authors state: "These five experts argued that costs rise rapidly as reactors become smaller, with the result that the 45-MWe reactor is especially disadvantaged."

As illustrated by the state run Chinese, Russian and South American experiences noted earlier, SMR projects face major cost overruns, not dissimilar to those affecting large reactors.

Massive government subsidies will be required for any SMR build in Australia.

DISADVANTAGES AND RISKS

There are a several other factor a play which are major barriers to the nuclear power, which simply do not apply in the case of renewables

DEMAND AND DESPATCHABLE POWER

Australia's grid electricity consumption has been declining over the last seven years due to a combination of efficiencies and renewables.[31]

Plants that can increase and decrease rapidly and respond to market demand are needed.

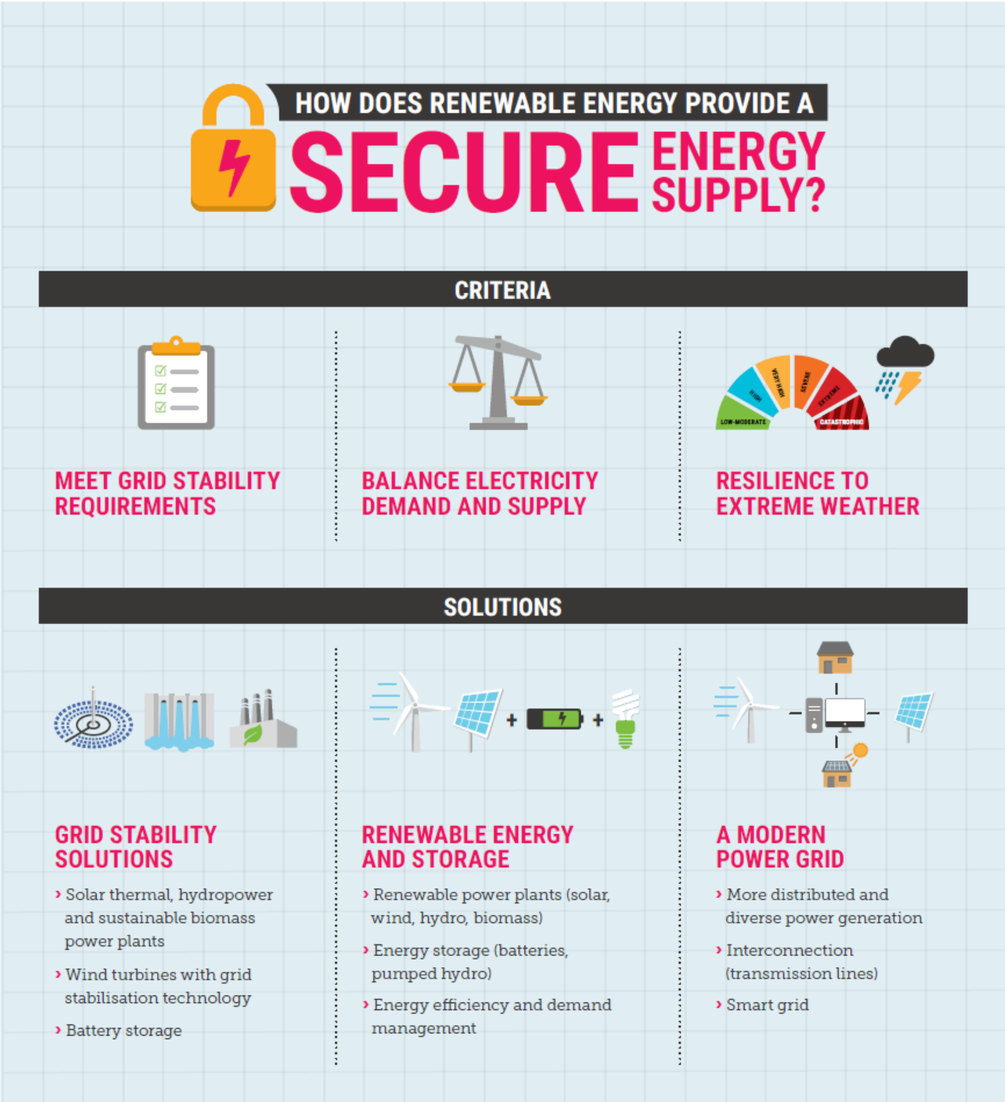
AEMO outlined in the 2018 *Integrated System Plan* (ISP), system reliability requires that new utility-scale renewable generation be complemented by storage, distributed energy resources (DER), flexible thermal capacity, and transmission, to ensure dispatchability in all hours. [32]

A panel presenting in August this year to the House of Representatives Standing Committee regarding the prerequisites for nuclear energy in Australia included representatives from Australia's energy market regulator (AER), rule maker (AEMC) and operator (AEMO). They noted a mix of distributed renewable energy generation and firming technologies including battery storage and pumped hydro, remains the best path forward for Australia's future grid.[33]

Planning to introduce large amounts of excess baseload power capacity, even if it is in another 30 years, would be economic vandalism of the current renewables market and significantly damage future investment.

[31] http://www.esaa.com.au/policy/data_and_statistics-_energy_in_australia
[32] https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan

[33] *https://reneweconomy.com.au/nuclear-inquiry-told-firmed-renewables-cheapest-and-best-option-for-future-58109/*



[34]

COST

Australian Energy Market Operator (AEMO) noted in its 2018 *Electricity Statement of Opportunities* (ESOO) forecasts: "It is critical that the investment environment and policy and regulatory arrangements, such as those contemplated by the reliability mechanism of the National Energy Guarantee, are capable of supporting a smooth transition to replacement resources as current generation retires. Government and industry must actively work towards creating the landscape for this to occur, without disruption to reliability, and at the lowest cost to consumers."[35]

It is clear nuclear generation would be neither a smooth transition, nor at the lowest cost to consumers. Nor would it be ready as the next rounds of generators retires.

Despite many claims to the contrary, worldwide nuclear plants have required massive government subsidies, uncompetitive pricing and loan guarantees. For example in the UK the Hinkley Point C reactors will require between 4.8 and 17.6 billion pounds subsidy, with

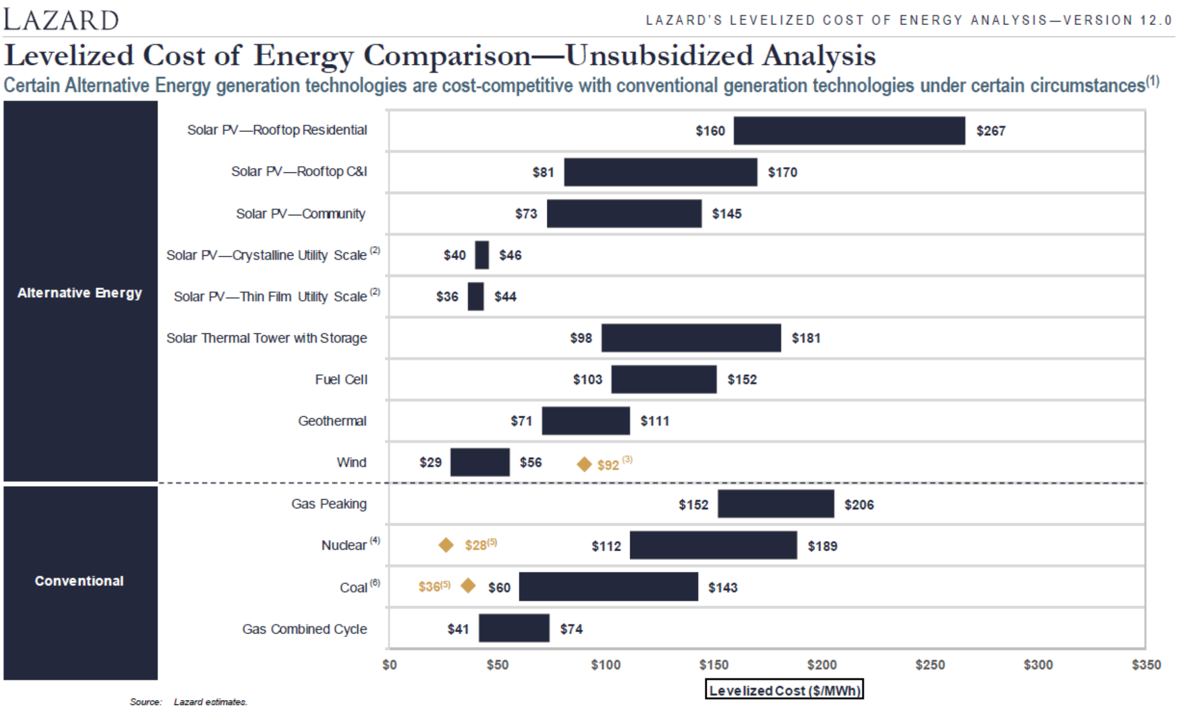
[34] https://www.climatecouncil.org.au/uploads/efaba1ac235ca4043c745f9f7f012f93.pdf
[35] https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities

electricity price guaranteed at more than twice the current wholesale rate[36]. In the USA, USD $12.5 billion in taxpayer backed loan guarantees have been required to encourage the building of new nuclear power plants[37].

