ISSUES PAPER THREE – ELECTRICITY GENERATED FROM NUCLEAR FUELS

Submission from the World Nuclear Association to the South Australian Nuclear Fuel Cycle Royal Commission

Introduction

The World Nuclear Association is grateful for this opportunity to answer in full the Royal Commission's questions regarding the potential development of nuclear energy in South Australia. We note that for this to be possible there must first be changes at the national level. Regardless of other outcomes, we hope to see the Commission recommend the revision of the federal Environment Protection and Biodiversity Conservation Act of 1999 and Australian Radiation Protection and Nuclear Safety Act of 1998, both of which currently prohibit nuclear power plants and other nuclear fuel cycle facilities from being constructed in Australia.

In many ways Australia is already a nuclear nation. It is home to one of the most advanced nuclear research and medical facilities in the world at Lucas Heights and is also one of the world's largest suppliers of uranium. Many advanced nuclear technologies have also been developed with the assistance of Australian scientists. The country has a long and proud nuclear history and is well placed from a technical, regulatory and social standpoint to start a nuclear power program.

We believe it is natural that a technologically sophisticated country like Australia should seek to make use of nuclear energy as it attempts to address its climate, energy and economic challenges. About two-thirds of the world's population live in countries which are supplied by nuclear energy and which enjoy reliable, affordable, clean electricity with negligible carbon emissions as a result. It is time for Australians to join them.

South Australians are confronted with a remarkable opportunity. By championing the introduction of nuclear energy in the country, the state could become a natural hub for nuclear expertise and investment as various companies and research organisations set up local operations. This investment would grow larger if the state also chooses to expand other nuclear fuel cycle activities. A nuclear power program would take several years to establish, granting South Australians a wide choice of nuclear technology options to select from. While there are many excellent and suitable nuclear reactor designs on offer today, the state may choose to be an early adopter of new technologies which are currently under development.

List of acronyms

BWR	Boiling water reactor
EU	European Union
EUR	European Utility Requirements
FNR	Fast neutron reactor
GCR	Gas-cooled reactor
GWe	Gigawatt (one billion watts of electric power)
GWh	Gigawatt hour (one billion watt-hours of power)
HTGC	High temperature gas-cooled reactor
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LWGR	Light water gas-cooled reactor
LWR	Light water reactor
MWe	Megawatt (one million watts of electric power)
MWh	Megawatt hour (one million watt-hours of power)
NRC	Nuclear Regulatory Commission
OECD	Organisation for Economic Cooperation and Development
PHWR	Pressurized heavy water reactor
PV	Photovoltaic
PWR	Pressurised water reactor
RBMK	*Reaktor Bolshoy Moshchnosti Kanalniy* (an LWGR)
TWh	Terawatt hour (one trillion watt-hours of power)
UN	United Nations
VVER	*Vodo-Vodyanoi Energetichesky Reactor* (a PWR)

Section A: NUCLEAR FUELS AND ELECTRICITY GENERATION

Question 3.1

a) Are there suitable areas in South Australia for the establishment of a nuclear reactor for generating electricity?

b) What is the basis for that assessment?

There are typically multiple siting options suitable for a nuclear power plant. Technical considerations for siting include grid access, transport and logistics, access to water and site geology. Coastal sites are particularly desirable due to the cost and efficiency benefits of once-through cooling and access to an unlimited body of water. It is also essential to build and maintain robust local support for any such project.

More broadly, the development of nuclear power programs in new countries is described exhaustively in the International Atomic Energy Agency's (IAEA's) Milestones in the Development of a National Infrastructure for Nuclear Power[1]. Before any decision to proceed, it is recommended to carry out a feasibility study[2].

Question 3.2

a) Are there commercial reactor technologies (or emerging technologies which may be commercially available in the next two decades) that can be installed and connected to the NEM?

Currently available reactor technologies would be suitable for South Australia if NEM connections eastward were significantly improved. The cost of connection improvements could be offset against lower costs per unit of nuclear generating capacity due to economies of scale with larger plant. Regarding the compatibility of nuclear and the grid, IAEA provides a guide[3]. The main reactor designs available today are tabulated, also see the World Nuclear Association information paper on Advanced Nuclear Power Reactors[4].

Table 1: Commercially available power reactor designs operational or under construction

Developer	Reactor	Size (MWe gross)	Design progress, notes
GE-Hitachi, Toshiba (USA, Japan)	ABWR	1380	Commercial operation in Japan since 1996-7 US design certification 1997 UK design certification application 2013
Westinghouse/ Toshiba (USA/Japan)	AP1000 (PWR)	1200-1250	Under construction in China and USA, many units planned in China US design certification 2005 UK design certification expected 2017 Canadian design certification in progress
Areva and EDF (France)	EPR (PWR)	1700-1750	Future French standard, French design approval. Being built in Finland, France and China UK design approval 2012
KEPCO and	APR 1400	1450	Under construction at Shin Kori in South Korea

[1] IAEA Nuclear Energy Series NG-G-3.1, Milestones in the Development of a National Infrastructure for Nuclear Power, 2007, http://www-pub.iaea.org/books/IAEABooks/7812/Milestones-in-the-Development-of-a-National-Infrastructure-for-Nuclear-Power

[2] Such as described in the following IAEA guide, Preparation of a Feasibility Study for New Nuclear Power Projects, 2014, http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1633Web-39794849.pdf

[3] IAEA Nuclear Energy Series NG-T-3.8, Electric Grid Reliability and Interface with Nuclear Power Plants, 2012, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1542_web.pdf

[4] World Nuclear Association, Advanced Nuclear Power, accessed 29 July 2015, http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Power-Reactors/Advanced-Nuclear-Power-Reactors/

KHNP (South Korea)	(PWR)		Under construction at Barakah in United Arab Emirates Korean design certification 2003 US design certification application
CNNC and CGN (China)	Hualong One (PWR)	1150	Main Chinese export design, under construction at Ningde
Gidropress (Russia)	VVER-1200 (PWR)	1200	Under construction at Leningrad and Novovoronezh plants as AES-2006 plant

Table 2: Commercially available power reactor designs ready for deployment

Developer	Reactor	Size (MWe gross)	Design progress, notes
GE-Hitachi (USA/Japan)	ESBWR (BWR)	1600	Planned for Fermi and North Anna in USA Developed from ABWR Design certification in USA 2014
Mitsubishi (Japan)	APWR (PWR)	1530	Planned for Tsuruga in Japan US design application as US-APWR EUR design approval as EU-APWR 2014
Areva and Mitsubishi (France, Japan)	Atmea1 (PWR)	1150	Planned for Sinop in Turkey French design approval 2012 Canadian design certification in progress
Candu Energy (Canada)	EC6 (PHWR)	750	Improved CANDU-6 model Canadian design certification June 2013
Gidropress (Russia)	VVER-TOI (PWR)	1300	Planned for Nizhny Novgorod in Russia and Akkuyu in Turkey Russian design certification in progress for European Utility Requirements
SNPI (China)	CAP1400 (PWR)	1400	Developed in China from AP1000 with Westinghouse support, for export First unit ready to start construction at Shidaowan

In addition, there are a number of smaller reactor designs and advanced nuclear technologies under development that are expected to be available within the next 10-15 years which would require substantially less upgrades to the NEM. These are described in World Nuclear Association information paper on Small Nuclear Power Reactors[5] and tabulated here.

