South Australia Royal Commission on the Nuclear Fuel Cycle

Submission by SMR Nuclear Technology Pty Ltd on Issues Paper 3

Introduction

SMR Nuclear Technology Pty Ltd (SMR-NT) is an independent Australian-owned specialist consulting company based in Sydney.
SMR-NT was established to advise on and facilitate the siting, development and operation of safe nuclear power generation technologies, principally Small Modular Reactors (SMRs).
SMR-NT's directors have over 100 years combined experience in power generation, including nearly 50 years of nuclear power generating experience.

This submission is in response to Issues paper 3 (Electricity Generation from Nuclear Fuels) and looks particularly at the role Small Modular Reactors (SMRs) could play in the future of nuclear power in South Australia.

An SMR is defined by the International Atomic Energy Agency (IAEA) as having a power output < 300 MWe, but in practice SMRs are more often less than 200 MWe. This makes them an appropriate size of unit for the South Australian grid system. The small size also avoids the high capital costs normally associated with large nuclear power plants.
The "Modular" refers to the factory built reactor module which is shipped to site as a complete unit. Factory build enables high Quality Assurance (QA), reduces the on-site construction time and hence reduces the risks of project delays.

Advantages and disadvantages of nuclear power (Question 3.8)

Diverse energy security

Historically the mix of generation in Australia was driven by the relatively cheap cost of fossil fuel generation and the limited opportunities for large hydro schemes. Coal traditionally had and still has a cost advantage relative to other fuel sources.
The reliance on fossil fuels has been very successful in providing cheap, reliable electricity supply in the past, but the international move towards low emissions electricity generation technologies could disadvantage Australia in the future. Nuclear power would provide diversity.
The utilisation of all low emissions electricity generation technologies will be essential to achieve long-term greenhouse gas emissions targets. A problem with one technology (as is now demonstrated with the reliance on fossil fuels and the emergence of climate change as a major problem) can be a severe disruption for an industry that relies on long-term planning.

For the financial year 2013-14, AEMO has reported that the electricity generation by fuel type in SA was 61% fossil, 33% wind and 6% solar. There is a high dependency on fossil fuels and it is uncertain how much more intermittent generation can be accommodated in SA. The 2015 Energy White Paper supports a technology neutrality approach to future electricity supply, in theory enabling all technologies to be considered.

Baseload, high capacity factor

The types of plant in the current Australian electricity system that provide the baseload, dispatchable power are coal, gas and hydro. Only hydro is a low emissions technology and a substantial increase in the amount of hydro generation is not possible in Australia due to limited water supplies. Nuclear power is a baseload, high capacity factor electricity generation technology. Baseload power is required to continue to supply the major industrial and commercial loads.

The average unit capability factor for the more than 400 nuclear power plants that report to WANO (World Association of Nuclear Operators) has been over 85% for the last 15 years and was 87% for the last reported year (2013)[1].

Low greenhouse gas emissions

On a lifecycle basis, including mining, enrichment, construction and operation, greenhouse gas emissions for nuclear power is comparable to other low emissions technologies, particularly solar and wind. This has been extensively studied by the IPCC [2], NEI [3], OECD [4], UMPNR [5].

If system factors are taken into account, then emissions from weather dependent technologies like wind and solar can be much higher, depending on the technology of the backup generation. For South Australia this is currently provided by fossil fuelled generators. This situation would change if the backup was provided by nuclear power.

A recent (2014) study by Hatch (Canada) [6] of worldwide Life Cycle Assessments (LCA) standardised under ISO 14040 examined 46 wind and 79 nuclear studies, including wind studies in Australia.

For nuclear these studies included the extraction and production of uranium fuel, operation of nuclear reactors, construction and decommissioning of the power plant, and the management of nuclear waste. Construction of waste management facilities for radioactive waste was also included.

The nuclear studies include the enrichment of uranium from 0.7% to 3%-5% for a typical Gen II/Gen III reactor. Some LCAs consider enrichment by gaseous diffusion which is a more energy intensive process (2,500 kWh/SWU) than the centrifuge process (40 kWh/SWU). All gaseous diffusion plants have now been shut down and replaced by centrifuge plants, so in this regard the studies over-estimate the GHG emissions.

The concentration of uranium in the ore depends on the location of the deposit and varies from 0.03% - 20% worldwide. The GHG emissions depend to some extent on the ore grade, mining technology and whether uranium is the sole product, or a by-product as at Olympic Dam, which is mainly a copper mine. Since uranium fuel for a possible nuclear power reactor in South Australia would be supplied by an international fuel fabricator, it is appropriate to consider an average international ore grade, and not particularly any South Australian ore grades.