Two analyses of levelised cost of energy are presented in the following tables: one from the Climate Council in 2017 and one from the financial advisory and asset management firm Lazard in November 2018. [38,39]

Power Technology	Levelised Cost of Energy (LCOE)$ (aus)/MWh
SA Solar Thermal Plant	$78[1]
Wind	$60 - 118[2]
Solar	$78 - 140
Gas Combined cycle	$74 - 90[3]
Coal	$134 - 203
Coal with CCS	$352

Source: BNEF Research 2017.
[1] Government of South Australia 2017.
[2] Note recent prices for wind are "well below" $60/MWh.
[3] Based on gas prices of $8/GJ. Current gas prices are much higher than this, and at peak times can be up to 2-3 times higher.



36 Trouble ahead for UK's nuclear hopes. Politico.eu 25/6/15 http://www.politico.eu/article/nuclear-uk-hinckley-point-areva-cameron-court-justice-austria-state-aid/

37 Department of Energy Issues Draft Loan Guarantee Solicitation for Advanced Nuclear Energy Projects http://energy.gov/articles/department-energy-issues-draft-loan-guarantee-solicitation-advanced-nuclear-energy-projects

38 https://www.climatecouncil.org.au/uploads/efaba1ac235ca4043c745f9f7f012f93.pdf

39 https://www.lazard.com/media/450773/lazards-levelized-cost-of-energy-version-120-vfinal.pdf

Clearly nuclear power generation is not cost competitive.

In addition Lazard's analysis of Levelised Costs of Storage in 2018 suggests commercial use cases for solar PV plus storage already provide moderately attractive returns in the markets assessed (e.g., California and Australia).[40] In the past decade, the cost of energy storage, solar and wind energy have all dramatically decreased, making solutions that pair storage with renewable energy more competitive. For example, in 2018 bidding for a project by Xcel Energy in Colorado, the median price for energy storage and wind was $21/MWh, and it was $36/MWh for solar and storage (versus $45/MWh for a similar solar and storage project in 2017).[41]

The panel presenting in August mentioned earlier, which included representatives from Australia's energy market regulator (AER), rule maker (AEMC) and operator (AEMO) noted that nuclear power cannot compete with firmed renewables – already at price parity with new-build coal and gas and clearly on track to becoming the lowest cost generation form for the National Electricity Market. [35]

They also explained nuclear power is around four times more expensive – $16,000/kW for the still mainly conceptual Small Modular Reactor technology – and not fit for purpose on a rapidly changing Australian grid.

At the same hearing Dr Ziggy Switkowski, who headed up the Coalition's last major inquiry into nuclear power, stated "The window (in Australia) is now closed for gigawatt-scale nuclear," noting that current large-scale versions of the technology had failed to find anywhere near the same economies of scale that had been enjoyed by solar and wind.

Current costs for SMR power generation, as modelled by the AEMO and CSIRO, are estimated at $16,000/kW, which is more expensive than large-scale nuclear by at least 50 per cent, and four or five times higher than capital cost of new solar wind.

And while other technologies are modelled to see a decrease in their cost over time – solar thermal and storage, for example, at $7,000/kW is expected to fall to around half that in 2050 – SMR nuclear costs stay flat in AEMO/CSIRO modelling out to 2050.

Carnegie Mellon University's Department of Engineering and Public Policy researched the existing financial aspects of the SMR industry and concluded that SMRs would not be viable unless the industry received *'several hundred billion dollars of direct and indirect subsidies'* over the next several decades.[42]

The same study noted recent efforts to kick start nuclear construction in the United States have failed. Construction of two Westinghouse AP1000s at the Virgil C. Summer plant in South Carolina was abandoned last year. Although the project was only 40% complete, it had already cost $9 billion. Southern Nuclear's efforts to build two of the same reactors at its Vogtle plant in Georgia are continuing, but the company currently expects the project to cost

[40] https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf
[41] https://www.eesi.org/papers/view/energy-storage-2019
[42] https://www.pnas.org/content/115/28/7184

approximately $25 billion, a staggering $11,000 per kW_e, and these costs are expected to rise.

The Carnegie Mellon researchers combined engineering economic analysis and the use of structured procedures to elicit expert judgments to evaluate the likely cost and performance of deploying these light water SMRs for the provision of electric power.

They found one light water SMR module would indeed cost much less than a large LWR, but it is highly likely that the cost per unit of power will be higher.

In other words, light water SMRs make nuclear power more affordable to build but are not more economically competitive for electric power generation. That vision of the dramatic cost reduction that SMR proponents describe is unlikely to materialize with the first generation of light water SMRs, even at *n*th-of-a-kind deployment.

"*Because light water SMRs incur both an economic premium and the considerable regulatory burden associated with any nuclear reactor, we do not see a clear path forward for the United States to deploy sufficient numbers of SMRs in the electric power sector to make a significant contribution to greenhouse gas mitigation by the middle of this century.*"[43]

SMR's face major challenges in cost, financing, regulation, community acceptability and operations.

Cost: comparing SMR's with natural gas, SMR's becomes cost-prohibitive. This is especially true in high-temperature applications where light water SMRs would support electric heating.

- Construction financing: Very few companies have a financial profile that supports such a large investment in a substitute technology, especially before it attains *n*th-of-a-kind costs and reliable performance and in the absence of an effective carbon policy.
- The large number of regulatory and siting issues that neither reactor designers nor regulators have resolved yet. These include emergency planning in the presence of many potentially hazardous effluents and community opposition.
- Operational challenges: light water SMRs with outlet temperatures of 320–350 °C can cater to many industrial markets, but not to those that demand high-temperature heat unless these reactors are supplemented with electric heating, which is possible but capital-intensive. Industry demands cheap heat, predictable performance, and low commercial risk.

When it comes time to sign contracts and pour concrete, it is highly unlikely that any business would opt for a light water SMR, let alone at first-of-a-kind.

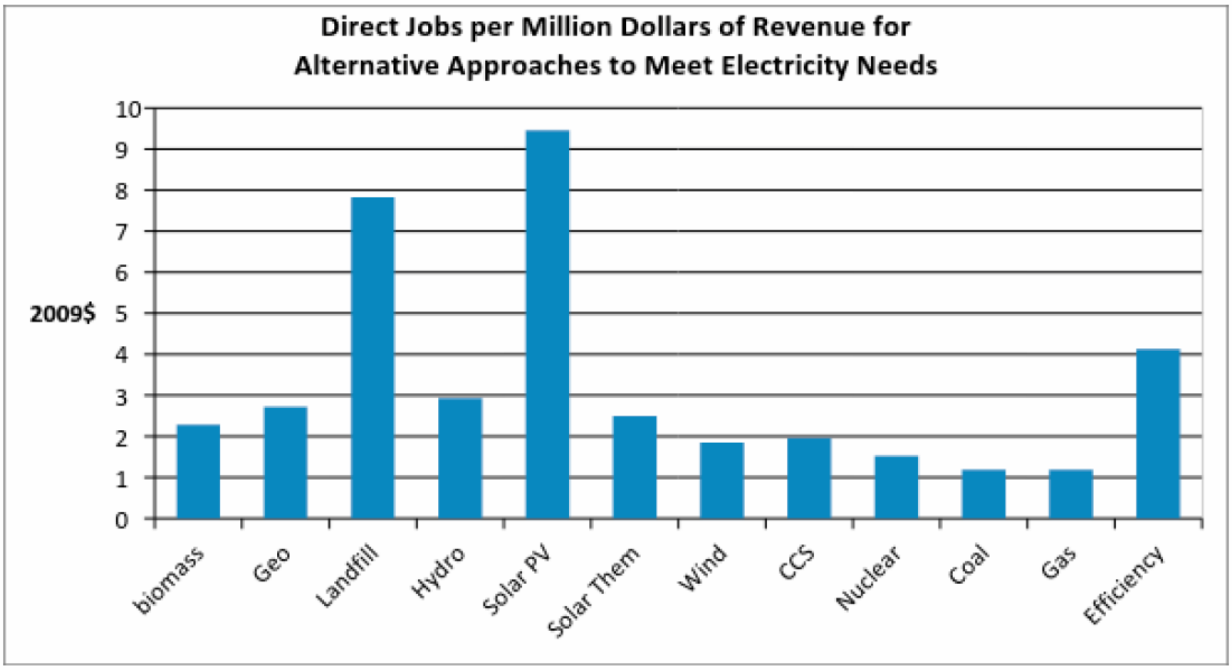
SMR's do not have the economies of scale and are therefore even more expensive to operate than large PW reactors. A study by WSP/Parsons Brinckerhoff, commissioned by the 2015/16 South Australian Nuclear Fuel Cycle Royal Commission, estimated costs of

A$180–184/MWh (US$127–130) for large pressurised water reactors and boiling water reactors, compared to A$198–225 (US$140–159) for SMRs.[43]

In addition SMRs face the perennial issues regarding massive water usage, waste disposal, security and nuclear weapons proliferation, which will be discussed later in this submission.

