Submission to the Inquiry into the prerequisites for nuclear energy in Australia

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This submission covers only the following Terms of Reference (ToR):

1. Waste management, transport and storage;
2. Health and safety
3. Economic feasibility
4. National consensus

ToR a: Waste management, transport and storage

An issue that irrationally scares people, is the storage and disposal of nuclear waste. This is not unique to Australia but is common to all democracies.

The world currently has a very large number of nuclear waste repositories but they are not generally recognised by the public and therefore little concern is expressed about their existence. These repositories are usually in hospitals and universities where nuclear medicines and materials are regularly used. They are also usually low to medium grade radioactive wastes. The difficult political decisions are usually about the storage of high level radioactive wastes, such as from nuclear power stations, but not exclusively from them.

Even the US has not been able to get political agreement on building a high level radioactive waste facility even though appropriate locations have been found. High level waste is still being stored temporarily around that country such as at existing nuclear reactor facilities.

The statistics on the size of the issue show that technically it is not a major problem.

The US currently has in storage less than 40,000 m^3 of high level radioactive waste. This is the total amount accumulated since the start of the Manhattan project in WW2. Similar statistics for other countries are not as readily available but the US would obviously be one of the largest contributors to the volume of high level radioactive waste in the world.

Dilution of the radioactive wastes by mixing with inert materials to only 1% concentration of radioactive material would take up less than 4,00,000 m^3. As one square kilometre is 1,000,000 m^2, it would be very easy to find sufficient area for effective, long-term safe disposal.

Australia institutions have expertise in handling and storing radioactive waste. Synroc was developed at the Australian National University. Synroc is a contraction of **syn**thetic **roc**k. It is an economical, extremely durable and safe solution for final storage of radioactive waste and is being developed and marketed by the Australian Nuclear Science and Technology Organisation.[i]

Australia has a very large number of potential sites for long-term nuclear waste storage. Criteria for selection:

- are low populations in the selected region, to minimise the number of people affected by the fear factor
- geological stability, to be measured in aeons, not millennia

The western two thirds of the Australian continent are suitable as is the Canadian Shield. Australia has the weather advantage over Canada, though both are suitable geologically, locationally and politically.

South Korea has implemented an interesting method of obtaining local support for a nuclear waste repository. Four sites were selected as being appropriate for the location of a nuclear waste repository. The four locations were asked to have local referendums on local support for the location of the repository. The winning location had almost 90% of its voters approving, with the next best contenders only having 84% and 79% in favour. This is a very good example of local democracy deciding the benefits and costs and making their decision compared to having one imposed upon them from higher levels of government

A nuclear waste repository could be a new export industry for Australia and could be serviced by a dedicated port facility and transport links. This would be especially suitable for declining States such as South Australia. The South Australian Royal Commission included a recommendation to pursue the opportunity to establish used nuclear fuel and intermediate-level waste storage and disposal facilities in South Australia.

In a decarbonising world, the only effective large-scale noncarbon source of reliable, despatchable power is from nuclear reactors.

However, there are fears about the safety of nuclear electric power, both in terms of production and waste disposal. It is currently politically unacceptable even though the fears are grossly exaggerated.

There are also concerns of how costly and how long it will take to build nuclear power stations.

All these concerns can be readily addressed by informing the public of the facts and demonstrating that it is a safe, viable, economical option.

ToR b: Health and safety

There is an irrational fear of any mention of radiation dosages for most of the population.

According to the Federal Government radiation protection authority ARPANSA:

"*Although different types of ionising radiation have different patterns of energy release and penetrating power, there is no general property that makes artificial ionising radiation different or more damaging than the ionising radiation that comes from natural radioactive material."*[ii]

The international standard measure of radiation dosage is called the Sievert.

ARPANSA estimates "*on average Australians are exposed to 1.5 millisieverts(mSv) each year from natural sources."*[iii] ARPANSA also noted "The largest source of radiation exposure comes from external exposure to natural radioactivity in rocks and soil (terrestrial radiation) and inhalation of radon gas that seeps from the ground into all buildings. There are also significant contributions from cosmic radiation and naturally occurring radioactivity in food and in the body."