Table 3: Small reactors operating

Developer	Reactor	Size (MWe gross)	Design progress, notes
CNNC (China)	CNP-300 (PWR)	300 MWe	Operational in Pakistan and China, more under construction
NPCIL (India)	PHWR-220 (PHWR)	220 MWe	Fourteen operating
Rosatom (Russia)	EGP-6 (LWGR)	11 MWe	Operating at Bilibino Siberia (cogeneration of heat)

[5] World Nuclear Association, Small Nuclear Power Reactors, accessed 14 July 2015, http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Power-Reactors/Small-Nuclear-Power-Reactors/

Table 4: Small reactor designs under construction

Developer	Reactor	Size (MWe gross)	Design progress, notes
OKBM (Russia)	KLT-40S (PWR)	35 MWe	Barge-mounted floating nuclear plant concept Reactor is commonly used in ice-breakers
CNEA and INVAP (Argentina)	CAREM (PWR)	27 MWe	Can be used as research reactor, for electricity generation or for desalination
INET, CNEC and Huaneng (China)	HTR-PM, HTR-200 (HTR)	2x105 MWe equivalent (one module)	Pebble bed fuel based reactor based on HTR-10 Two units will drive a single steam turbine

Table 5: Small and advanced reactor designs for near-term deployment – development underway

Developer	Reactor	Size (MWe gross)
OKBM (Russia)	VBER-300 (PWR)	300 MWe
NuScale Power and Fluor (USA)	NuScale (PWR)	50 MWe
Westinghouse/Toshiba (USA/Japan)	Westinghouse SMR (PWR)	225 MWe
Babcock & Wilcox and Bechtel (USA)	mPower (PWR)	180 MWe
Holtec (USA)	SMR-160 (PWR)	160 MWe
CNNC and Guodian (China)	ACP100 (PWR)	100 MWe
KAERI (South Korea)	SMART (PWR)	100 MWe
GE-Hitachi (USA)	PRISM (FNR)	311 MWe
RDIPE (Russia)	BREST (FNR)	300 MWe
AKME-engineering (Russia)	SVBR-100 (FNR)	100 MWe

b) If so, what are those technologies, and what are the characteristics that make them technically suitable?

The general characteristics of nuclear power plants are that they provide clean (especially low-carbon), continuous, reliable electricity supply on a medium to large scale at competitive cost. Nuclear plants also contribute to grid stability, notably frequency and voltage control, and the security of supply. However, system operators usually consider that new individual capacity should not exceed around 10% of the maximum grid capacity, to avoid supply impacts when the unit goes off-line for any reason. The European Network of Transmission System Operators for Electricity (ENTSO-E) publishes rules to achieve this.

c) What are the characteristics of the NEM that determine the suitability of a reactor for connection?

The NEM links a wide range of generation sources and could accommodate either up to 20 large nuclear units of 1000-1300 MWe each, as proposed in the Uranium Mining, Processing and Nuclear Energy Review

(UMPNER) report[6] and/or a greater number of smaller ones. As South Australia becomes better linked to the eastern states part of NEM, constraints on size and capacity will reduce.

Question 3.3

a) Are there commercial reactor technologies (or emerging technologies which may be commercially available in the next two decades) that can be installed and connected in an off-grid setting?

b) If so, what are those technologies, and what are the characteristics that make them technically suitable?

Some of the small reactors or plants described in the World Nuclear Association's information paper on Small Nuclear Power Reactors, tabulated above, are suitable for use in an off-grid setting. The Russian floating nuclear power plant with twin KLT-40s reactors is essentially an off-grid concept, as are the small 11 MWe reactors which have been operating at Bilibino since 1976 (although not now commercially available). Most of the units up to 100 or 160 MWe would or could be suitable, given provision for back-up during refuelling or other outages.

c) What are the characteristics of any particular off-grid setting that determine the suitability of a reactor for connection?

Any design which has, or could have, an air-cooled condenser circuit would have obvious advantages for off-grid deployment. Smaller units are the most obvious candidates, and some are marketed with this potential.

[6] The UMNPER figure is actually up to 25 units. Uranium Mining, Processing and Nuclear Energy Review (UMPNER), 2006, http://www.ansto.gov.au/__data/assets/pdf_file/0005/38975/Umpner_report_2006.pdf

Section B: VIABILITY

Question 3.4

a) What factors affect the assessment of viability for installing any facility to generate electricity in the NEM? How might those factors be quantified and assessed?

Having a major component of reliable, dispatchable capacity in any grid system is becoming an increasingly important priority as greater contribution from intermittent renewables poses a growing challenge to transmission system operators (TSOs) in maintaining system stability - voltage and frequency control in particular. The World Nuclear Association information paper on Electricity Transmission Systems comments on this matter[7]. In general it is desirable that a balanced energy system consisting of nuclear and renewables as well as low-carbon fossil fuel options should be used to meet energy objectives at the lowest overall cost to consumers.

The June 2015 paper by Heard et al, Beyond wind: furthering development of clean energy in South Australia, provides a thorough treatment of the electricity supply situation in South Australia, and we support its conclusion that "nuclear power offers a mature technology from a competitive global market of suppliers with a solid track record of delivering deeply decarbonised and reliable electricity supply in concert with other technologies"[8].

In the EU, the permanently permissible range of generator voltage variation is defined as 95% to 105% of rated voltage for up to 15 minutes. For a limited time, generators ought to be capable of operating in a voltage range from 92% to 108% of rated voltage in order to compensate for TSO issues, basically to ensure synchronous operation of the grid and support the system when local voltage problems occur (e.g. to avoid voltage collapse). At the transmission system connection point for distribution, the voltage is allowed to vary by 10%. Controlling voltage and frequency coupled with rapid ramp up and down are the main challenges arising from the increasing share of solar and wind renewables in any grid. Nuclear plants by contrast tend to stabilise voltage.

In the NEM, a consideration of fleet replacement requirements, and how much is best met by dispatchable plant, is fundamental.

Question 3.5

a) What are the conditions that would be necessary for new nuclear generation capacity to be viable in the NEM?

First and foremost are legislative change to allow nuclear energy to be properly considered. Specifically there would need to be changes to the:

- Environment Protection and Biodiversity Conservation Act of 1999.
- Australian Radiation Protection and Nuclear Safety Act of 1998.

Apart from this, some specific legislation required is outlined in the IAEA Milestones in the Development of a National Infrastructure for Nuclear Power, referred to above.