EMPLOYMENT

Nuclear power generation has been put forward as a possible employment generator. In an economic analysis of the energy sector, Mark Cooper[44] from the Institute for Energy and the Environment in Vermont noted evidence in the electricity sector, which shows that nuclear creates many fewer jobs than efficiency and solar and about the same number of jobs as wind.



Source: Direct jobs: Max Wei, Shana Patadia and Daniel Kammen, "Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US?" ***Energy Policy*****, 38 (2010);**

Australia's lack of a trained/experienced nuclear power workforce would add to the already considerable delays in any nuclear power reactor planning or construction.

WATER

Australia is the world's driest continent. With climate change it is predicted that the southern part of Australia will get drier. Nuclear power stations require large amounts of water. A 2006 parliamentary library research paper [45] quoted a 2006 Australian Nuclear Science and Technology Organisation (ANSTO) report. The plant referred to in this report was an Advanced Pressurized Water Reactor (AP1000) developed by Westinghouse. This plant

[43] nuclearrc.sa.gov.au/app/uploads/2016/05/WSP-Parsons-Brinckerhoff-Report.pdf
[44] Cooper M. Power Shift. Institute for Energy and the Environment June 2015
[45] Water requirements of nuclear power stations Department of Parliamentary Services Parliament of Australia December 2006, no. 12, 2006–07

would have an operating output of between 1,115 and 1,150 megawatts depending on the cooling technique employed.

The paper then used a report by the US Department of Energy which published estimates of the likely cooling water requirements of this sort of plant. These were stated to be between 450,000 to 750,000 US gallons per minute. This equates to an annual average usage rate of between 779 and 1,338 mega litres per megawatt which is consistent with existing nuclear power plants. To try to give this figure some meaning, annual use would be between 347,000 and 615,000 Olympic swimming pools.

Per megawatt existing nuclear power stations *use* and *consume* more water than power stations using other fuel sources. Depending on the cooling technology utilised, the water requirements for a nuclear power station can vary between 20 to 83 per cent more than for fossil fuel power stations. Most renewable energy sources, such as wind and PV solar power, do not require water when generating electricity.

NUCLEAR REACTORS AND RADIATION

The nuclear reactor core is highly radioactive, containing nuclear fuel rods and where heat is generated through nuclear fission, and hence is heavily shielded accounting for virtually no ionising radiation to the surrounding region. Every day, however, in the course of their activity nuclear reactors routinely produce radioactive gases and liquids. These are captured and stored on-site until their activity decays to a sufficient level to enable their release into the environment ensuring the activity is below regulatory limits. These amounts are highly regulated and tritium is the largest of the nuclide emissions, by activity, from civilian reactors, apart from noble gases in some types of reactors. The radioactive effluents almost completely account for all radioactive emissions from nuclear power plants.

Why is ionising radiation of biological importance?

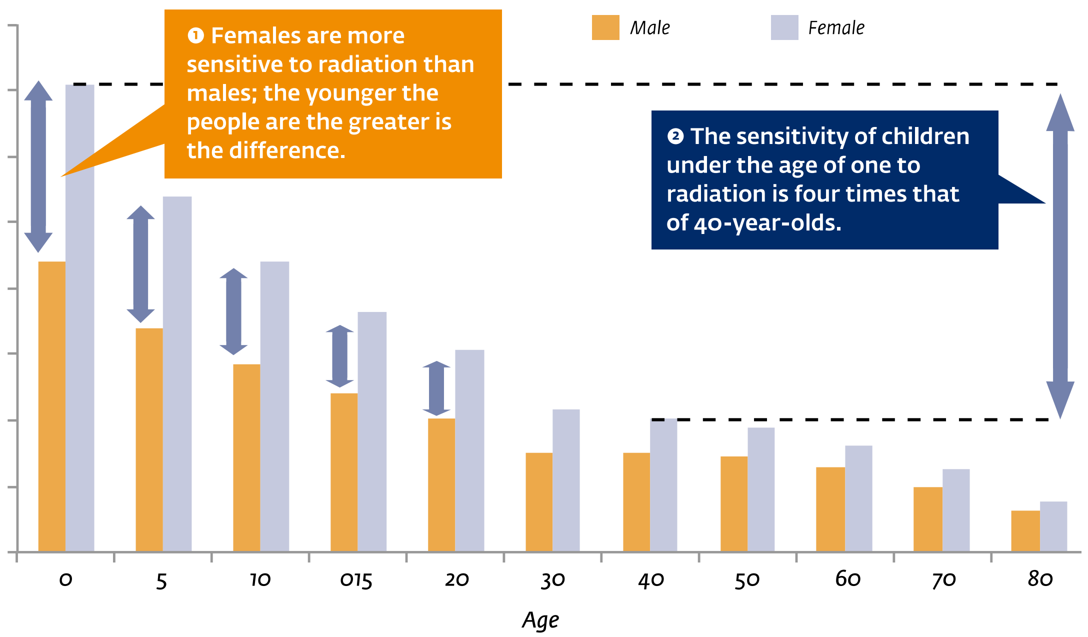
Ionising radiation is intensely biologically injurious, not because it contains extraordinarily large amounts of energy, but because its energy is bundled and delivered to cells in large packets.

Large complex molecular chains, especially of DNA, define who we are, regulate many biological processes, and are both our most precious inheritance and the most vital legacy we pass on to our children. One of the strands of the double DNA helixes inside each of our cells is derived from our mother, the other from our father. These large molecules are particularly vulnerable to disruption by ionising radiation. Radiation may cause direct damage to DNA, or cause indirect damage through the production of highly reactive chemicals, like free radical ions, which then react with DNA.

A variety of types of damage may result—single and double-strand DNA breaks, oxidative changes to the nucleotide bases that make up DNA, deletions of sections of DNA; and resulting gene and chromosomal damage. The frequency of chromosomal aberrations, particularly dicentric forms, in blood lymphocytes can be used within weeks of whole-body radiation to estimate the dose received. Stable and persistent chromosomal changes which do not kill affected cells, like translocations (rearrangements of segments of chromosomes), have been demonstrated at increased frequencies even more than 50 years after exposure in Japanese *hibakusha* (nuclear bombing survivors) and New Zealand nuclear test veterans.[46]

DNA damage from radiation can have various outcomes, including effective repair, cell death (especially at high doses), impaired function, induction of cancer, or result in DNA changes transmissable to subsequent generations. Cells have mechanisms to repair DNA damage, but these are not complete or error-free. DNA is most susceptible to radiation damage when cells are dividing, so rapidly dividing and growing tissues are most vulnerable, such as blood-forming cells in the bone marrow, germ cells in the ovary and testis, cells lining the gastro-intestinal tract, and hair follicles. Radiation exposure to a fetus in the womb can lead to fetal damage (such as mental retardation) and malformations. Young children and fetuses are especially sensitive to radiation effects, and a cancer-prone mutation occurring early in prenatal life is likely to transmit to a larger number of daughter cells than a mutation occurring later, when a cell undergoing a mutation will produce fewer daughter cells.

Increased lifetime cancer risk by age and gender associated with an extra radiation dose of 10 mSv



Source: NAIIC (2012), based on data from Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation.[47]

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[46] Elevated chromosome translocation frequencies in New Zealand nuclear test veterans. https://www.ncbi.nlm.nih.gov/pubmed/18544930

[47] Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2 (2006) https://www.nap.edu/initiative/committee-to-assess-health-risks-from-exposure-to-low-levels-of-ionizing-radiation

Increased vulnerability of young people also applies to the non-cancer health risks of radiation exposure. In recent research for the British population, by way of example, a similar increase in risk occurs associated with younger age of exposure for cardiovascular disease. It was estimated that the increased lifetime risk of death from circulatory disease is about 10 times higher for a child exposed to radiation before 10 years of age compared with exposure after age 70. Similarly, an exposed child's risk of death from solid cancer was estimated to be more than 20 times higher than for exposure occurring over the age of 70, and about double that associated with the same exposure at age 30–39 years.