The Nuclear Fuel Cycle Royal Commission in South Australia cited a study[iv] which had the natural background radiation in Australia between 1.69 and 3.79 mSv. In all the studies on the exposure and effects of radiation, there are divergences in individual measures but for all technologies they are in the same orders of magnitude.

The University of California has developed a novel method of presentation of the exposure people face from a variety of radiation sources. They have developed the banana equivalent dose (B.E.D) of radiation. It is based upon the radioactivity contained within the average banana. A small fraction of the potassium in bananas naturally occurs as the radioactive potassium-40 isotope.

An average banana contains the equivalent of 0.1 microsieverts of radiation. A microsievert is 1/1,000,000 of a Sievert. Therefore, the B.E.D is 1/10,000,000 of a Sievert.

The average annual Australian radiation exposure according to the ARPANSA estimate is 15,000 B.E.D and for the study cited by the Nuclear Royal Commission 16,900 to 37,900 B.E.D.

From the University of California, typical radiation exposures expressed in B.E.D. from natural and man-made sources are detailed in Table 1.

Table 1: Banana Equivalent Doses (B.E.D.) of various forms of radiation exposure

Radiation source	**B.E.D**
Background radiation in everyday life	
Living one day	100
Flying from Brisbane to Perth	400
Living in a concrete, stone or brick building for one year	700
Six months of an average food intake (or twenty-two bananas per day)	4,000
Modern technology exposures to radiation	
Airport security scan	2.5
Dental x-ray	50
Mammogram	400
Full body CT scan	100,000
Radiation exposures from nuclear power	
Living within 80 km of a nuclear power station	0.9
Average radiation dose within 16 km of the 3 Mile Island accident	800
Visiting Fukushima for 1 hour, 3 km from the reactors 2 months after the accident	1,000
Average dose of Chernobyl residents after 1986 accident	3,500,000
Non-fatal dose for temporary radiation sickness	10,000,000
Fatal dose of radiation leading to death within two weeks	100,000,000

Mortalities from the different electricity generation technologies

There are other externalities created by the different electricity generation technologies. One that is rarely discussed is the deathprint of the different electricity generation technologies.

The deathprint is the number of people killed by one kind of energy or another per unit of electricity produced.

Coal and other fossil fuelled generation is ranked the worst and wind and nuclear are ranked the safest.

A perception readily promoted by antinuclear power activists is that nuclear power is dangerous to human health, especially for workers in the industry. All economic activities have some level of risk from minimal to extremely high. The empirical evidence compared to the popular perception shows that nuclear power is the lowest risk form of power generation taking into account the entire production chain for both workers and consumers.

Prof Kerry Emanuel from Massachusetts Institute of Technology has provided the following information in Table 2 on the mortality rates from the different technologies of electricity generation. The mortality rates are standardised using PetaWatthours or million billion Watt-hours of electricity generated.

Table 2: Mortality rate per PWh of electricity generated

Electricity production technology	Deaths
Coal – China	90,000
Coal – USA	15,000
Oil	36,000
Biofuel	12,000
Gas	4,000
Hydro	100
Hydro - including disasters	1,400
Solar– Rooftop	440
Wind	150
Nuclear-Including Fukushima and Chernobyl	90

Source: K Emanuel, MIT

There have been a variety of estimates provided on mortality rates over the decades for the different technologies. Though the estimates vary for the specific technologies they are all generally within the same order of magnitude. There is no change in the ranking of the deathprint of the electricity generation technologies.

From the original study used as the basis for Professor Emanuel's Table "deaths from accidents and air pollution have been combined, it's important to note that air-pollution related deaths are dominant. In the case of, coal, oil and gas, they account for greater than 99% of deaths, as well as 70% of nuclear-related deaths, and all biomass-related deaths."[v]

Coal-Fired Generators

The death print from particulate pollution from coal-fired generators is reducing as a US study noted that deaths were primarily "in the east-central United States and in the Midwest: Eastern power plants tend to use coal with higher sulphur content than Western plants." [vi]The US Government has mandated the use of sulphur dioxide scrubbers which significantly reduces particulate pollution from high sulphur coals.