Market structure also plays a large role in determining nuclear viability. The cost profile of new nuclear power is similar to renewable technologies in that they are both capital intensive per unit of installed capacity and thus have long payback times, while operating costs are low. Nuclear therefore faces the same challenges in

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[7] World Nuclear Association, Electricity Transmission Systems, accessed 15 July 2015, http://www.world-nuclear.org/info/Current-and-Future-Generation/Electricity-Transmission-Grids/

[8] Ben Heard, Corey J. A. Bradshaw & Barry W. Brook, 2015, Beyond wind: furthering development of clean energy in South Australia, Transactions of the Royal Society of South Australia, 139:1, 57-82, DOI: 10.1080/03721426.2015.1035217, http://www.tandfonline.com/doi/pdf/10.1080/03721426.2015.1035217

being brought to market, namely investor confidence especially in the light of future policy and market risk. For any very large unit there is an investment challenge due to the long lead time before revenue, which can constrain a utility's ability to finance other investments.

Most nuclear power plants, including those under construction today, have been built in either regulated or state-controlled markets which prioritise long-term price stability and energy security. This helps to secure the necessary financing and, of course, significantly reduces policy risk and the associated risk premium. In liberalised markets where these benefits are not accounted for, the emphasis of energy investors is on maximizing risk-adjusted returns. This is a clear case of market failure which governments in those countries need to address if clean, reliable and affordable electricity is to be ensured.

While there is an urgent need to fix market failures and achieve policy goals, especially environmental ones, in deregulated markets, this should be done in a prudent and unbiased way that minimizes total costs (direct and system costs) to consumers. In particular, one of the major and apparently unintended consequences of increasing levels of subsidized intermittent renewable inputs has been decreased wholesale prices in times of high renewables supply to the point where prices routinely go negative in some markets[9]. This harshly impacts the viability of the other generators, including nuclear power plants, which are nevertheless expected to provide power at low prices when the renewable supply is suddenly absent a few hours later. Such impacts have led to a particularly perverse situation in Germany, where brand new gas units have been mothballed while cheaper new coal-fired generating capacity is being brought on line despite the greenhouse gas emission implications. Absent the right market incentives, high capital cost plant with low operating cost needs high utilisation to be economic.

Reconfiguring electricity markets needs to be done entirely at the system level, taking into account the practicalities and full system costs of all the policy choices. Piecemeal changes give rise to effects which present significant downsides and costs[10].

A further factor that will boost viability is robust long-term community support. There are a number of nuclear projects where public opposition rose to levels strong enough to force late and expensive regulatory changes and even halt construction[11]. While external events may have played a role in this, there was clearly more that could have been done in terms of stakeholder engagement. This requires ongoing commitment by industry but also clear support from government. While it may be difficult to build initial support for a nuclear power plant it is interesting to note that once a plant is operating local communities almost without exception become very supportive. US polling of neighbours of nuclear power plants shows 83% support in 2015[12].

b) Would there be a need, for example, for new infrastructure such as transmission lines to be constructed, or changes to how the generator is scheduled or paid.

If new nuclear plants of similar capacity were situated close to retiring coal-fired plants, no new transmission infrastructure would necessarily be needed.

To finance any capital-intensive new plant – nuclear, solar or wind – electricity market arrangements must allow for financing and amortisation of capital as mentioned above. Subsidies for renewables – either Feed In Tariffs or Renewable Portfolio Standards – address this. In the absence of specific subsidies for nuclear, some interventions regarding long-term electricity prices needs to be made. The UK Electricity Market Reforms are one such arrangement[13].

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[9] Exelon Public Policy Position, http://www.exeloncorp.com/performance/policypositions/overview.aspx#section_2

[10] The UK Department of Energy and Climate Change's pathways calculator indicates some of the variables that need to be considered. Its Low Cost Pathway example is instructive in relation to the South Australia situation, http://2050-calculator-tool.decc.gov.uk/pathways

[11] Notable examples include Austria and the Philippines which both completed reactors that never operated

[12] Nuclear Energy Institute, Plant Neighbors Express Strong Support for Nuclear Energy, http://www.nei.org/Knowledge-Center/Public-Opinion

[13] UK Department of Energy and Climate Change, Electricity Market Reform: policy overview, 2012, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65634/7090-electricity-market-reform-policy-overview-.pdf

Question 3.6

a) What are the specific models and case studies that demonstrate the best practice for the establishment and operation of new facilities for the generation of electricity from nuclear fuels?

b) Where have they been implemented in practice?

As a nuclear newcomer country, Australia will build either a modern reactor design, or possibly even an advanced technology not yet commercially available. The country stands to benefit from the extensive experience gained by those with established programs, but need not repeat their mistakes.

Arguably the most relevant case study for Australia is the United Arab Emirates. The UAE began construction on its first nuclear power plant, Barakah, in 2012. Apart from Belarus, the UAE is the most recent country to begin a nuclear power program. The country prepared regulatory and other infrastructure in close collaboration with the IAEA, and chose a modern design from a supplier with good on-time and on-budget credentials. The Barakah contractors are benefiting from the experience gained on the Shin Kori 3 and 4 reference plant in South Korea.

The first modern – so-called Generation III – nuclear power reactors to be built were Kashiwazaki Kariwa units 6 and 7 in Japan. They are Advanced Boiling Water Reactors (ABWRs)[14]. The pair were built rapidly by a consortium of General Electric, Toshiba and Hitachi using modular construction. They have run well since 1996-97, though interrupted by two large earthquakes. Two further ABWRs, Hamaoka 5 and Shika 2, joined them in 2005 and 2006. The four units were built in 37 to 43 months.

The only small plants under construction on land at the moment are the Chinese CNP-300 units at Chashma in Pakistan, the HTR-PM unit at Shidaowan in China's Shandong province and the small CAREM prototype unit in Argentina. If South Australia chooses to pursue smaller reactors then the performance of these projects should be informative.

c) What relevant lessons can be drawn from them if such facilities were established in South Australia?

Choose a design for which a reference plant has already been built, and use suppliers and builders with demonstrated experience of nuclear quality requirements. For more information refer to the World Nuclear Association report, Nuclear Power Economics and Project Structuring[15].

Question 3.7

a) What place is there in the generation market, if any, for electricity generated from nuclear fuels to play in the medium or long term? Why?

Irrespective of location, disptachable power will always be a basic power system requirement. Nuclear energy offers this as well as reducing carbon emissions, increasing stability of electricity prices (by lowering sensitivity to fuel prices), contributing to development (jobs creation, economic multipliers, industrial development), public health considerations (air pollution), and energy independence and security.

The particular situation for South Australia is addressed in the previously cited paper by Heard et al, 2015, while the Australia-wide situation is addressed by the CSIRO eFuture projections[16]. The general characteristics of nuclear energy make it an excellent substitute for coal. At the moment coal makes up the majority of Australian electricity supply, as indicated in Figure 1. Nuclear energy could easily replace a significant amount of this coal dependency if other states were to also permit its use. A modest initial target for a nuclear program would be 20% of Australia's current overall electricity demand.