For wind, these studies included extraction, production, transportation and waste management of all consumables for construction, decommissioning and operation of onshore wind farms. Studies which included the beneficial impacts of recycling and re-use provided an emissions credit. System emissions due to the requirement for backup for wind were not considered, as this requires consideration of the local power system.

The statistical mean total lifecycle emissions of greenhouse gases are:

Technology	**GHG kgCO_2-e/MWh**
Onshore wind	10.5
Nuclear	18.5
Natural gas combined cycle gas turbine (NCCGT)	478
Mix 20% wind + 80% NCCGT	385

This comprehensive analysis of worldwide studies demonstrates that lifecycle emissions from nuclear are comparable to wind and solar.

In the Australian context, AEMO issue a report of daily emissions [7] for each state in the NEM based on calculations from individual power station data of their operating emissions:

Figures for operating emissions for 18 July 2015

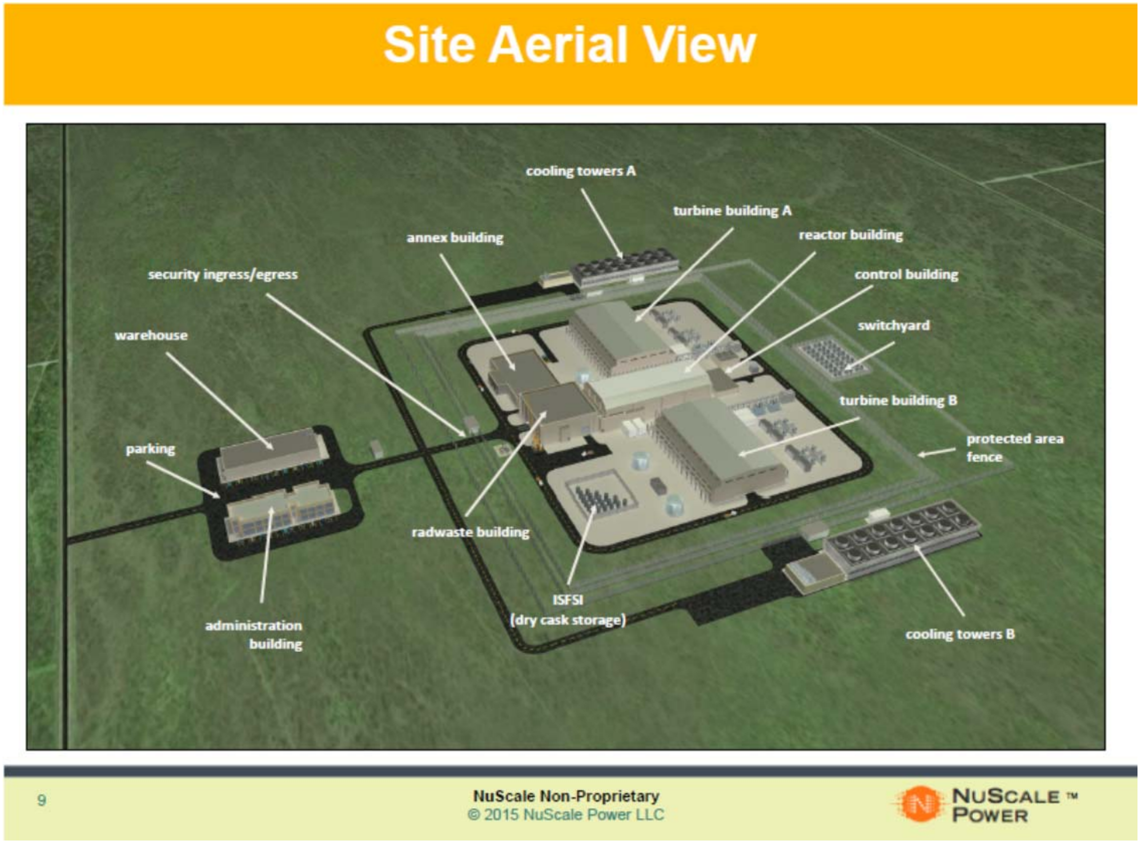
	CO_2-e emissions Kg/MWh	Comments
Victoria	1,236	Brown coal generation
NSW	951	Black coal generation
Queensland	892	Black coal
South Australia	794	Wind supported by fossil fuels
Tasmania	3	Hydro and wind
NEM	952	Heavily dependent on fossil fuels

Although typically lower than Victoria, Queensland and NSW, the South Australia figure is still relatively high, in spite of the 1,477 MW registered wind capacity in the State. This is because of the intermittency of the wind generation and hence the requirement for backup by fossil fuel plant. The difference is clearly apparent in Tasmania where wind is backed up by hydro.

For the financial year 2013-14, AEMO have reported that the electricity generation by fuel type in SA was 61% fossil, 33% wind and 6% solar.