The study also noted "The greatest number of emissions-related premature deaths came from road transportation, with 53,000 early deaths per year attributed to exhaust from the tailpipes of cars and trucks."

One of the authors of the report in a media statement said "It was surprising to me just how significant road transportation was, especially when you imagine [that] coal-fired power stations are burning relatively dirty fuel."[vii]

China has also implemented programs to reduced particulate pollution from its coal-fired generators. Deaths caused by coal particulate pollution are nearly an order of magnitude higher than in the US.

Hydroelectricity

Hydroelectric generation is a very safe industry for most people with a low ranking of mortalities, generally at the construction stage. However, if things do go wrong the mortality rate from the technology can be extreme such as the 171,000 deaths from the Banqiao, China hydroelectric dam failure in 1976. There have been several other dam failures causing significant deaths and these few incidents have raised the average mortality rate for the technology quite significantly.

Solar Photovoltaics

The relatively high deathprint from Solar Photovoltaics is from a US study of deaths in the construction industry. Falls are the leading cause of fatalities in that industry. In the US roof working is now the 5th most dangerous occupation in the country, rising in the latest rankings.[viii]

Solar PV installation and maintenance requires significant work on roofs in the US and Australia.

Specific fatalities due to work on solar PV installations is not available in Australia but fatalities from falls from a height indicate that it is likely to be a major death risk as shown in Table 3.

Table 3: Worker fatalities: Construction industry, falls from a height fatalities by breakdown agency, 2007 to 2016 (combined)

Breakdown agency	No. of fatalities	% of fatalities
Buildings and other structures	36	38%
Ladders	24	25%
Scaffolding and elevated work platforms	15	16%
Openings in floors, walls or ceilings	4	4%
Other agencies	17	18%
Falls from a height – Total	96	100%

Source: Work-related Traumatic Injury Fatalities 2016, Safe Work Australia

Wind generation

Most wind generation deaths are attributable to the construction and maintenance of the plant. Again it is a technology relying on working on heights with the consequent dangers. There are additional dangers, especially in colder climates, such that G.E. Energy, a manufacturer of large wind turbines warned that "rotating turbine blades may propel ice fragments some distance from the turbine— up to several hundred meters if conditions are right".[ix]

Pink Batts scheme deathprint

Australia provides an example of the deathprint from an energy efficiency technology. A previous Australian government introduced a subsidy to rooftop home insulation, which was commonly known as the Pink Batts scheme. There were four deaths recorded from participants installing the insulation. Crawford and Stephan[x] from the University of Melbourne have estimated the savings in electricity generated because of the scheme out to 2030. Their estimates were based upon savings in petajoules of electricity which has been converted to PetaWatthours for comparison with all the other technologies. The cost in mortalities for comparison with generation technologies is provided in Table 4.

Though the actual number of deaths was only 4, the savings in electricity production were minuscule.

Table 4: Mortality rate per PWh of electricity generation saved

Electricity usage saving technology	Deaths
Australian ceiling insulation "Pink batts" program	210

Nuclear generation

Though it is shown in Table 2 that nuclear electricity generation is the safest form of electricity generation with the lowest overall deathprint, there is a general fear of nuclear power plants in the community, probably from the high profile public coverage of the 3 nuclear power station problem events – Three Mile Island, Fukushima and Chernobyl. Analysis of these events demonstrate that concerns about safety are extremely excessive compared to the continuing and larger deathprints of all alternative electricity generation technologies.

Three Mile Island

On 28 March 1979, an accident at Three Mile Island (TMI) nuclear power plant in Pennsylvania produced the release of small quantities of xenon and iodine radioisotopes into the environment.

A 20 year comprehensive scientific health assessment was undertaken by a team from the University of Pittsburgh, in Pennsylvania, for the period 1979 to 1998 for over 30,000 participants[xi].

That study found that zero deaths could be conclusively attributed to radiation from the accident.

Scientists estimated maximum and likely radiation exposures for each individual.