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[14] Hitachi-GE, Advanced Boiling Water Reactor – the only Generation III+ reactor in operation today

[15] World Nuclear Association, 2012, Nuclear Power Economics and Project Structuring

[16] CSIRO eFuture scenarios, http://www.efuture.csiro.au/#scenarios

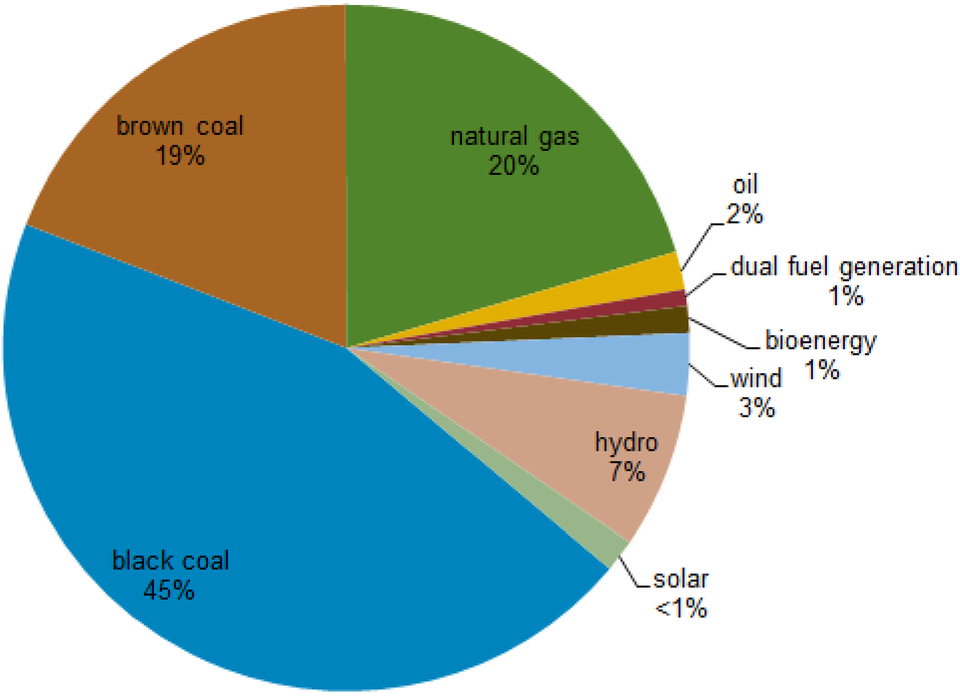

Figure 1: Australian electricity by source in 2013. Graphic by US Energy Information Administration based on data from the Australian Bureau of Resources and Energy Economics

b) What is the basis for that prediction including the relevant demand scenarios?

It is impossible to predict future trends in electricity demand with 100% accuracy. While demand may have been decreasing in recent years, there are no guarantees this will continue indefinitely. Notably, any future increase in the use of electric heating or transport – both rather likely outcomes of attempts to mitigate climate change – will increase demand, especially the proportion which needs to be supplied at night time.

The target of a 20% nuclear share of electricity allows for the realisation of financial benefits that come with building a series of reactors instead of just one or two units. However, it is unlikely that these reactors would need to operate as anything other than baseload, even if demand continues to fall for some time to come. In this way the target is sufficiently conservative. It could always be ramped up in the long term depending on the success of the nuclear program and future demand. The 20% target also just so happens to be quite a close match to the global share outlined for nuclear by the International Energy Agency in their 2 Degree Scenario.

Section C: RISKS AND OPPORTUNITIES

Question 3.8

a) What issues should be considered in a comparative analysis of the advantages and disadvantages of the generation of electricity from nuclear fuels as opposed to other sources?

The following are nuclear energy's key advantages:

- Nuclear is a cost-effective way of producing reliable low-carbon electricity on a large scale. Its increased use will substantially assist in preventing more than 2°C of warming (above pre-industrial times) and avoiding the damaging impacts of climate change.

- Nuclear energy contributes significantly to energy security. Uranium is abundant and supplied by many countries (and notably Australia) and can be stockpiled in large quantities relatively inexpensively. Furthermore, nuclear power costs are relatively insensitive to fuel price movements, which contributes to power price stability.

- Nuclear power projects are growth engines for the regions and countries in which they are constructed – injecting significant funds into local economies. They provide long-term opportunities for a large number of workers across diverse fields, and contribute greatly to skills development.

- Public acceptance for nuclear power is stronger than most people realize. Many high profile environmentalists have come to support the technology as they have discovered more about it and many countries are evaluating it as they confront choices on their energy future.

The OECD IEA and Nuclear Energy Agency (NEA) list the following among key challenges[17]:

- Nuclear safety remains the highest priority for the nuclear sector. Regulators play a major role in ensuring that all operations are carried out with the highest levels of safety. Safety culture must be promoted at all levels in the nuclear sector (operators and industry, including the supply chain, and regulators) and especially in newcomer countries.

- Governments have a role to play in ensuring a stable, long-term investment framework that allows capital-intensive projects to be developed and provides adequate electricity prices over the long term. Governments should also continue to support nuclear research and development, especially in the area of nuclear safety, advanced fuel cycles, waste management and innovative designs.

- Nuclear energy is a mature low-carbon technology, which has followed a trend towards increased safety levels and power output to benefit from economies of scale. This trajectory has come with an increased cost for Generation III reactors compared with previous generations.

b) What are the most important issues? Why? How should they be analysed?

The traditional objections to nuclear energy are centred on safety (accident risk), wastes, nuclear weapons proliferation, and more recently economics. Safety and waste are discussed elsewhere in this and other Issues Papers. Managing these are a fundamental part of day-to-day nuclear operations and should therefore be analysed in terms of industry good practise. Objections to nuclear energy based on safety and waste appear to be rooted in fears of radiation which, it may be strongly argued, are massively out of proportion to the actual risk. These can be more precisely defined as public acceptance issues and should be addressed as such, with stakeholder outreach and education. Australia's record with non-proliferation means this issue can effectively be removed from this list. Economic issues are discussed briefly in section

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[17] OECD NEA, Nuclear Technology Roadmap, https://www.iea.org/publications/freepublications/publication/technology-roadmap-nuclear-energy-1.html

B above, are addressed in 3.16 below and more fully answered in the World Nuclear Association information paper on The Economics of Nuclear Power[18].

The principal advantages of nuclear energy are its exceptionally low environmental footprint and its positive contributions to energy security and grid reliability. Nuclear plants release no harmful emissions during routine operation and the very high energy density of uranium fuel means that impacts are low across the fuel cycle[19], while the fuel is comparatively easy to extract, transport and store. A well run nuclear plant can be expected to achieve capacity factors of greater than 90% and will typically schedule planned outages for periods of low energy demand. Nuclear plants can operate regardless of any normal kinds of weather event, and through most extreme ones. During the 2014 polar vortex weather phenomena in the USA, when temperatures plunged to below zero for long enough to stretch gas supplies and freeze coal stockpiles, almost the entire US nuclear fleet stayed online[20].

Question 3.9

a) What are the lessons to be learned from accidents, such as that at Fukushima, in relation to the possible establishment of any proposed nuclear facility to generate electricity in South Australia?