Compact site

Nuclear is a very dense source of power and a nuclear power plant requires only a small area, as shown by the 600 MWe NuScale SMR which occupies 18 hectares (see illustration below). This reduces the cost of land for the site, and provides greater flexibility in locations.



Site Aerial View

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NuScale Non-Proprietary
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Fig 1 NuScale (USA) 12 modules site 600 MWe (12 x 50MWe modules) – 18 hectares
(Based on Nyngan, a solar plant of this size would occupy 1,470 hectares)

Nuclear is not weather dependent
Nuclear power operates day and night, regardless of the weather. The reactor module of a modern SMR is underground, providing protection from external hazards and unauthorised access.

Multipurpose
The new generation of reactors can be multipurpose, supplying not only electricity but also process heat and desalination. For example the China National Nuclear Corporation/Nuclear Power Institute of China ACP-100 SMR has been designed to supply 100 MWe and 12 million litres/day desalination and 420t/hr steam at 3.5 MPa, 250°C [19].
Sodium Fast Reactors (SFR) operate at temperatures of 550°C and enable the production of heat for industrial processes such as petroleum refining and oil shale and oil sand processing.
High Temperature Gas Reactors (HTGR) operate at up to 900°C providing heat for higher temperature processes such as hydrogen production, coal gasification and steam reforming of natural gas. The 110 MWe HTR-PM High Temperature Gas Reactor is under construction at Shandong, China and is scheduled to begin operating in 2016 [19].

Remote locations

Nuclear power plants can be located in remote locations where transport of fossil fuels is expensive or where it is inconvenient to construct a new gas pipeline. The turbine condenser can be air cooled removing the requirement for large cooling water supplies.

Low fuel costs and fuel security

Fuel costs are typically only 25%-30% of the production costs of a nuclear power plant, compared to 70%-80% for coal and gas plants. This makes nuclear plants less sensitive to changes in fuel costs.

The energy density of nuclear fuel (Uranium 235) is far greater than that of fossil fuels. Approximately 27 tonnes of uranium fuel is required each year by a 1000MWe nuclear reactor power plant, in contrast a coal fired power station that requires more than two and a half million tonnes of coal to produce the same electrical output [8]. Nuclear Power plants keep at least two years' supply of nuclear fuel assemblies on site, which provides security against supply interruptions.

Long plant lifetime

Modern nuclear power reactors are designed with a sixty year life.

Proven technology

There is sixty years' experience of nuclear power reactors, particularly light water reactors which make up 82% of the 439 power reactors currently operable worldwide (ENS Jan 2015). The majority (63%) of power reactors are Pressurised Water Reactors (PWR). The SMRs which are likely to be deployed first are based on PWRs. Small PWRs have for many years been employed as propulsion systems for submarines and icebreakers where reliable supply is essential.

Sustainability

There are current world uranium resources for > 100 years using uranium in light water reactors [9]. In addition there is uranium and plutonium from reprocessing spent fuel and uranium from the nuclear weapons programs of particularly Russia, downblended for use in commercial power reactors.

The Integral Fast Reactor (IFR) recycles existing spent fuel enabling 150x more energy to be extracted from uranium. There are large stores of spent fuel available worldwide for this process.

Thorium is 4 times more abundant than uranium. The technology has been demonstrated in the UK, Germany and the USA but was not continued due to the abundance of uranium. Thorium is now being revisited, particularly in China. Australia (ANSTO) is assisting with this work.

Finally progress is being made towards the commercial power use of fusion, particularly with the International Thermonuclear Experimental reactor (ITER) being built in France. A one GW fusion plant would require only 125 kg/yr of deuterium and 125 kg/yr of tritium for fuel.

Regulation

The International Atomic Energy Agency (IAEA) establishes the standards and international best practices for the nuclear industry worldwide. Australia has a permanent seat on the Board of Governors of the IAEA and plays an important role in establishing these standards. There is extensive international experience of nuclear regulation and there are already very competent, well established Australian nuclear regulators (see also responses to Questions 3.10 and 3.14).

Particular advantages of Small Modular Reactors (SMRs)

- SMRs are suitable for small grid systems and remote locations
- Smaller reactors can be easily cooled by natural (passive) systems like gravity and natural convection
- The reactor vessel can be installed below ground level - providing protection against external hazards and unauthorised interference
- The reactor module is factory built, with the economy and high QA of factory mass production of a simple standard design
- The reactor module is factory built minimising on-site construction time and reducing the probability of project delays
- SMRs are designed to be simple to operate and maintain, with low maintenance costs for passive cooling systems
- SMRs have smaller initial capital costs compared to large reactors
- Modules can be added as demand increases and cashflow returns from the first modules can be generated whilst additional modules are installed.