The estimated average likely and maximum doses were on a Banana Equivalent Dose 900 and 2500 respectively. The US provides an estimate of the average annual exposure from natural background radiation is approximately 30,000 B.E.D.

Fukushima

There were no direct deaths from the Fukushima reactor accident.

A Japanese academic study[xii] estimated that the exposure to radiation varied considerably over relatively short distances. This variation was due to factors such as topography, rain and wind events.

Table 5: Fukushima radiation exposure

Japanese region	Banana Equivalent Dose
Naka-Dori	100,000
Iitate	400,000
northern Ibaraki and eastern Saitama	2,000
southern Ibaraki and northern Chiba	20,000

The radiation doses all were all much lower than the generally accepted UNSCEAR threshold[xiii] for fatal disease development of 1 million Bananas Equivalent Dose.

There are expected to be mortalities from the Fukushima accident. However, 1600 premature deaths are expected to be related to induced stress, especially for older residents, from the evacuation process – including loss of their homes – rather than from direct radiation exposure.[xiv] As a case study a 102-year-old man took his own life after being ordered to leave his home following the Fukushima disaster.[xv]

Chernobyl

Chernobyl is the only one of the 3 major nuclear power station accidents where there were direct mortalities. There has been a perception that extremely large numbers of people were killed in the nuclear accident. Following are the actual statistics which show that mortalities were significantly less than many other industrial and other accidents such as from buildings burning down and collapsing in the United Kingdom or Bangladesh.

In the Chernobyl accident of April 1986, 134 people received high doses and suffered from radiation sickness. Of these, 28 were plant staff or first responders who died in the first three months and another 15 died in the period 1987-2004 according to a report by the United Nations Scientific Committee on the Effects of Atomic Radiation..[xvi]

The Secretary-General of the UN submitted a report on the Chernobyl accident to the General Assembly which "observed that it was often difficult for the public and the media to appreciate that radiation risks, while serious for some exposed groups, were, for the general population, not as significant from a health point of view as they were often represented to be."[xvii]

The reviews of the 3 major nuclear accidents confirm the ranking of nuclear power in the mortality statistics of the different electricity generation technologies. Public perceptions of the dangers of nuclear electricity compared to other electricity generation sources are not founded on empirical, scientific studies.

ToR: e. Economic feasibility

Australia has already had a comprehensive examination of the potential for nuclear electricity and the issues that need to be resolved. It was the report of the Nuclear Fuel Cycle Royal Commission in South Australia. The Report was wide-ranging on nuclear issues from waste repository to nuclear generation of electricity. It was an extremely comprehensive report and can be used as the basis for policy discussions.

There are already some organisations and groups that understand the issues. For example, Engineers Australia, the industry association for one of the more rational professions, has stated:

"*Electricity generation from nuclear power ...provides secure, reliable energy...*

Nuclear power also has the ability to provide long term energy security as modern nuclear power reactors are built with sixty-year life spans, and they also have near-zero carbon emissions. Modern build reactors have minimal greenhouse gas and other airborne emissions, high fuel efficiency, minimal and manageable residual waste, built-in proliferation protection and advanced safety protection"[xviii]

The debate does not need to waste time and effort in repeating the analyses already undertaken.

This is especially the case if the worst case scenarios on climate change are starting to be realised and rapid international decarbonisation is required.

There are options for the Australian Government and Parliament to undertake preparations in case such an outcome is necessary without committing to follow through, unless science and international agreements and cooperation are fully supportive. The options to be investigated should include short-term and long-term.

The Australian Government should investigate alternative reactor designs and builders. Westinghouse, Toshiba and Alstom are all nuclear power plant builders and all currently have records of going over budget and over time in construction of new large-scale baseload power stations. The South Koreans on the other hand have a reputation of delivering their nuclear power stations on time and on budget. This should be the first port of call for investigating potential large baseload power stations.

The Koreans build Generation 3 nuclear reactors and the cost of electricity from their power stations in 2008 was approximately $A48 per megawatt hour and their coal-fired power stations were at $A65 per megawatt hour from the only publicly available data point. [xix] Coal fired power in South Korea would be more expensive than in Australia because of the much greater transport costs.