The science of radiation and health is still evolving. It has often been considered that the same dose of radiation delivered quickly is one and a half to two times more injurious than the same total dose delivered over a longer time. However, recent evidence suggests that this is not the case. *Bystander effects* are a feature of many types of radiation, whereby radiation damage to one cell damages nearby cells, even without initial DNA damage occurring. Inflammatory responses are thought to be involved. *Genomic instability* describes radiation-related gene damage causing increased susceptibility to further damage; and can be transmitted from parent to daughter cells. Both bystander effects and genomic instability can be delayed.

TRENDS REGARDING RADIATION EFFECTS

There has been a consistent trend over time that the more we know about radiation effects, the greater the evidence indicates those effects to be.

Maximum permitted radiation dose limits have never been raised over time; they have always been lowered.

For example, from 1950 to 1991, the maximum recommended whole-body radiation annual dose limits for radiation industry workers declined from approximately 250 to currently 20 mSv. The current recommended dose limit is not a dose below which there is no health risk. Rather, it represents the most recent compromise between safety and optimally protecting people on the one hand, and commercial and other vested interests and cost considerations on the other.

Ionising radiation also increases the risk of occurrence and death from some non-cancer diseases, including cardiovascular and respiratory disease. This has been clearly demonstrated at moderate and high doses, and recent evidence has confirmed that circulatory disease mortality (principally from heart attacks and strokes) as well deaths due to all causes other than cancer also increase at low total doses and dose rates, such as occur in nuclear industry workers.[48] The increased risk of death from heart and other circulatory diseases is estimated to be comparable in magnitude to the radiation-related

[48] Mortality from Circulatory Diseases and other Non-Cancer Outcomes among Nuclear Workers in France, the United Kingdom and the United States (INWORKS). https://www.ncbi.nlm.nih.gov/pubmed/28692406

cancer risk, meaning that the total extra risk of dying because of exposure to radiation is likely to be around double the increased risk of death from cancer alone.[49]

NUCLEAR POWER AND HEALTH IMPACTS

Powerful new epidemiological studies over the past decade have provided estimates both more accurate and demonstrating greater radiation-related health risks than previously estimated.[50] These studies are made possible by electronically linking data on radiation exposure, especially at low doses, and health outcomes for large numbers of people, such as for children who underwent a CT scan funded by national health insurance, who subsequently developed a cancer reported to their local cancer registry. The most important of these new studies are outlined below.

Childhood leukaemia near nuclear power plants

Apparent excesses of leukaemia occurring in children living near nuclear power plants have caused concern and controversy over decades. Perhaps the most prominent was an excess of leukaemia and lymphoma cases around the Sellafield nuclear plant in England in the 1980s, which was the location of the Windscale accident and fire in 1957, and, before the 1986 Chernobyl disaster, the most radioactively polluting nuclear facility in Europe. An investigation recommended by a government commissioned committee unexpectedly found that the risks for leukaemia and lymphoma were higher in children born within 5 km of Sellafield, and in children with fathers employed at the plant, particularly those recording high radiation doses before their child's conception.[51] A 2007 meta-analysis supported by the US Department of Energy examined all of the reliable data available worldwide, confirming a statistically significant increase in leukaemia for children living near nuclear power plants.[52]

The most definitive findings come from a large national German study, which examined leukaemia among children living near any of Germany's 16 operating nuclear plants over a 25-year period. It showed that the risk of leukaemia more than doubled for children living within 5 km of a nuclear plant, with elevated risk extending beyond 50 km from a plant.[53] This finding was highly statistically significant. A subsequent but less powerful study in France found a similar increase.

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[49] Systematic Review and Meta-analysis of Circulatory Disease from Exposure to Low-Level Ionizing Radiation and Estimates of Potential Population Mortality Risks https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3556625/

[50] A New Era of Low-Dose Radiation Epidemiology. https://www.ncbi.nlm.nih.gov/pubmed/26231501

[51] Results of case-control study of leukaemia and lymphoma among young people near Sellafield nuclear plant in West Cumbria. https://www.bmj.com/content/300/6722/423

[52] Meta-analysis of standardized incidence and mortality rates of childhood leukaemia in proximity to nuclear facilities. https://www.ncbi.nlm.nih.gov/pubmed/17587361

[53] Childhood Leukemia in the Vicinity of Nuclear Power Plants in Germany https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2696975/

While these findings have been challenged on grounds that they are not explicable on the basis of prevailing estimates of the radiation exposures involved and their predicted effects, this in no way changes the strength of the association, whatever its cause, and no possible cause other than radiation has been identified. Actual data on real-world outcomes always trumps any theoretical model. It is likely that either radiation exposures have been underestimated, and/or the effects of radiation exposure are greater than previously estimated.

Childhood cancer following CT scans

A major part of growing medical radiation exposure worldwide is due to CT scans. These use X-rays to take spiralled images to show closely spaced cross-sections of the body, and involve effective whole-body exposures of 1 to 10 or more (up to 20+) mSv. A number of studies have now documented cancer risks following CT scans in children that are much greater than previously estimated. The largest to date is an Australian study of cancer risk after CT scans in 680,000 young people (aged less than 20 years), compared with the 10.3 million young Australians who did not have CT scans, over the same 20-year period.[54] The study involved 10 times as many people exposed and four times the total radiation dose as the Japanese survivor data for low doses of radiation (approximately 70,000 people who received less than 100 mSv).

The CT study demonstrated a 24 per cent increase in cancer in the decade following one CT scan delivering an average effective dose of only 4.5 mSv, and 16 per cent greater cancer risk for each additional scan.[51] Cancers occurred as early as two years after exposure. The average length of follow-up after the first CT scan was close to a decade, so new cancers will continue to occur through the life of exposed individuals. For similar ages of exposure and lengths of follow up, the risk for leukaemia related to CT radiation was similar to that among the survivors of the Japanese bombings, the *hibakusha*; however, the risk of solid cancer in the more powerful CT study was 13.5 times higher for brain cancer[55] and nine times higher for solid cancers overall[51] than in the *hibakusha* studies. The findings for leukaemia and brain cancer are quite similar in the Australian study and a smaller British study (which did not include other solid cancers).[56]

The Australian study is now the largest population-based study of low dose radiation ever conducted, in children who are the group most susceptible to radiation, giving its results great importance. These studies fill important gaps in the *hibakusha* studies regarding low doses, early onset cancers, and children. Longer term follow-up of these children and examining the risks associated with nuclear medicine procedures are underway and can be expected to yield important new findings in coming years. Already the results of these

[54] Cancer risk in 680 000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians https://www.bmj.com/content/346/bmj.f2360

[55] Exposure to ionizing radiation and brain cancer incidence: The Life Span Study cohort https://www.sciencedirect.com/science/article/pii/S1877782116300315

[56] Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. https://www.ncbi.nlm.nih.gov/pubmed/22681860

studies warrant upward revision of radiation risk estimates and reduction of recommended radiation dose limits in order to effectively protect the most vulnerable. One strong likelihood is that the dose–response curve for radiation-related cancer risk is not linear as generally assumed, but steeper at low doses, with a greater effect per mSv at low doses than at higher doses, particularly for children.[52] It is also likely that the greatest increase in cancers related to radiation is in those occurring early after exposure, among people most susceptible.