There is extensive experience with much of the technology employed by modern SMRs. For many years they have provided the power supply for submarines and icebreakers where totally reliable power is essential. Examples of SMRs based on this proven PWR technology are:

Country	Reactor	Module size	2015 Status
USA	Generation mPower	180 MWe	Basic design completed, test facility and simulator built
USA	NuScale	45 MWe	Design certification application scheduled for 2016. Construction licence application 2017
South Korea	KAERI SMART	100 MWe	Design approval 2012, first construction expected soon
Argentina	CNEA/INVAP CAREM	27 MWE	Under construction, operation scheduled for 2017
Russia	KLT-40S	35 MWe	Floating plant under construction, deployment 2016
China	CNNC/NPIC ACP-100	100 MWe	Design completed, start of first construction expected 2015

Disadvantages

Nuclear Liability

Adequate funds have to be available to provide for potential liability claims for personal injury and property damage in the event of a nuclear accident. Because of the potential for cross border consequences of a nuclear accident, an international nuclear liability convention is required. There are a number of international instruments (e.g. Paris Convention, Vienna Convention) but at present no Convention to which all countries are contracted. The best possibility is the *Convention on Supplementary Compensation for Nuclear Damage* which came into force on 15 April 2015. Australia has signed (but not ratified) this Convention.

Nuclear power owners pay for insurance, typically up to a set level, and the State is responsible for higher levels. For example the Price-Anderson Act in the USA requires owners of power plants to take out a first tier insurance for $375m. There is also a second tier available where every reactor owner would pay a prorated share of the excess up to $127.3m each. The second tier would currently provide $13.2 billion. The average annual premium is $830,000 for a single reactor unit, with a discount for more than one reactor on a site. These are for very large USA reactors and it is likely that the premium for a Small Modular Reactor with passive safety would be lower, but still a significant cost.

In Australia there is unlimited Commonwealth Government nuclear liability to cover, in particular, the activities of ANSTO.

However the nuclear liability system also has an advantage for anyone affected by a nuclear accident in that there is absolute operator liability regardless of fault. The claimant only has to prove a causal link between the incident and damage.

Legislation

The major obstacle to the deployment of nuclear power in Australia is the two pieces of Commonwealth legislation that prohibits the licensing of a nuclear power reactor in Australia.

The Acts are:

- Environmental Protection and Biodiversity Conservation (EPBC) Act 1999 section 140A
- Australian Radiation Protection and Nuclear Safety (ARPANS) Act 1998 section 10

There are also prohibitions in three States, but not in South Australia.

Perceived Disadvantages

Radiation

Radiation is still perceived by many members of the public as always and everywhere dangerous, whereas radiation is part of our everyday environment, in the atmosphere, ground, food and radon, plus additional radiation from air travel, medical diagnosis and treatment, etc.

Radiation is easy to detect at levels far below any dangerous level and below the detection threshold of any noxious substance. Protection against radiation is by distance, time and shielding.

Safety

There are two steps that require to be taken to make a reactor safe in an emergency situation:

1. Stop the nuclear fission (chain reaction) by inserting neutron absorbing control rods into the reactor. This operates on a failsafe basis. In the case of Fukushima, all control rods were inserted and the nuclear reaction stopped.
2. The reactor continues to produce some heat after shutdown and this residual heat has to be removed. Old reactors, like the type at Fukushima, typically rely on pumped water and back-up diesel electrical supplies to ensure the safety of the reactor. Modern reactors employ natural (passive) water cooling by gravity feed and natural convection and conduction. These systems are within the reactor containment, protected from external hazards, and do not depend on external electrical supplies. Similar to the OPAL reactor at Lucas Heights, the NuScale SMR illustrated in Fig 1 sits in a large pool of water which removes the heat in an incident. There is no operator action required and no external electrical supplies required.

All operators and nuclear regulators worldwide have re-examined their nuclear power plants and taken into account the lessons from Fukushima. Modern nuclear power plants, particularly SMRs, have passive safety systems.

South Australia is in a mild seismic activity area. However, all nuclear reactors (including the OPAL reactor at Lucas Heights) are designed to international seismic standards. Even at Fukushima, all of the reactor's seismic protection worked correctly and the reactors were not damaged by the seismic event. They were damaged by the following tsunami. Nuclear power plants in Japan that were also affected by the tsunami (eg Onagawa) survived because, unlike Fukushima, they had an adequately engineered seawall to protect against a tsunami.