There is now a formidable body of official literature from expert organisations detailing the progression of the Fukushima accident and the lessons learned which the Commission may wish to peruse, including:

- Tepco's ongoing accident report investigation:
  - Fukushima Nuclear Accident Analysis Report (Interim Report)[21]
  - Report on the Investigation and Study of Unconfirmed/Unclear Matters In the Fukushima Nuclear Accident Progress Report No.2 (August 2014)[22]
  - Report on the Investigation and Study of Unconfirmed/Unclear Matters In the Fukushima Nuclear Accident Progress Report No.3 (May 2015)[23]

- The two Japanese government sponsored investigation committees:
  - Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company (July 2012)[24]
  - The official report of The Fukushima Nuclear Accident Independent Investigation Commission (July 2012)[25]

- The Institute of Nuclear Power Operations Special Report on the Nuclear Accident at the Fukushima Daiichi Nuclear Power Station (November 2011)[26]

- Electric Power Research Institute's Fukushima Technical Evaluation: Phase 1 - MAAP5 Analysis[27]

- International Atomic Energy Agency's The Fukushima Daiichi Accident Report by the Director General (circulated to Member States in May 2015 and soon to be publicly available)

[18] World Nuclear Association, The Economics of Nuclear Power, http://www.world-nuclear.org/info/Economic-Aspects/Economics-of-Nuclear-Power/
[19] Barry Brook, Corey Bradshaw, Key role for nuclear energy in global biodiversity conservation, Journal of Conservation Biology, 2014, http://onlinelibrary.wiley.com/doi/10.1111/cobi.12433/full
[20] James Conca, 'Polar Vortex – Nuclear Saves the Day', Forbes, 2014, http://www.forbes.com/sites/jamesconca/2014/01/12/polar-vortex-nuclear-saves-the-day/
[21] http://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/111202e14.pdf
[22] http://www.tepco.co.jp/en/press/corp-com/release/betu14_e/images/140806e0101.pdf
[23] http://www.tepco.co.jp/en/press/corp-com/release/betu15_e/images/150520e0101.pdf
[24] http://www.cas.go.jp/jp/seisaku/icanps/eng/finalgaiyou.pdf
[25] http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/report/
[26] http://www.nei.org/corporatesite/media/filefolder/11_005_Special_Report_on_Fukushima_Daiichi_MASTER_11_08_11_1.pdf
[27] http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001025750

While there are many lessons on the nuclear safety considerations of the accident contained in these reports, we would like to highlight here some of the conclusions on radiation impacts and response from the IAEA report:

- The report repeats the conclusions of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), which states that there were no immediate radiation fatalities and that *"no discernible increased incidence of radiation-related health effects are expected among exposed members of the public and their descendants."* IAEA also repeated UNSCEAR's statement that, *"The most important health effect [from the accident] is on mental and social well-being, related to the enormous impact of the earthquake, tsunami and nuclear accident, and the fear and stigma related to the perceived risk of exposure to ionizing radiation."*

- *"Arrangements need to be in place to ensure that protective actions and other response actions in a nuclear emergency do more good than harm. A comprehensive approach to decision making needs to be in place to ensure that this balance is achieved."*

- *"Relevant international bodies need to develop explanations of the principles and criteria for radiation protection that are understandable for non-specialists in order to make their application clearer for decision makers and the public. As some protracted protection measures were disruptive for the affected people, a better communication strategy is needed to convey the justification for such measures and actions to all stakeholders, including the public."*

- *"The risks of radiation exposure and the attribution of health effects to radiation need to be clearly presented to stakeholders, making it unambiguous that any increases in the occurrence of health effects in populations are not attributable to exposure to radiation, if levels of exposure are similar to the global average background levels of radiation."*

- *"There is a need for radiological protection guidance to address the psychological consequences to members of the affected populations in the aftermath of radiological accidents"*

Simply put, the take-home message is that the perceived threats of nuclear accidents and radiation have traditionally been vastly overstated. In fact, the reaction to accidents – both the psychological reaction of the general public and the severity of some of the protective measures ordered by government – has been the dominant cause of public harm. Internalising this fact, and addressing the communication and decision making challenges it raises, are an advisable prerequisite for a nuclear energy program.

b) Have those demonstrated risks and other known safety risks associated with the operation of nuclear plants been addressed? How and by what means?

Accident risks have been addressed by numerous provisions arising from basic reactor design as evolved so far, and reinforced by the regulatory requirements and operator action which have arisen from post-Fukushima reviews carried out all over the world. In the European Union a comprehensive and transparent risk and safety assessment was carried out on every nuclear plant – the so-called stress tests[28]. In the USA the regulator has insisted upon a three-tier response to the accident[29]. It is worth noting that the US nuclear industry had in fact already made many relevant upgrades following the terrorist attacks of 11 September 2001. The FLEX program has since been adapted to the Fukushima accident and provides for an extra level of diverse and flexible emergency equipment[30]. In Japan, where the entire fleet of operable nuclear reactors have been idled for about two years now, the regulator has been completely reformed and new and

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[28] European Nuclear Safety Regulators Group, EU Stress Tests and Follow-up, http://www.ensreg.eu/eu-stress-tests
[29] Nuclear Regulatory Commission, What Are the Lessons Learned From Fukushima, http://www.nrc.gov/reactors/operating/ops-experience/japan-dashboard/priorities.html
[30] Nuclear Energy Institute, FLEX: The Industry Strategy to Enhance Safety, http://safetyfirst.nei.org/industry-actions/flex-the-industry-strategy-to-enhance-safety/

upgraded safety requirements agreed upon and implemented[31]. A potential nuclear newcomer country such as Australia Plant will benefit from the fact that design considerations arising from the accident will have been addressed by vendors and factored into modern and advanced nuclear technologies.

More generally, nuclear safety is ensured in all nuclear plants by a 'defence in depth' approach, which includes:

- High-quality design and construction.
- Equipment which prevents operational disturbances or human failures and errors developing into problems.
- Comprehensive monitoring and regular testing to detect equipment or operator failures.
- Redundant and diverse systems to control damage to the fuel and prevent significant radioactive releases.
- Provision to confine the effects of severe fuel damage (or any other problem) to the plant itself.

These are applied to the three basic safety functions of a nuclear reactor:

- To control reactivity.
- To cool the fuel.
- To contain radioactive substances.

These deal mostly with prevention, but in the aftermath of the Fukushima accident and the black swan natural disaster which was the direct cause, a fourth basic safety function now beginning to be developed in much greater detail is accident mitigation and emergency response.

c) What are the processes that would need to be undertaken to build confidence in the community generally, or specific communities, in the design, establishment and operation of such facilities?

A competent and independent regulator is essential for establishing trust in nuclear operations. Both the nuclear industry and the regulator should seek to be transparent and committed to pro-active two-way public communication as a primary concern. At the project feasibility assessment stage, it is important for extensive stakeholder consultation and a frank discussion of the local benefits (which will be substantial) and drawbacks. If there are enough potential sites it may even be possible to set up a volunteer selection process, where communities compete to host facilities.