Another alternative for investigation are the relatively small modular nuclear power reactors. There are a large number under development but none currently commercially operational. This work is being undertaken in a number of countries.

There are modular nuclear power reactors in use but not commercially. US aircraft carriers are powered by twin nuclear reactors. Official estimates of performance are not available but unofficial estimates put their capacity at around 200 MW of power each reactor. This is sufficient to drive a 100,000 tonne ship at over 60 km an hour while carrying a complement of 20,000 people who have to have meals prepared for them, washing etc while running a large number of power intensive sophisticated electronic systems. These reactors also have long lives. A carrier has a service life of fifty years and only has to be refuelled once in that period which indicates a minimum of twenty-five years between refuellings. These reactors could be commercially viable at short notice as they are proven technically.

Longer term priority

In the longer term for a nuclear electricity industry, Australia is developing the research and expertise as in 2016 we joined the Generation IV International Forum which includes the US, China, Russia, Japan, Canada, South Korea and the European Atomic Energy Community

Generation IV reactors are a set of nuclear reactor designs currently being researched for commercial applications by the Forum countries.

Presently the majority of reactors in operation around the world are considered second generation reactor systems, as the vast majority of the first generation systems were retired some time ago. There are a limited number of Generation III power plants in operation around the world with the appropriate certifications. South Korea has one operational and is building 3 more in South Korea and an additional 4 in the United Arab Emirates.

Australia has expressed interest in research activities for very high temperature and molten salt reactors for the Generation IV Forum. Australian Nuclear Science and Technology Organisation (ANSTO) have already hired expertise from South Africa who worked on their pebble-bed modular reactor (PBMR).

ToR: i. National consensus

On all rational criteria for investments in electricity generation in Australia under the current Australian and international policy context, nuclear generation is the best option. It has:

- no carbon emissions
- reliable, baseload despatchable power
- the lowest deathprint of all electricity generation technologies
- the best location and technology for long-term storage of nuclear waste.

With the exclusion of all carbon fossil fuel electricity generators, because of the carbon constraint, nuclear becomes the only available option to provide the quantity of reliable electricity supply required at a price that is better than all the non-carbon alternatives.

There have been only 3 national polls undertaken in Australia since 1979 on views on nuclear power stations in Australia. They were by McNair Gallop and the results are shown in Table 6.

According to their surveys there has been a gradual move in favouritism towards nuclear power.

Table 6: McNair Gallop polls on nuclear power

"Do you favour or oppose the construction of nuclear power stations in Australia?"	**1979**	**2007**	**2009**
Favour	34%	41%	49%
Oppose	56%	53%	43%
Don't Know	10%	6%	8%

A 2014 "independent survey" held before their Code Black, commissioned by the South Australian Chamber of Mines & Energy, of 1,214 South Australians revealed a community supporting consideration of nuclear energy.

Table 7: South Australian Chamber of Mines and Energy poll

Please rate your level of support for Nuclear Power?	TOTAL	Female	Male	18-34	35-50	51-65	65+
Total Support	48.0%	44.5%	64.4%	52.3%	53.8%	52.3%	59.8%
Neutral	19.5%	26.2%	16.9%	22.9%	20.6%	21.6%	21.8%
Total Oppose	32.6%	29.3%	18.6%	24.7%	25.6%	26.0%	18.4%

The changing polls reflect the commonsense of Australians in recognising a problem and seeking a solution in contrast to the public noise of vested interests and false claims.

As noted in a paper by the Royal Academy of Engineering *"it is likely that significant adverse political impacts would result from any kind of electricity shortfall, especially because historically high levels of security of supply mean that people are accustomed to – and feel that they have a right to – continuous power supply."* [xx]

The debate has started and progress needs to be made quickly as there are likely to be more Code Blacks in the network because of the unreliability from the increasing proportion of non-despatchable power, with consequent human tragedies and economic distress .

There should be preparation in research in looking at the various nuclear alternatives and costs of providing reliability in the electricity supply generation system.

After addressing the issues of safety and waste disposal, it will be necessary for the Commonwealth and State Governments remove their legislative provisions against the establishment of reliable nuclear generators.

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