Even including older nuclear technology, historically, nuclear power is one of the safest technologies for the generation of electricity [10]. The relative safety is reflected in a study commissioned by Friends of the Earth in the UK [11] which concluded that:
"*overall the safety risks associated with nuclear power appear to be more in line with lifecycle impacts from renewable energy technologies, and significantly lower than for coal and natural gas per MWh of supplied energy".*

Proliferation

Some people are concerned that a nuclear power program would be a route to development of a nuclear weapon. There are two routes to development of nuclear weapons:

1. Highly enriched uranium, requiring >80% enriched U-235. Natural uranium contains 0.7% u-235 and it is enriched to <5% for commercial nuclear reactor fuel. It would be useless to divert commercial nuclear reactor fuel for use in a nuclear weapon.
2. Plutonium, requiring quite pure plutonium-239. The majority of reactors worldwide are light water reactors, refuelled off-load, every 12 – 18 months or more. After

radiation in the reactor, commercial spent fuel contains Pu-239, Pu-240, Pu-241 and other higher actinides rendering it unfit for a nuclear weapon.

The IAEA Non-Proliferation Treaty safeguards system, to which Australia already reports, tracks all nuclear material.

Economics

The cost of nuclear power is sometimes perceived as too high, but the BREE Australian Energy Technology Assessment 2013 LCOE figures [12] for Australian conditions indicated that nuclear is one of the lowest cost baseload low emissions technologies for the generation of electricity.

The initial capital cost in particular is perceived to be too high, but capital cost comparisons often do not take into account the effects of capacity factor on true capital costs.

The table below compares the NuScale SMR with the latest renewable energy projects:

Plant	Output MWe net	Capital cost A$m	Cost/MWe A$m	Capacity Factor	Comparative cost/MWe for 90% CF $m
NuScale SMR (6 modules)	285	US1425	US5	90%	US$5
Hornsdale wind	270	900	3.33	44%	6.8
Boco Rock wind	113	361	3.2	35%	8.3
Royolla solar	20	60	3	21%	12.8
Broken Hill/Nyngan solar	155	440	2.8	25.7%	9.8

On a realistic comparison of capital costs/MWe, nuclear is seen to be competitive. A NuScale plant has not yet been constructed, therefore the estimated cost still has to be proven, although NuScale has carried out detailed cost studies.

True comparisons of capital cost have implications for the cost of CO_2 abatement.

Radioactive waste

There may be a concern amongst some members of the public that the industry does not know how to manage radioactive waste. In this regard, it might be noted that a 1,000 MWe light water reactor produces around 150m^3/year of **Low Level Waste (LLW)** [14]. Typical waste is paper, cleaning materials, resins, filters and lightly contaminated scrap metal. The waste is sorted, and compacted into 220 litre drums and stored on site. No shielding is required as the radiation level on the outside of the drum is low. The drum provides containment. Radionuclides with half-lives of less than about thirty years are considered to be short lived. The time for LLW to decay to background levels is normally assumed to be within 300 years.

The IAEA guidance for this waste is in a Near Surface Repository [15]. This has engineered features to contain the waste for 300 years, i.e. a number of barriers to restrict release of the radionuclides to the environment.

There are many good examples of Near Surface Repositories worldwide, e.g.:

UK – Drigg, Dounreay
France – Centre de la Manche, Centre de L’Aube
Japan – Rokkasho-Mura
Spain – El Cabril

The multiple barrier technology is simple and well understood.

If Australia were to start a nuclear power program, the typical quantity of **Intermediate Level Waste (ILW)** produced would be around 8.6m^3/year for a 1,000 MWe reactor [14]. This is mainly resins from radioactive water treatment systems. The quantity would be much smaller for a Small Modular Reactor.

If South Australia decided to develop a Near Surface Repository for LLW, then it could consider co-locating an ILW store. This would be a building which would house shielded metal/concrete casks containing the ILW on an interim basis. There is extensive international experience with these types of casks.

High Level Waste (HLW) is higher activity and produces heat. The normally accepted definition of the heat load is > 2kW/m^3. HLW is not produced during routine day to day reactor operations; it is only associated with spent fuel.

When a power reactor is refuelled, the spent fuel that is removed is highly radioactive and still producing heat. Good industry practice would require the spent fuel to be stored in a cooling pond close to the reactor for several years to allow the radioactivity and heat load to decay. There are then four alternatives for spent fuel management:

- interim dry store – extensive experience of casks, widely used in many countries
- reprocess – PUREX process used for about one third of all spent fuel. Recycles uranium and plutonium (MOX fuel), final waste product is still HLW but in a more stable vitrified form
- final disposal – deep underground disposal facilities now in licensing process at Forsmark (Sweden) and Okiluoto (Finland). Construction expected to commence in 2015.[16]
- burn in a fast neutron reactor – Integral Fast Reactor (IFR)[17, 18]

Decommissioning

Up to 2015, globally, about 110 commercial power reactors, 46 experimental reactors and 250 research reactors have been retired from operation and some have been fully dismantled [13]. Twelve large power reactors have been completely dismantled in the USA.