Community support can also be built through information exchange between local people potentially affected and host communities abroad. For example, uranium mining company Cameco brought Canadian First Nations people to Western Australia and took Martu people from there to Canada to see first-hand how the company manages its uranium mining operations.

It is worth noting that public confidence is not a nuclear-specific issue (other industries need public confidence to develop, such as the chemical industry), but there are nuclear-specific issues which have to be taken into account.

Question 3.10

a) If a facility to generate electricity from nuclear fuels was established in South Australia, what regulatory regime to address safety would need to be established?

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[31] Perhaps the most visually impressive such upgrade is the tsunami wall at Hamaoka.

The natural choice would be to expand the role of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). In general, the basic characteristics of an effective nuclear regulator are that it is committed to improving safety culture, is competent, independent and open and transparent[32].

In practice, many different approaches to regulating nuclear energy are exhibited internationally but the two main different approaches to nuclear regulation are:

- Rule based: Under which nuclear facilities are deemed safe when they meet the requirements of published rules. e.g. the system overseen by the US Nuclear Regulatory Commission.

- Outcome based: Under which nuclear facilities are deemed safe when the regulator is convinced that certain outcomes will be delivered. e.g. the Canadian Nuclear Safety Commission (CNSC) and the UK Office of Nuclear Regulation (ONR).

There is no clearly superior approach. Rather there are benefits and drawbacks to each. Australia needs to develop its national nuclear regulator with reference to those in other countries which are effective, and to fit with cultural characteristics of the federal government and its agencies. ARPANSA could work closely with these regulators to build competence, and where these national regulators have licensed certain nuclear reactor designs, it should be possible to simplify and reduce ARPANSA's work in this area.

b) What are the best examples of those regimes? What can be drawn from them?

Given Australia's history and enduring relationship with the UK, the ONR is perhaps an obvious choice to seek to partner with and to be a model. The ONR is also currently engaged in a generic design assessment process of three modern reactor technologies – the EPR (now complete), the AP1000 and the ABWR. Depending on the future UK waste plan for utilising separated plutonium it may soon consider assessing either a CANDU EC6 or PRISM reactor and there are clear indications that it may soon be looking at the Hualong One reactor design. It may also address licensing of a small modular reactor designs. This recent experience in the licensing of diverse designs should be of value to the Australian regulator, especially if similar reactor technologies were to be considered.

A significant question to be faced by Australia is the extent to which something like the UK generic design approval process needs to be replicated for a design which has been approved by ONR in the UK or NRC in the USA. The question is more acute for small reactors which may be largely factory-made, and where local certification might be more analogous to that for civil aircraft.

Question 3.11

a) How might a comparison of the emission of greenhouse gases from generating electricity in South Australia from nuclear fuels as opposed to other sources be quantified, assessed or modelled?

A good approach is to undertake standard life-cycle analysis (LCA). For the South Australian case we point to Think Climate Consulting publications on the subject, focused on alternatives to the proposed solar thermal plant at Port Augusta[33].

b) What information, including that drawn from relevant operational experience should be used in that comparative assessment?

c) What general considerations are relevant in conducting those assessments or developing these models?

The recent Working Group III report of the Intergovernmental Panel on Climate Change (IPCC) states plainly: "The life cycle GHG emissions per kWh from nuclear power plants are two orders of magnitude lower

[32] OECD NEA, The Characteristics of an Effective Nuclear Regulator, 2014, https://www.oecd-nea.org/nsd/docs/2014/cnra-r2014-3.pdf

[33] ThinkClimate consulting, Zero Carbon Options, 2015, https://decarbonisesa.files.wordpress.com/2015/07/zco-2015.pdf

than those of fossil-fuelled electricity generation and comparable to most renewables"[34]. Nuclear energy is not a fossil fuel and the fissioning of uranium does not produce carbon dioxide or any other greenhouse gas. Nor do other parts of the fuel cycle contribute to significant emissions. There is simply no need to carry out any further assessment or modelling.

Consider that major climate change mitigations scenarios, notably from the IEA and IPCC, all require substantial nuclear contribution. IEA World Energy Outlook 2014 has a 450 Scenario calling for more nuclear by 2040 (862 GWe) than the High Nuclear Case (767 GWe), despite the IEA being very optimistic about the potential role of renewables.

Question 3.12

> *a) What are the wastes (other than greenhouse gases) produced in generating electricity from nuclear and other fuels and technologies?*

The most notable waste stream from nuclear power generation is a small amount of used fuel. If not reprocessed this is classified as high-level radioactive waste, though most of it can be recycled. There is also some intermediate-level and low-level radioactive waste, which are easily managed as shown worldwide for 60 years. We cover nuclear waste in detail in our submission to Issues Paper 4.

> *b) What is the evidence of the impacts of those wastes on the community and the environment?*

Nuclear wastes from civil nuclear power plants and supporting fuel cycle facilities have to our knowledge had no documented adverse impacts on the public or the environment.

While not usually considered a 'waste' some facilities have experienced issues with tritium, a radioactive isotope of hydrogen that is produced in nuclear reactors, and which, when bound into a water molecule, is almost impossible to filter out and remove. If this escapes containment it may make its way into groundwater and contribute to a hypothetically increased environmental risk. However tritium is a very low-energy beta emitter with a half-life of about 12 years. Its potential for damage is extremely small and needs to be present in very high concentration and ingested for harm to occur. Indeed, the normal way of dealing with tritium produced during operation is controlled releases to a large water body where it is diluted to harmless levels.

> *c) Is there any accepted means by which those impacts can be compared? Have such assessments making those comparisons been undertaken, and if so, what are the results?*
>
> *d) Can those results be adapted so as to be relevant to an analysis of the generation of electricity in South Australia?*

One study outlining the comparative impacts of nuclear waste was performed by Rashad and Hammad in 2000[35].

Question 3.13

> *a) What risks for health and safety would be created by establishing facilities for the generation of electricity from nuclear fuels?*
>
> *b) What needs to be done to ensure that risks do not exceed safe levels?*

There are two broad categories of risks to health and safety. The first are the usual industrial risks linked to construction and operation of an industrial facility, such as risks to workers: handling electrical equipment, use of chemical products, falling from height, and risks to the population and to the environment linked to

[34] IPCC, Working Group III: Mitigation 'Section 3.8.4.2 – Nuclear Power',
http://www.ipcc.ch/ipccreports/tar/wg3/index.php?idp=128

[35] Rashad and Hammad, Nuclear Power and the Environment: Comparative Assessment of Environmental and Health Impacts of Electricity-Generating Systems; Applied Energy 65, 2000

potential chemical release. A direct comparison would be to that of a well-managed fossil power plant but minus the hazards of handling a large combustible fuel source and the associated emissions. The second are nuclear-specific (radiation) risks to workers during operation and maintenance activities, and to the wider population and environment in case of a core-damage event.