Childhood cancer and background radiation

Recent evidence demonstrates that background radiation, even involving quite small radiation doses, is more important in cancer causation that previously recognised. A UK study of data from the National Registry of Childhood Tumours between 1980 and 2006 found that the risk of a child developing leukemia increased by 12% for every additional mSv of cumulative radiation exposure to their bone marrow.[57]

A more powerful national study was undertaken in Switzerland, where alpine areas are associated with higher levels of background radiation than flatter sedimentary northern areas of the country. Census data linked to Swiss Childhood Cancer Registry data identified a 3% increased risk of cancer 8 to 18 years later for each mSv of cumulative external radiation exposure, with overall cancers increased by 64% and leukemia more than doubled for children living in areas where background external radiation levels were more than 1.8mSv/year, compared with areas where levels were below 0.9 mSv/y.[58]

Cancer risks for nuclear industry workers

Updated results of large long-term studies of hundreds of thousands of nuclear industry workers coordinated by the International Agency for Research on Cancer on risks for leukaemia[59] and cancer [60] were reported in 2015. The studies included 308,000 workers from France, the UK, and the US, some of them followed up since 1944, with a mean follow-up period of 26 years, to an average age of 58 years, and involving total measured colon radiation dose (a common measure of internal organ exposure) more than five times the collective dose received by *hibakusha* who received low doses. The mean dose rate for the workers involved was only 1.1 mGy per year, less than background radiation in most places,

[57] A record-based case-control study of natural background radiation and the incidence of childhood leukaemia and other cancers in Great Britain during 1980-2006. https://www.ncbi.nlm.nih.gov/pubmed/22766784

[58] Background ionizing radiation and the risk of childhood cancer: a census-based nationwide cohort study. https://www.ncbi.nlm.nih.gov/pubmed/25707026

[59] Ionising radiation and risk of death from leukaemia and lymphoma in radiation-monitored workers (INWORKS): an international cohort study https://www.thelancet.com/journals/lanhae/article/PIIS2352-3026(15)00094-0/fulltext

[60] Risk of cancer from occupational exposure to ionising radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS). https://www.ncbi.nlm.nih.gov/pubmed/26487649

with cumulative doses well within the current most widely recommended dose limit for nuclear industry workers of an average of no more than 20 mSv per year (the average total dose received by each worker in the study during their average 12-year employment in the industry was close to 20 mSv).

The solid cancer risk was statistically compatible with, but 50 per cent higher than, that in 20–60-year-old male *hibakusha*, and will continue to rise as the subjects age. The leukaemia risk identified was similar to that in 20–60-year-old male *hibukusha*. It is important to note that at the average age of workers in the study of 58 years, the incidence of cancer and chronic diseases is beginning to accelerate.

Site-specific estimates of mortality for different solid cancers in the INWORKS cohort confirm radiation-related increases across a wide range of cancer types (Richardson et al 2018).[61]

These large and powerful studies show risks even at very low-dose rates and doses well within recommended occupational limits. They do not support a reduction of risk for the same total dose if the dose is delivered over a longer time (low-dose rates compared with high-dose rates).

Together, the CT scan and worker studies conclusively demonstrate the absence of a threshold for ionising radiation related cancer risk. In other words any exposure does harm, and the amount of harm is increased with increased exposure.

Cancer and other health effects in people exposed to the Chernobyl and Fukushima Daiichi nuclear disasters

The effects of the 1986 Chernobyl nuclear disaster have recently been independently reviewed.[62]

Major findings include:

- an estimated 40,000 excess fatal cancers in Europe by 2065;
- 6,000 additional cases of thyroid cancer have already occurred. An additional 10,000 are expected by 2065. Initially these were almost exclusively in children; more recently, cases are also occurring at older ages. Increases in thyroid cancer have also been found in a number of other countries, such as Austria, Slovakia, the Czech Republic, and Poland. It is likely that at least some of this increase is due to Chernobyl;
- increasing rates of leukaemia and thyroid cancer among the estimated total 600,000–800,000 clean-up workers, as well as increased risk of cataracts at a lower threshold dose than previously thought (100–250 mGy);
- despite international agencies assuming that no increases in congenital malformations will be detectable in Chernobyl-contaminated areas, increases in nervous system birth defects have been found in the highly contaminated Rivne-

[61] Site-specific Solid Cancer Mortality After Exposure to Ionizing Radiation: A Cohort Study of Workers (INWORKS). https://www.ncbi.nlm.nih.gov/pubmed/28991003

[62] TORCH 2016 www.ianfairlie.org/wp-content/uploads/2016/03/chernobyl-report-version-1.1.pdf

Polissia region of Ukraine. These include neural tube defects like spina bifida, anencephaly, microcephaly, and small or missing eyes;[63]

- increasing rates of breast cancer in the most contaminated regions of Belarus and Ukraine; and
- dislocation of lives due to radioactive contamination and long-term worry about radiation risks can also have adverse health consequences - among clean-up workers, depression and post-traumatic stress disorder rates are elevated even decades later, and mothers of exposed young children are at high risk of depression, anxiety, and other mental disorders.

While various Japanese and international agencies stated that no radiation related adverse health consequences were likely to be detected as a result of the Fukushima nuclear disaster, this implausible assessment has already been shown to be in error. The Japanese government's Reconstruction Agency estimated 3,407 nuclear-disaster related deaths to early 2016 in Fukushima prefecture (including due to inadequate evacuations and continuing care of chronically ill patients in contaminated regions, and suicides). A lack of comprehensive health screening and follow-up for the exposed population and inadequate cancer registries in many of the relevant areas of Japan mean that the capacity to detect and respond to health problems is constrained.

The one area where more effective screening is taking place in Fukushima prefecture (but not in other fallout-affected areas) is in periodic ultrasound examinations of the thyroid glands of children aged less than 18 years at the time of the disaster. Even though 24–29 per cent of the eligible population have not participated (to September 2016), such an active search for thyroid abnormalities can be expected to find more cysts and nodules than would come to medical attention in the absence of an active screening program, the findings to date suggest that despite thyroid radiation doses being estimated to be much lower in Fukushima than following the Chernobyl disaster, early evidence of an epidemic of thyroid cancer appears to be emerging.

This evidence is summarised on the basis of 113 thyroid cancers in children in Fukushima diagnosed to the end of 2015, including 51 diagnosed in the second round of ultrasound screening:[64,65]

- the rates of thyroid cancer detected initially in Fukushima were between 20 and 50 times higher than the Japanese national average;
- among the cancers diagnosed on the second ultrasound screening, two years after the first, the rate is still 20 to 38 times the national average, likely too great a difference to be explained by active screening alone;

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[63] Chronic Radiation Exposure in the Rivne-Polissia Region of Ukraine: Implications for Birth Defects http://scholar.google.com.au/scholar_url?url=http://www.academia.edu/download/43237882/Chronic_radiation_exposure_in_the_Rivne-20160301-25098-14syf7.pdf&hl=en&sa=X&scisig=AAGBfm17vWYv5S5YK474pKOBk5s-8TV6Nw&nossl=1&oi=scholarr

[64] Associations Between Childhood Thyroid Cancer and External Radiation Dose After the Fukushima Daiichi Nuclear Power Plant Accident. https://www.ncbi.nlm.nih.gov/pubmed/30399001/

[65] Thyroid Cancer Detection by Ultrasound Among Residents Ages 18 Years and Younger in Fukushima, Japan: 2011 to 2014. https://www.ncbi.nlm.nih.gov/pubmed/26441345

- within Fukushima prefecture, the rate in the most contaminated district was 2.6 times higher than in the least contaminated areas; and
- the cancers diagnosed were not disproportionately benign—92 per cent of the operated cases had spread outside the thyroid gland, to lymph nodes, or to distant organs.

To September 2016, the number of reported thyroid cancer cases among children screened in Fukushima had increased to 145.

Policy makers therefore need to factor this increasingly strong scientific evidence into their decision-making. Local populations are unlikely to find this information reassuring.

Legislators considering introducing or expanding nuclear power should consider these health implications. Nuclear regulators also need to revisit their assumptions and consider revising standards at existing nuclear plants.

NUCLEAR ACCIDENTS

The German studies and similar studies in the UK and France reflect disturbing possibilities of nuclear power plants in so-called normal or routine function. But of far greater significance is the potential for large scale radioactive contamination resulting from unplanned releases, caused by deliberate or accidental events. Public awareness of these potential incidents has been raised by the recent events in Japan at the Fukushima Daiichi complex. This builds on previous international experience at Chernobyl in the Ukraine in 1986 and at the Three Mile Island complex in Pennsylvania in 1979 which, although not leading to large scale loss of life was a major influence in the stagnation of the US Nuclear Power Program (NPP). Other unplanned events have also led to loss of life as well of loss of confidence in the capacity of NPP to safely address modern urban electricity generation requirements. These have included partial core meltdowns at:

- NRX (military), Ontario, Canada, in 1952
- EBR-I (military), Idaho, USA, in 1955
- Windscale (military), Sellafield, England, in 1957
- Santa Susana Field Laboratory (military), Simi Hills, California, in 1959
- SL-1, Idaho, USA in 1961. (US military)
- Enrico Fermi Nuclear Generating Station (civil), Newport, Michigan, USA, in 1966
- Chapelcross, Dumfries and Galloway, Scotland, in 1967
- Lucens reactor, Switzerland, in 1969
- A1 plant at Jaslovské Bohunice, Czechoslovakia in 1977

FUKUSHIMA

Eight years after the world's most complex nuclear disaster, the damaged Fukushima Daiichi nuclear power plants and spent fuel ponds are still leaking and dangerous, vast amounts of contaminated water continue to accumulate, 8000 odd clean-up workers labour daily and will need to for many decades, the needs of people exposed to radioactivity are still neglected, no one is in prison for a disaster fundamentally caused by the negligence of the operator and the government, and most of the lessons of Fukushima have yet to heeded.