The cost of decommissioning is typically covered by building up a fund during the operation of the plant. For example, in the USA utilities collect 0.1 -0.2cents/kWh to fund decommissioning [13].

The advantage for a new reactor build in South Australia is that modern reactors take account of decommissioning in their initial design. For example ANSTO’s OPAL reactor has design features to simplify decommissioning and this was part of the safety case submitted to the regulator (ARPANSA) for the construction licence.

There is a fully costed example of decommissioning in Australia. ANSTO’s MOATA research reactor operated between 1961 - 1995. The reactor fuel was removed immediately following shutdown, to remove the major source of radioactivity. This has now been returned to the USA, without return of any waste, in accordance with the USA research reactor agreement. In 2009/2010 the reactor was completely dismantled and the site is now being reused. The cost was $4.15m. The IAEA are using this ANSTO project as an example of good international practice for decommissioning.

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Nuclear Regulation (Question 3.10)

Australia already has a competent and very well managed Commonwealth nuclear regulator – the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) established under the *Australian Radiation Protection and Nuclear Safety Act 1998* (*Commonwealth*) ('the ARPANS Act' or 'the Act'). The clear objective of the Act under Section 3 is "*to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation*."

International Atomic Energy Agency (IAEA)

The IAEA issued a new Safety Standard *Governmental, Legal and Regulatory Framework for Safety* GSR Part 1 in October 2010 [1]. This establishes the responsibilities of the Government and the Regulatory Body in respect of the regulatory framework for safety. The objective is to protect the safety of people and the environment from the effects of ionising radiation. The nuclear power plant operator must have the prime responsibility for safety. The public and the operator must have confidence in the nuclear regulator.
The standard emphasises the importance of an <u>independent</u> regulator with the competences, resources and authority to fulfil its statutory obligations.

"The Government, through the legal system, shall establish and maintain a regulatory body, and shall confer on it the legal authority and provide it with the competence and the resources necessary to fulfil its statutory obligation for the regulatory control of facilities and activities"(GSR Part 1 Requirement 3).

Key requirements are:

- The regulatory body must be effectively **independent** in its safety related decision making and has functional separation from entities having responsibilities or interests that could unduly influence its decision making. For example, the regulatory body must not be established within a government department that has any responsibilities for industry.
- The regulator must have appropriate **competencies**. The regulatory body must have a full time staff capable of either performing regulatory reviews and assessments, or evaluating any assessments performed for it by consultants. For the foreseeable future, the number of nuclear facilities in Australia would be too few to require a separate Technical Support Organisation as for example exists in France.

International best practice is for the establishment of a **national** nuclear regulator. It would not be efficient or effective for each state and territory to establish its own nuclear regulator. The jurisdiction for an Australian nuclear regulator should be the Commonwealth for all facilities and activities, except mining and milling.

The single national nuclear regulator is normally responsible for:

- Radiation safety
- Nuclear safety
- Nuclear security
- Safeguards
- Transport of radioactive materials

The area where it is more appropriate for States to be involved is mining. This is particularly appropriate for South Australia where Olympic Dam is principally a copper mine and uranium is a by-product.

International best practice is to keep environmental and WHS regulation separate from nuclear regulation.

IAEA Integrated Regulatory Review Service (IRRS)

In 2007, an International Regulatory Review Team from the IAEA reviewed ARPANSA's activities and made a number of recommendations. There was a follow up mission in 2011. These reviews confirmed the competence of ARPANSA and identified some good practices. It also identified areas where the ARPANSA Act should be strengthened.

The ARPANS Act

Since the passing of the ARPANS Act in 1998, there have been a number of improvements in international best practice in regulation. The ARPANSA Amendment Bill [2] before Federal Parliament (2015) draws on the recommendations of the IAEA new Safety Standard *Governmental, Legal and Regulatory Framework for Safety* GSR Part 1 and the IRRS and makes changes to the legislation which provide:

- greater clarity regarding application of the legislation to contractors
- adoption of a risk-based approach
- requirement for a licence holder to provide information
- power to issue improvement licences
- power to issue time limited licences
- power to regulate activities on legacy sites

These changes to the ARPANS Act strengthen the powers of ARPANSA without imposing unnecessary additional burdens on licence holders and are in accordance with international best practice in regulation. However the ARPANSA Act still contains a prohibition that should be removed.