For industrial risks, the normal industrial provisions for safety and the protection of health and the environment are commitment to best practice, training and oversight. For each recognised risk, prevention and mitigation plans must be established.

For radiation risk, nuclear safety culture has developed over 60 years to minimise this at all stages (design, construction, operation and maintenance, dismantling). A strong safety culture requires commitment from every part of a nuclear power organisation. Maintaining safety is a part of everybody's job and a top operational priority. As such it should be integrated with the operational plans and organisational structure of the company. A good frame of reference for nuclear safety culture is that present in the aerospace and aviation industry.

The key to preventing risks from becoming impacts is adequate risk assessment and in-depth mitigation and contingency planning. Nuclear operating companies need to be learning organisations, but they don't have to make mistakes to learn from them. All the world's nuclear power plant operators are members of the World Association of Nuclear Operators (WANO) and any Australian operators would be expected to join. WANO provides a large database of operational events and incidents submitted by its members as well as facilitating peer reviews from other international operators. There are many nuclear organisations which also offer advice on nuclear safety, including the IAEA, the US Institute of Nuclear Power Operations (INPO) and reactor owners groups, to name a few.

Another key aspect of safety culture is that management needs to be committed to two-way dialogue with the ability to listen and act on safety concerns brought up by individual workers. A breakdown in this communication is one of the root causes of the Fukushima Daiichi nuclear accident.

Question 3.14

a) What safeguards issues are created by the establishment of a facility for the generation of electricity from nuclear fuels?

b) Can those implications be addressed adequately? If so, by what means?

Safeguards issues are not greatly increased from those addressed now by the Australian Safeguards and Non-proliferation Office (ASNO), which has the most rigorous provisions in the world, with bilateral treaties backing up international arrangements under IAEA. Nuclear power plants in general cannot be said to contribute to proliferation risk in any meaningful way. Enrichment and reprocessing facilities are potentially sensitive fuel cycle technologies, which could potentially be used for weapons-related purposes, and require controls accordingly. If Australia decides to develop these facilities it will need to address proliferation concerns in more detail.

Question 3.15

a) What impact might the establishment of a facility to generate electricity from nuclear fuels have on the electricity market and existing generation sources?

Low operating costs mean that nuclear power plants would likely provide base-load power, and should have priority grid access as capital-intensive low-carbon power source. Nuclear plants are a direct competitor to coal and provide a very similar electricity supply profile. Nuclear plants in South Australia should lead to the replacement of some ageing coal plants with a view to diversifying the energy mix, reducing emissions intensity and ensuring reliable and grid stability. They would reduce South Australian dependence on Victorian power supply and allow South Australia to maintain clean power supply when wind generation is low.

b) What is the evidence from other existing markets internationally in which nuclear energy is generated?

A good example of nuclear power's ability to replace coal use is to be found in the Canadian province of Ontario, which by refurbishing some older nuclear plants was able to close down its last coal plant in 2014, having made the political commitment to do so only ten years before. The Ontario electricity supply is now almost entirely decarbonised with nuclear providing 62%, hydro providing 24%, Gas and oil at 10%, and wind at 4% in 2014[36].

c) Would it complement other sources and in what circumstances?

Nuclear energy complements other power sources in all circumstances but particularly in cold winter high-pressure systems. Recent US experience with the polar vortex weather system underlines this.

Sometimes questions are raised about the ability of nuclear power plants to co-exist with high levels of variable renewable energy sources which may fluctuate from zero to 100% of electricity output in a relatively short time. Certainly nuclear power plants are best operated in baseload mode, for a variety of reasons both economical and operational. However nuclear reactors are capable of load following[37] and this is common in France and Germany. There would need to be sufficient economic signal to justify this mode of operation, but given that this level of variable (and likely subsidised) renewable energy would have market distorting effects in the first place, the right market environment for all other generators would need to be established more generally.

d) What sources might it be a substitute for, and in what circumstances?

Primarily nuclear power would substitute for coal, but also to some extent natural gas.

Question 3.16

a) How might a comparison of the unit costs in generating electricity in South Australia from nuclear fuels as opposed to other sources be quantified, assessed or modelled?

The 2012 Australian Energy Technology Assessment (AETA) by the Bureau of Resource & Energy Economics (BREE)[38] evaluated 40 utility-scale generation technologies including large nuclear plants and small modular reactors. These two were among the six lowest cost options by 2040. Also the eFuture study by CSIRO showed that the inclusion of nuclear power as an option caused wholesale prices to be 34-37% lower, and led to a 53% nuclear share in 2050. See also UMPNER report 2006.

b) What information, including that drawn from relevant operational experience, should be used in that comparative assessment?

c) What general considerations should be borne in mind in conducting those assessments or models?

Economic assessment of different energy sources is usually conducted based on the levelised cost of electricity (LCOE) approach, as found for example in the OECD publication Projected Generating Costs of Generating Electricity[39]. However, there are a few points to be made about this kind of assessment.

Firstly, the costs of energy technologies keep changing, meaning information dates rapidly. Notably the cost of solar PV has declined substantially over the past decade or so and this trend will probably continue.

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[36] Independent Electricity System Operator, Supply Overview, http://www.ieso.ca/Pages/Power-Data/Supply.aspx
[37] Nuclear load following does not provide fast-responding reserve. For more information: OECD NEA, Technical and Economic Aspects of Load Following with Nuclear Power Plants, 2011, http://www.oecd-nea.org/ndd/reports/2011/load-following-npp.pdf
[38] Bureau of Resources and Energy Economics, Australian Energy Technology Assessment, 2012
[39] International Energy Agency, Projected Costs of Generating Electricity, 2010, https://www.iea.org/publications/freepublications/publication/projected_costs.pdf

Nuclear capital costs, which were clearly underestimated for certain modern designs, can be expected to fall as countries move past first-of-a kind units. Fossil generation LCOE will fluctuate partly with fuel costs, which depend among other things on availability and international demand.

Financing costs have a huge impact on the LCOE for nuclear. An energy market structure which finds a way to reduce these will enjoy the benefits of cheaper energy. The OECD publication illustrates the profound impact that changing the discount rate has on nuclear economics. Avoiding rework and other issues during nuclear construction is crucial for viability, as delays lead to increased capital costs and a longer period before payback can begin.

Project economics matter more for nuclear than general assessments. For example a favourable site with an existing grid connection and other infrastructure will lower the costs of a nuclear plant, as will building multiple units on that site. There is a lot of variance in nuclear project costs, especially between countries, and the cost of other energy options also varies. Many nuclear projects are awarded via competitive tender and it is certainly important to know what is offered before judging the viability of nuclear technology.

Depending on the vendor and technology selected, and how much of the supply chain is localised, a substantial amount of the money spent during the construction a nuclear power plant can stay within a country. As Figure 2 illustrates, there are multiple opportunities to tap into the value of nuclear new-build and much of this value can work its way into local and regional communities. In addition to the major parts such as the reactor, the turbine and possibly cooling towers, there are many components that go to make up a nuclear plant, including cables, pipes, concrete and many more. Generally it makes good business sense for operators to rely on local suppliers for the sourcing of common components and pieces of equipment, while the more sophisticated and specialised components can be localised if a larger number of units is planned.