Professor Kiyoshi Kurokawa, who chaired the Nuclear Accident Independent Investigation Commission, Japan's first ever independent parliamentary investigation commission, has written recently that since the Commission submitted its recommendations to the national Diet in 2012, "little progress of significance can be observed".[66] He describes the regulatory changes as "only amounting to cosmetic changes".

This textbook case of regulatory capture, with Japanese nuclear regulatory agencies serving the interests of the nuclear power industry instead of protecting the safety of the people, has changed relatively little.

Kurokawa describes the changes prompted by the Commission's report amongst governmental bodies "have been formalities at the minimum required level". He writes "that the structures of regulatory capture are still firmly maintained".

It is the people of Japan who not only suffer the impacts of the disaster, but largely bear the cost, such as through the US$119 billion interest-free loan TEPCO secured from the government, paid by citizens' taxes.

Over 150,000 people were evacuated from the 20km exclusion zone and many may never return to their homes, with the land now uninhabitable. Total economic costs are estimated at $300bn, comparable to that of the earthquake and tsunami that precipitated the nuclear disaster. Heroic (and expensive) plans are afoot to remove contaminated soil from over 2,500km^2 to reclaim as much land as possible in the densely populated country. The total volume of the contaminated soil waste will approximate that of all the high level nuclear waste ever generated in the history of nuclear power (30 million cubic metres).

The former prime minister, Naoto Kan, revealed that there was a real possibility of requiring the evacuation of 35 million Tokyo residents were the fallout to threaten the capital. It was dumb luck that it didn't, given that the prevailing winds in the first week of the disaster were offshore, dumping most of the fallout in the sea and preventing an unimaginable catastrophe. Recall, nuclear fallout does not respect national boundaries – neighbouring countries might be the biggest victims of a nuclear accident.

The investigation into the Fukushima reactor disaster by the Japanese Diet (parliament) found there was a combination of inadequate safety culture, mismanagement and deception on the part of regulators and operators, confronting a natural event of devastating but not unpredictable or unique proportions.

In the decade prior to the tsunami 2 separate models predicted the need for better measures to protect the reactor, but these steps were not undertaken.

[66] Kurokawa K, NInomiya AR. Examining regulatory capture: looking back at the Fukushima nuclear power plant disaster, seven years later. *University of Pennsylvania Asian Law Review* 2018;13(2), Article 2. https://scholarship.law.upenn.edu/alr/vol13/iss2/2/

What Fukushima has done is demolish the nuclear power industry's standing exhortations that they should be trusted with the welfare of millions of citizens because their industry is inherently safe.

Japan is one of the most technologically advanced countries in the world, with a mature nuclear power industry dating from the middle of last century – long enough to 'work out the bugs'. The country is also a mature democracy, so there are structural checks and balances. Furthermore, with a Transparency International (TI) ranking of 17 on the Corruption Index, Japan's public sector corruption should not be a major issue. Japan has also been subject to regular IAEA (International Atomic Energy Agency) inspections. If Japan couldn't prevent this disaster, what are the prospects for most of the new reactors planned for Asian and Middle Eastern Countries which lack any semblance of transparency or accountability, long-term experience, and have TI rankings far below that of Japan?

The root cause of the Fukushima nuclear disaster was an insular, politically well-connected nuclear industry which was intertwined with a nuclear regulator that lacked the will and ability to fulfil its role of protecting the public. Many nuclear utilities' engineers and senior management sit on the regulator's safety committee. In essence, the Japanese nuclear regulator became captive to the government and industry's goal of nuclear promotion at any cost, leading to a poor safety culture.

The organisational structure of the industry corrupted the normal checks and balances vital to ensuring safety. The nuclear regulatory agency was an arm of the ministry responsible for nuclear promotion.

TEPCO, the operator of the Fukushima Daiichi nuclear plant, and indeed the whole Japanese nuclear industry, has revealed a long history of poor safety, falsified maintenance and safety records, as well as fraudulently concealed accidents over many decades. In 2002, TEPCO, the operator of the Fukushima nuclear plant, admitted it had falsified repair reports at nuclear plants for more than two decades, It was not alone. The revelation follows the confession by all four companies – TEPCO, Chubu Electric Power, Japan Atomic Power and Tohoku Electric Power – that they concealed flaws in their reactors from government regulators.

Unfortunately, the Japanese nuclear power industry was portrayed during this time as the face of a vibrant, responsible and safe utility by the World Nuclear Association (the industry lobby group) and Japan a role model for all countries to follow.

The IAEA, which is responsible for overseeing the industry, sadly failed in its responsibility to alert the public, instead keeping its assessments closed to the general public. Its obligations only extend to informing the governments of its member states. Freshly revealed reports from the IAEA, dating from the 1990s, describe safety precautions at Japanese nuclear reactors as 'dangerously weak'. IAEA inspectors visited four reactors in 1992 and 1995, finding 90 deficiencies in safety procedures.

In a Wikileaks cable an official from the IAEA said in December 2008 that Japanese nuclear safety rules were out of date and strong earthquakes would pose a 'serious problem' for nuclear power stations, which were only rated to withstand a 7.0 earthquake (compared to the recent 9.1 earthquake) and tsunamis of only 5 metres (compared to the 14m recent tsunami). This was seen as a compromise between safety and commercial viability. In other words, it would have significantly eroded the economic viability of the plant if it was rated to a higher standard.

Flaws in the boiling water reactors typical for Fukushima were known for several decades. The cascade of events at Fukushima had been foretold in a report published in the United States two decades ago. The 1990 report by the US Nuclear Regulatory Commission (NRC), an independent agency responsible for safety at the country's power plants, identified earthquake-induced diesel generator failure and power outage leading to failure of cooling systems as one of the 'most likely causes' of nuclear accidents from an external event.

Documents from 1972 of the Atomic Energy Commission (AEC), the precursor of the NRC, reveal that an AEC safety expert raised concerns about the vulnerability of the boiled water reactor's less robust containment capability that would make it vulnerable to a hydrogen explosion — the same scenario occurring in the Fukushima fiasco. There was an internal sympathetic response from Joseph Hendrie, later the leader of the NRC, who told his colleague who had suggested a ban on the GE design that, while such a ban might be 'attractive', it would 'be the end of nuclear power'.

Whilst the Japanese nuclear industry was rightfully portrayed by the Diet as dangerous and its regulator incompetent and ineffectual, it is clear that without the tacit complicity of the IAEA and other national regulators that enabled Japan to avoid proper international scrutiny and accountability, its deficiencies would have been made public decades ago, perhaps averting this disaster.

Rather than full transparency and accountability, the hallmarks of a good safety culture, the nuclear industry is characterised by a culture of obfuscation and opaqueness.

RISK ASSESSMENT

The estimated probability of major nuclear accidents, which was considered very small in the past has increased significantly. The pre-Fukushima estimate for the probability of a major nuclear accident with significant release of radioactivity was roughly 1 in 100,000 for each of the 440 reactors in operation per annum. Of course, probabilistic risk assessments on which the industry estimates are based, and which often rest heavily on nothing more than best guesses, have always been problematic. Now we know they are next to useless. The likelihood of core melt and containment failure had been underestimated: the accidents in Chernobyl and Fukushima amount to catastrophic meltdown in four nuclear reactors over the past few decades, more than originally assumed.

Furthermore, given that, in the history of nuclear energy, 582 reactors have operated for a total of 14,400 years (counting each year of operation by one reactor as a reactor-year), a core-damage accident has happened once every 1,309 years of operation with a total of 12 core melts. With 400 reactors operating worldwide, the rate would yield a core melt an average of once every three calendar years, and a major accident with release of radioactivity once every 9 years. This contrast with earlier estimates, expecting one major accident with radioactive release over a 100-year period, and a core melt with no loss of containment every 10 years, with the current reactor fleet.

Globally, there have been at least 99 (civilian and military) recorded nuclear reactor accidents from 1952 to 2009 (defined as incidents that either resulted in the loss of human life or more than US$50,000 of property damage, the amount the US government uses to define major energy accidents that must be reported), totalling US$20.5 billion in property damages (this excludes the costs associated with Chernobyl and Fukushima).[67] Property damage costs include destruction of property, emergency response, environmental remediation, evacuation, lost production, fines, and court claims. Because nuclear reactors are large and complex, accidents onsite tend to be relatively expensive.

Therefore, we should be very sceptical of the nuclear industry's risk estimates for its Generation III reactors (which have no operational history) of one major accident per reactor every million years, i.e., ten times safer than the current Generation II. Small modular reactor risk estimates should also be viewed with scepticism.