ARPANS ACT Section 10 – Prohibition on certain nuclear installations

Section 10 of the Act prohibits the authorisation of the construction and operation of any of the following nuclear installations:

a) a nuclear fuel fabrication plant;
b) a nuclear power plant;
c) an enrichment plant;
d) a reprocessing facility

Section 10 was introduced before Australia had adopted all the international conventions on nuclear safety and before there was an understanding of the importance of reducing

greenhouse gas emissions and the part that nuclear power plays internationally in the reduction of emissions.
One of the Energy White Paper key themes is technology neutrality. This is not possible if one of the main low emissions technologies is prohibited.

ARPANSA's Regulatory Assessment Principles: (1) A Strong Safety Culture and (2) Defence in Depth

ARPANSA has a set of regulatory assessment principles that apply to applications for a facility licence (see *"Regulatory Assessment Principles for Controlled Facilities,"* RB-STD-42-00 Rev 1, October 2001) These draw on the IAEA's safety principles for nuclear power plants.

ARPANSA's regulatory assessment principles emphasise two fundamental expectations: (1) a strong safety culture in the operating organisation and (2) defence in depth:

"*Defence in depth is a methodology that is widely accepted in the nuclear industry as part of international best practice. Defence in depth is implemented in the form of a hierarchy of diverse levels of equipment and procedures. ARPANSA strongly supports its application to controlled facilities and particularly looks for its proper implementation. When properly implemented, the principle should ensure that no single human or equipment failure would lead to injury to the public, and unlikely combinations of failures would lead to little or no injury".*

The Requirement of International Best Practice

In pursuing its statutory objective of protecting public health and safety, and deciding whether to issue a licence for a nuclear facility, the CEO of ARPANSA is required by Section 32(3) of the Act to "*take into account international best practice in relation to radiation protection and nuclear safety*." This was implemented in the case of the OPAL research reactor. In 2002, the issue by ARPANSA of a licence to ANSTO to construct the OPAL reactor was challenged by Greenpeace in the Federal Court of Australia. Greenpeace complained that ARPANSA had failed to follow international best practice but the complaint was rejected by the Court (see Greenpeace v CEO of ARPANSA [2002] FCA 1144 per Beaumont J).

The Management of ARPANSA

Australia has a competent and very well managed Commonwealth nuclear regulatory regime with staff with wide international experience.
In March 2010, Dr Carl-Magnus Larsson was appointed as the CEO of ARPANSA. He has extensive nuclear regulatory experience from his management positions at the Swedish Radiation Safety Authority which has enabled him to identify areas for improvement.
Three bodies have been established under Part 4 of the Act to provide advice to the CEO. These are:

The Radiation Health and Safety Advisory Council (the Advisory Council)

The Advisory Council identifies emerging issues relating to radiation protection and nuclear safety, examines matters of major concern to the community in relation to radiation protection and nuclear safety, and advises the CEO on the adoption of recommendations, policies, codes and standards in relation to radiation protection and nuclear safety.

The Radiation Health Committee (RHC)

On request, the RHC advises the CEO on matters relating to radiation protection, including formulating draft national policies, codes and standards for consideration by the Commonwealth, states and the territories.

The Nuclear Safety Committee (NSC)

On request, the NSC advises the CEO on matters relating to nuclear safety and the safety of controlled facilities, including developing and assessing the effectiveness of standards, codes, practices and procedures.

Nonetheless, a change to the administrative structure could provide better support to the CEO of ARPANSA and greater reassurance to the public about the competence and independence of the regulatory regime.

By way of example, the latest country to start a nuclear power program is the United Arab Emirates (UAE). They have established the *Federal Authority for Nuclear Regulation (FANR)* which has a Director General and a board with nine members.

The UK has one of the most experienced nuclear regulators in the world (established 1959). In 2011, they became the *Office for Nuclear Regulation* (ONR) and increased their scope to include safeguards, security and transport which were previously the responsibilities of other government departments. They also changed the structure to a CEO and Board of Directors and established a Public Corporation in 2014.

A more suitable administrative structure for ARPANSA would be to have a CEO and Board of Directors. The board would be appointed by the government to guarantee a diversity of knowledge and experience and provide for stakeholder representation. The board should include an appointee to represent the public and there should be a limitation of time of service to ensure regular turnover and provide fresh thinking at board level.

Under the current regulatory regime*,* ARPANSA is responsible for radiation safety and nuclear safety whilst the *Australian Safeguards and Non-Proliferation Office* (ASNO) is responsible for security and safeguards, as further described below. There is inevitably some overlap, particularly in the security area, and it would be preferable in the longer term if the security and safeguards responsibilities were transferred from ASNO to ARPANSA.
ASNO, as part of DFAT, could still retain responsibility for international treaties.

Conclusions

Australia already has a competent, independent and very well managed Commonwealth nuclear regulatory regime.
There is nonetheless a strong case for improvements to ARPANSA's administrative structure as outlined in the preceding section of this submission.
The Commonwealth legislation will also require revision to include the States and Territories and to remove the prohibitions on various nuclear activities.

ARPANSA will require additional human resources to cope with the additional workload if the prohibitions on nuclear power are removed.
In the longer term, the security and safeguards functions of ASNO (as described below) ought to be consolidated within ARPANSA as a single regulatory body.

References

[1] IAEA Safety Standard *Governmental, Legal and Regulatory Framework for Safety* GSR Part 1, Oct 2010

[2] ARPANS Amendment Bill
http://www.aph.gov.au/Parliamentary_Business/Bills_LEGislation/Bills_Search_Results/Result?bId=r5490

Nuclear Safeguards (Question 3.14)

"Safeguards" refers to the total system for accounting for *nuclear materials*. Safeguards are measures applied by the International Atomic Energy Agency (IAEA) to verify that non-proliferation commitments made by States under Safeguards Agreements with the IAEA are fulfilled. This system is already working well in Australia.

Nuclear material

For the purpose of the functions of the Australian Safeguards and Non-Proliferation Office, nuclear material means any source or any special fissionable material as defined below (see the *Nuclear Non-Proliferation (Safeguards) Act 1987,* and Article XX of the Statute of the International Atomic Energy Agency):

(a) The term "special fissionable material" means plutonium-239; uranium- 233; uranium enriched in the isotopes 235 or 233; any material containing one or more of the foregoing; but the term "special fissionable material" does not include source material.

(b) The term "uranium enriched in the isotopes 235 or 233" means uranium containing the isotopes 235 or 233 or both in an amount such that the abundance ratio of the sum of these isotopes to the isotope 238 is greater than the ratio of the isotope 235 to the isotope 238 occurring in nature.

(c) The term "source material" means uranium containing the mixture of isotopes occurring in nature; uranium depleted in the isotope 235; thorium; any of the foregoing in the form of metal, alloy, chemical compound, or concentrate.

For a nuclear power plant (NPP) the accounting system starts with the delivery of new fuel assemblies. There is a formal transfer of the nuclear material in the new fuel assemblies, typically low enriched uranium with <5% U-235, from the fuel manufacturer to the NPP operator. Often the fuel manufacturer and the NPP are located in different countries so this involves a transfer of nuclear material between countries. The fuel assemblies are stored in a dedicated fuel store on the reactor site until required for refuelling the reactor.

After loading into the reactor and irradiation, the fuel composition changes due to fission and absorption processes. Typical light water reactor irradiated spent fuel consists of:

- Mainly U-238
- Reduced quantity of U-235, typically ~ 1% enriched
- Isotopes of plutonium, including Pu-239, Pu-240, Pu-241, Pu-242
- Other minor actinides, e.g. americium, neptunium, curium
- Fission products, e.g. cesium, strontium, iodine, xenon

The quantities of *nuclear material* in the fuel discharged from the reactor (spent fuel) cannot be easily measured. The reactor operator uses an approved code to estimate the quantities of uranium and plutonium in the spent fuel for safeguards purposes.

The safeguards issues that arise with the establishment of a nuclear power plant relate to both the new fuel and spent fuel. There are well established internationally agreed practices.

In practice in Australia, safeguards are applied at three levels:

1. The NPP organisation will have its own safeguards department which should be independent of the operating organisation. This safeguards department maintains records of all nuclear material on site. For example, the Australian Nuclear Science and Technology Organisation (ANSTO) has a safeguards department which accounts for all nuclear material on site. They have 58 years' experience of safeguards for ANSTO's nuclear reactors.
2. The Australian Safeguards and Non-Proliferation Office (ASNO), in the Department of Foreign Affairs and Trade, is responsible for ensuring Australia's obligations for safeguards. The *Nuclear Non-Proliferation (Safeguards) Act 1987* gives effect to Australia's obligations under the NPT including the Safeguards Agreements and Additional Protocol with the IAEA. In the case of ANSTO, ASNO independently checks the quantities of nuclear materials held for example in connection with the OPAL reactor.
3. The IAEA is the verifying authority for the Nuclear Non-Proliferation Treaty (NPT) and the world's inspectorate for nuclear materials control. Australia signed the Safeguards Agreement as required by the NPT in 1974. In practice, a team of IAEA inspectors regularly visits the ANSTO site to verify the quantities of nuclear materials held.

Conclusion

For the establishment of a new facility for the generation of electricity by nuclear fuels in South Australia, there is a well-established safeguards system already in place in Australia. The new facility would require its own independent safeguards department. Although ASNO may require more human resources to cope with the additional work, a full safeguards system is already in existence.