We should be equally sceptical of industry claims that the accident numbers are skewed by accidents early in the evolution of nuclear power and that the industry has improved its safety credentials. Remember, the two worst nuclear disasters (Chernobyl and Fukushima) have occurred in the last 25 years over an almost 60 year history. Just as unconvincing is the claim that new nuclear reactors are safer than the older current reactors.

And only 15 of the nuclear reactors operating in the world possess passive safety systems (allegedly safer because they require less human input). It is misleading to imply that the Fukushima plant was somehow unique in the world's nuclear fleet as a mitigating factor in its failure – nearly all nuclear plants around the world, existing and planned, are of the same vintage and design as the Fukushima plant. Why? Because **advanced redundant safety systems dramatically increase the cost of a nuclear power plant and nuclear power is already uneconomic.**

A nuclear accident has the potential to bankrupt many countries. The cost of a worst-case nuclear accident at a plant in Germany, for example, has been estimated to total as much as €7.6 trillion ($11 trillion), while the mandatory reactor insurance is only €2.5 billion.

Japan has decided not to build any further nuclear plants and will progressively become less reliant on nuclear power as existing plants are decommissioned. Several OECD countries (Belgium, Germany, Italy, Japan and Switzerland, among others) have already decided to either not commence or phase out existing nuclear reactors at the end of their useful life and have cancelled plans for new ones.

In the event of a solar farm undergoing a major disaster the results could be significant in terms of energy supply – but will not involve the contamination of the surrounding environment with identified carcinogens for many generations hence, or require the permanent evacuation of hundreds of thousands of civilians as has occurred already on 2 occasions from NPP.

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[67] Nuclear and radiation accidents and incidents https://en.wikipedia.org/wiki/Nuclear_and_radiation_accidents_and_incidents

NUCLEAR TERRORISM AND DELIBERATE HARM

In the modern era it is necessary for planners and legislators to anticipate and plan for deliberate attacks on infrastructure. To date there have been no major incidents involving war or terrorism but multiple attempts and minor incursions, including involving the research reactor in Sydney. A major coolant loss caused by accident or malice could cause a massive release of radioactive isotopes in to the surrounding environment, with profound consequences in terms of morbidity, mortality, social disruption, tourism and agriculture as has been evident in the Fukushima prefecture of Japan.

A successful terrorist attack on the scale of those carried out on September 11, 2001, could lead to a major release of radiation. The US Nuclear Regulatory Commission (NRC) considers the likelihood of this kind of attack occurring as small. The NRC furthermore considers that nuclear power plants are difficult targets due to them being low lying and the reactor core being a small target. However, we should not forget that the probability of the World Trade Centre towers collapsing due to the impact of civilian aircraft was also considered to be small before they fell. It is disingenuous for the NRC to surmise firstly that the risk of such an event is low. The most that can be reliably stated is that the probability might be low, however, we just don't have the data to make any more than educated guesses.

It is equally fallacious for the NRC to claim that the consequence of an aircraft impact is unlikely to lead to a breach of containment. For example, a sudden shutdown of a nuclear reactor ('scram') in the event of a terrorist attack does not necessarily guarantee the reactor core will not continue to increase in temperature and melt, particularly if the impact has disabled the emergency cooling systems. If the containment structure has been breached from an aircraft impact, this could lead to a major release of radioactive contaminants into the atmosphere.

Additionally, it does not consider the consequences of an impact on the spent fuel cooling ponds which may ignite if there is a loss of cooling water and disperse radioactivity into the atmosphere. As a result of the World Trade Centre attacks, the Design Basis Threat of US nuclear reactors was upgraded in 2007 to include various terrorist attacks. However, controversially the NRC did not include aircraft attacks, despite internal staff strongly advocating it although being overruled. It instead insisted ambiguously that only *new* reactors be able to withstand an aircraft attack*. If this had been included in the upgraded DBT all existing reactors would have been required to be retrofitted accordingly, which the NRC insisted was not required.* Hence, ironically, all current US reactors are vulnerable to commercial aircraft terrorist attacks and will be for their operational life due to the nuclear regulator's opposition to safety upgrades.[68]

In addition, according to Yukiya Amano, director general of the International Atomic Energy Agency (IAEA) Nuclear facilities around the world are facing daily cyberattacks on their systems:
"Reports of actual or attempted cyberattacks are now virtually a daily occurrence. Last year alone, there were cases of random malware-based attacks at nuclear power plants and of such facilities being specifically targeted … staff responsible for nuclear security should

[68] http://www.iaea.org/Publications/Factsheets/English/manradwa.html#note_c

know how to repel cyber-attacks and to limit the damage if systems are actually penetrated. The IAEA is doing what it can to help governments, organizations, and individuals adapt to evolving technology-driven threats from skilled cyber adversaries".[69]

In addition to the threat of terrorist attack, deliberate sabotage by operating staff or others is also possible. There have been a number of airline mass deaths due to deliberate pilot decisions, presumed to be due to mental illness. The most recent of these was the Germanwings crash in 2015. These types of attack are extremely difficult to prevent.

NUCLEAR WEAPONS

In terms of catastrophic events associated with the nuclear fuel chain, nothing compares in magnitude to the explosive capacity of a nuclear fission explosion. The impact of one small explosion has been extensively documented at both Hiroshima and Nagasaki. Recent authoritative research has demonstrated that the detonation of 100 Hiroshima-sized nuclear bombs - less than one per cent of the global nuclear arsenal - would generate more than five million tons of soot and smoke if targeted at cities. In addition to local devastation and widespread radioactive contamination, the climate and environmental impacts would be catastrophic. Global cooling would persist for over a decade, decimating global agriculture. On top of that there would be hoarding of food; food riots; intrastate and potential interstate conflicts over food supplies; the disease epidemics that inevitably spread through malnourished populations; disruption to trade and the complex international supply chains for agricultural inputs – seed, fertiliser, pesticides, fuel and machinery.

World grain reserves currently range between 60 and 70 days supply. The 870 million people in the world who are chronically malnourished today have a baseline consumption of 1,750 calories or less per day. Even a 10% decline in their food consumption would put this entire group at risk. In addition, the anticipated suspension of exports from grain growing countries would threaten the food supplies of several hundred million additional people who have adequate nutrition today, but who live in countries that are highly dependent on food imports.

Finally, more than a billion people in China would also face severe food insecurity. The number of people threatened by nuclear-war induced famine would be well over two billion.[70]

Such global nuclear famine is well within the capacity not only of the US and Russian arsenals, with between them more than 90 per cent of the world's nearly 15,000 nuclear weapons, but also the smaller arsenals of China, France, UK, India, Israel and Pakistan – in fact all the current nine nuclear-armed states except for North Korea.

The technologies of fission whether civil or military are the same - enriched nuclear fuel is employed to generate a reaction – either controlled in the civil case or uncontrolled in the case of an explosion. The fuel is the same, the expertise is the same and the technologies

[69] http://www.scmagazine.com/international-conference-on-computer-security-hosted-for-first-time/article/418241/

[70] http://www.ippnw.org/pdf/nuclear-famine-two-billion-at-risk-2013.pdf

can and have often been shared. Multiple examples of the dual use capability of the fuel, expertise and technology abound. The ongoing concerns surrounding the Iranian nuclear program attest to this – and to the enormous hazards associated with enrichment of uranium, irrespective of the articulated purpose of such practices.

The historical interrelationships between the civilian and military sectors exist to this day. They include, but are not limited to:

- the dual nature of uranium enrichment capabilities (it is easier to enrich low enriched fuel grade uranium to weapons grade uranium than it is to produce the fuel enriched uranium),
- the ability to extract plutonium from nuclear reactor fuel rods (for maximum plutonium production the fuel rods are normally kept in the core for no longer than ninety days and then sent to a reprocessing plant, compared to around 18 months for exclusively electricity production), and
- the difficulty in thus determining the true intentions of a country's nuclear program, as evidenced by the nuclear program in Iran. Often the first indication that a country has developed weapons-grade uranium is their announcement. The IAEA acknowledges it is underfunded for the task, and furthermore, can only engage in physical inspections of a miscreant state if they grant permission.

Even if a state with nuclear power has not developed nuclear weapons, the infrastructure's dual purpose means that weapons development is only months to a few years away if desired.

The spread of SMRs would markedly increase the risk of nuclear weapons proliferation.

The International Panel on Fissile Materials, an authoritative independent international group of experts has observed that:

> *"A phase-out of civilian nuclear energy would provide the most effective and enduring constraint on proliferation risks in a nuclear weapon-free world." (IPFM, 2009)* [71]

This conclusion was underlined by the Board of Sponsors of the Bulletin of the Atomic Scientists - which includes 19 Nobel laureates - in 2010:

> *"…the world is not now safe for a rapid expansion of nuclear energy. Such an expansion carries with it a high risk of misusing uranium enrichment plants and separated plutonium to create bombs."* [72]

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[71] IPFM (International Panel on Fissile Materials) (2010) *Global fissile material report 2010. Balancing the books: production and stocks.* Available at: http://www.fissilematerials.org.

[72] BAS (Board of the Bulletin of the Atomic Scientists) (2010) It is 6 minutes to midnight. *Bulletin of the Atomic Scientists*, Jan 14. Available at: http://thebulletin.org/content/media-center/announcements/2010/01/14/it-6-minutes-to-midnight.

The German Institute for Economic Research surveyed 674 nuclear power plants that have ever been built.[73] They found private economic motives never played a role, but instead military interests have always been the driving force behind their construction.

They also noted that nuclear energy cannot be called "clean" due to radioactive emissions, which will endanger humans and the natural environment for over one million years. In addition nuclear power harbors the high risk of proliferation.

Even ignoring the expense of dismantling nuclear power plants and the long-term storage of nuclear waste, private economy-only investment in nuclear power plant would result in high losses - an average of five billion euros per nuclear power plant, as one financial simulation revealed.

In countries such as China and Russia, where nuclear power plants are still being built, private investment does not play a role either.

Nuclear power programs facilitate weapons proliferation: Australia's own brief and curtailed flirtation with nuclear energy was acknowledged at the time by the enthusiastic Prime Minister as a disguised nuclear weapons program. John Gorton had military ambitions for a nuclear power reactor he wanted to have constructed in the late 1960s at Jervis Bay. He later said: "We were interested in this thing because it could provide electricity to everybody and it could, if you decided later on, it could make an atomic bomb."[74]

Given this history and the nature of international nuclear diplomacy, any move towards enhanced nuclear fuel processing or enhanced nuclear fission would be a proliferative signal to our neighbours.

A concerted effort to develop Australian nuclear reactors has the potential to contribute to a nuclear arms race in our region.

NUCLEAR WASTE

The radioactive waste management experience to date - internationally and nationally - should alert policy makers and legislators to the enormity of the task of dealing with this aspect of the nuclear fuel chain. At this point it is worth observing that there is nothing particularly 'cyclical' about the nuclear fuel industry – it starts with mining uranium, progresses to enrichment and fuel fabrication through reactors and weapons to waste. The idea that there is a 'cycle' comes from proposals to harvest and reprocess the waste stream and thus close the loop; this is barely more than a fantasy after 70 years of the industry and billions spent on research.

What we have instead is mountains of radioactive waste all over the planet and only four countries with anything like a program to deal with it. The most advanced – Finland - is working on the first of a necessary five deep geological repositories to deal with its own reactor waste alone.

[73] https://www.diw.de/documents/publikationen/73/diw_01.c.670581.de/dwr-19-30-1.pdf
[74] Pilita Clark, 1 Jan 1999, 'PM's Story: Very much alive... and unfazed', Sydney Morning Herald.

The average nuclear power reactor produces 300 m^3 of low and intermediate level waste per year and some 30 tonnes of *high* level solid packed waste per year.[74] Every year, there is 12,000 tonnes of spent fuel (high level) being produced globally, which will triple if the so-called nuclear renaissance ever occurs.

In 2019 the IAEA reported that in 2015 there existed approximately 385,000 tonnes of nuclear fuel derived waste around the world.[75] Currently this is being stored on-site in dry casks or pools at most nuclear power plants, or at reprocessing facilities such as La Hague (France), as an interim solution. Greatly complicating this task are the very long half-lives of some of the radionuclides present in this waste (for example plutonium-239 – half-life of 24,000 years, technetium-99 – half-life of 212,000 years, cesium-135 – half-life of 2.3 million years, and iodine-129 – half-life of 15.7 million years). These are highly hazardous to humans and require ultimately isolation from the biosphere for hundreds of thousands to a million years.

The aim is to prevent water reacting with the waste since this is the main mechanism by which the waste can re-enter the biosphere. The IAEA states that deep geologic disposal using a system of engineered and natural barriers to isolate the waste is the best method. The principal features of the geological repository concept is to place packaged waste in a stable formation several hundred meters below the surface with engineered barriers around and/or between the waste packages and the surrounding rock.

Worldwide there is no deep geological repository for HLW currently in operation despite the nuclear power industry being in existence for over 70 years. Internationally, no country currently plans to have a repository in operation before 2025, and all proposals have encountered problems.

High level waste (including spent fuel) accounts for 2% by volume although 90% by radioactivity and requires permanent storage in deep geological formations for a few hundred thousand years.[76] Due to the complexity of the problem and the long time periods considered, the ability of a repository to retain radioactivity has a significant degree of uncertainty. Similar to assessing the safety of a nuclear reactor, conceptual and statistical models are employed.

Furthermore, similar assumptions usually based on insufficient or absent data are made to simulate the behaviour of a repository over an arc of time orders of magnitude beyond that of recorded human history.

Meanwhile, Australia has been trying for decades unsuccessfully to manage its relatively small volume of waste: under no circumstances start building a reactor if we have not identified and approved the site for deep geological disposal of the HLW. That alone would add another decade at least to the IAEA framework of safe nuclear power plant development.

[75] **IAEA Worldwide Summary** https://newmdb.iaea.org/dashboard.aspx

[76] To put this in perspective, the Egyptian pharaohs were in power only five thousand years ago, and homo sapiens are understood to have appeared in East Africa between 100,000 and 200,000 years ago.

We attach as an appendix the MAPW submission from March 2018 to the Senate Standing Committees on Economics **Inquiry into the Selection Process for a national radioactive waste management facility in South Australia.**

OTHER RELEVANT MATTERS

Regulatory Capture in Australia

Uranium is a key component of nuclear power generation. Uranium mining in Australia is inadequately regulated.

A clear example is the Olympic Dam mining facility at Roxby Downs in South Australia, which is exempt from many important pieces of legislation.

The South Australian Government enacted the Roxby Downs (Indenture Ratification) Act 1982 (Indenture Act) and updated it with the Roxby Expansion Indenture Bill in 2011. The Government has legislated that 1.5 million hectares in central South Australia, including the Roxby Downs mine and surrounding areas, are exempt from some of our most important environmental and indigenous rights legislation. The Indenture Acts provides BHP Billiton the legal authority to override the:

· Aboriginal Heritage Act 1988
· Development Act 1993
· Environmental Protection Act 1993
· Freedom of Information Act 1991
· Mining Act 1971
· Natural Resources Act 2004 (including the Water Resources Act 1997)

An indication of the sweeping nature of the legal privileges is the statement in the Indenture Act that: "The law of the state is so far modified as is necessary to give full effect to the indenture and the provisions of any law of the state shall accordingly be construed subject to the modifications that take effect under this Act."

In other words, the Indenture Act trumps all other SA legislation.

Recently BHP applied to increase its tailings storage facilities at Olympic Dam.

Currently BHP has 67 tailings storage facilities (TSF) internationally. BHP has a record of mine tailings dam failures, most notably at the BHP and Vale joint venture mine at Samarco in Brazil in 2015. This resulted in flooding that destroyed the village of Bento Rodrigues and killed 19 people.

In June this year, after pressure from investor stakeholders, BHP released a global assessment of all their tailings facilities.[77] The classification of the tailings facilities is based on the most recent classification of the facilities by the Engineer of Record at each mine.

Of these 67 TSF, five TSF are listed as “extreme risk”. “Extreme risk” refers to the potential loss of life of at least 100 workers, and means environmental rehabilitation of the site would

[77] ESG briefing: Tailings dams BHP June 2019 https://www.bhp.com/-/media/documents/media/reports-and-presentations/2019/190607_esgbriefingtailingsdams.pdf?la=en

be impossible after a failure of the TSF. In addition, in such an event infrastructure and economic losses are listed as extreme.

One of these “extreme risk” sites is in the USA, but that mine has been closed. The four remaining “extreme risk” TSFs are all in Australia, and three out of four are at Olympic Dam.

Olympic Dam does not comply with South Australian standards, let alone international standards.

Olympic Dam should be subject to legislative and regulatory controls and standards at least as rigorous as those that apply to smaller projects. Existing standards are indefensible.

The current “extreme risk” tailings facilities represent complete abrogation of regulation for both worker and environmental safety, and yet it is likely BHP will gain approval to build more.

This legislative example does little to engender confidence that a nuclear power industry would be safely regulated in Australia.