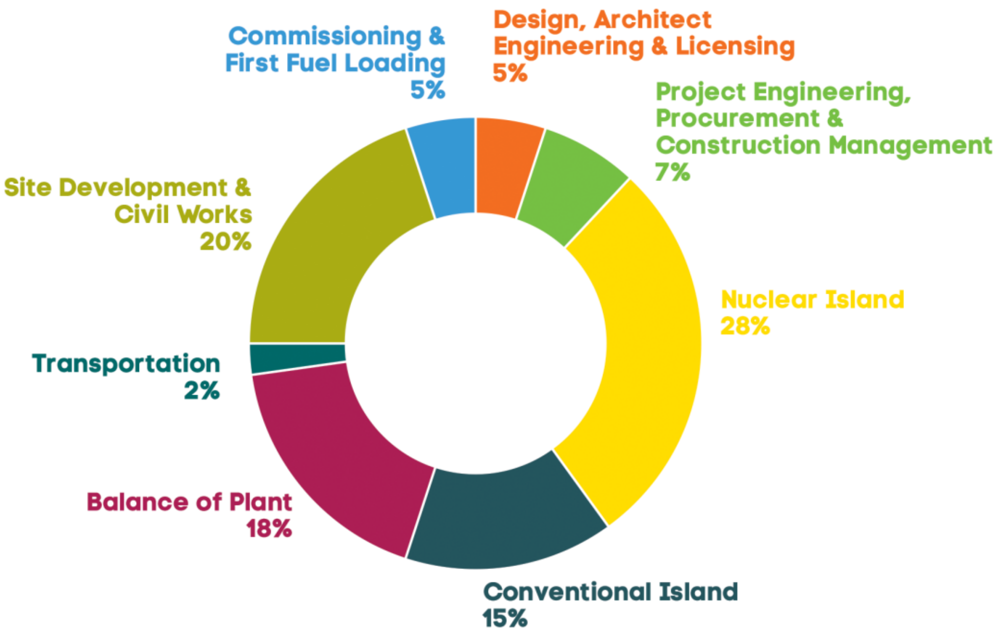

Figure 2: A typical breakdown of the value chain in nuclear new build. Source: UK Nuclear Industry Association

The LCOE matters mostly for potential investors, but as far as energy consumers are concerned it is the price of delivered electricity – what they see on their bill – that is most important. This depends not on the cost of any one generator but rather that of the energy system. For disptachable generators, such as nuclear, the system costs added are negligible but for intermittent sources, such as solar and wind the system costs are about ten times higher[40] – and past a certain penetration level (typically 20%) this starts to

[40] OECD NEA, Nuclear Energy and Renewables, System Effects in Low-Carbon Electricity Systems, 2012, https://www.oecd-nea.org/ndd/pubs/2012/7056-system-effects.pdf

rapidly inflate the cost to consumers. A serious economic assessment of low-carbon energy pathways needs to consider the system costs.

Finally, every form of energy production gives rise to externalities, but different energy sources make vastly different allowances for this. We have touched upon the perceived downsides of nuclear generation, accidents and wastes, elsewhere. The nuclear industry attempts to internalise these costs. In the case of wastes and decommissioning, ring-fenced funds are usually built up from a fixed charge that forms part of the generation cost. These are included in LCOE assessments. As for accidents, these costs are potential rather than actual, and to avoid them operators invest heavily in safety and are subjected to rigorous regulation. Plant operators also are typically required to pay for insurance or maintain some other financial protection to cover external damage if it were to occur. When comparing externalities it should be stressed that during normal operations nuclear plants give rise to negligible emissions of any kind and take up a very small environmental footprint. This can be compared to fossil fuel and biomass operations which are essentially licensed to emit and to renewable energy operations which often are not required to set aside special decommissioning or clean-up funds.

Question 3.17

a) Would the establishment of such facilities give rise to impacts on other sectors of the economy? How should they be estimated and using what information?

Establishment of nuclear generating capacity would greatly enhance the skills base of South Australian industry[41]. It would also greatly boost the local and regional economies around the plants – especially during the construction phase, but also during operation. There are no obvious parts of the economy upon which a viable nuclear power plant project should have any negative impacts.

In preparing for the UK nuclear new build program, EDF engaged consultancy company IPPR to look at the benefits of nuclear infrastructure investment[42]. The take-home figures were:

- Building new nuclear energy capacity could boost UK GDP by up to 0.34 per cent a year (equivalent to £5.1 billion in 2011) for 15 years and if capacity reached 18GWe, nuclear power would account for 0.4 per cent of GDP in the operational phase.
- Delivering additional nuclear energy capacity could result in up to an additional 32,500 jobs annually: 11,250 direct and indirect jobs together with a further 5000 to 10,000 induced jobs.
- Annual exports from the nuclear industry could increase from £700 million a year to £1.1 to £1.6 billion.

Two US case studies of the benefits of operating nuclear power plants, prepared by the US Nuclear Energy Institute (NEI), are summarised here.

Case study 1: Ginna Nuclear power plant (580MWe PWR)[43] generates an average annual economic output of over $350 million in western New York state and has an impact on the US economy of about $450 million per year. The plant employs about 700 people directly, adding another 800 to 1000 periodic jobs during reactor refueling and maintenance outages every 18 months. Annual payroll is about $100 million. Secondary employment involves another 800 jobs. Ginna is the largest taxpayer in the county. Operating at more than 95% capacity factor, it is a very reliable source of low-cost electricity.

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[41] Local industry body BusinessSA is in a good position to comment on this in greater depth

[42] IPPR, 2012, Benefits from Infrastructure Investment: A Case Study in Nuclear Energy, http://www.thecmlink.com/wordpress/wp-content/uploads/2013/10/2012-June-Benifits-from-Infrastructure-Investment-A-Case-Study-in-Nuclear-Energy.pdf

[43] Nuclear Energy Institute, 2015, Economic Impacts of The R.E. Ginna Nuclear Power Plant, http://www.nei.org/CorporateSite/media/filefolder/Policy/Papers/GinnaEconomicBenefits.pdf?ext=.pdf

Case study 2: Indian Point 2 and 3 in New York state (1020 and 1041 MWe net)[44] contribute an estimated $1.6 billion to the state's economy annually and $2.5 billion to the USA as a whole. Benefits to local counties around the plant are $1.3 billion per year, including about $30 million in state and local property taxes and an annual payroll of about $140 million for the plant's nearly 1000 employees. The total tax benefit to the local, state and federal governments from the plant is about $340 million a year, and the plant's direct employees support another 5400 indirect jobs in New York state and 5300 outside it.

b) Have such impacts been demonstrated in other economies similar to Australia?

These are the benefits of a major infrastructure projects and have been realised wherever nuclear plants have been built. The UAE would be a recent case study relevant to South Australia.

[44] Nuclear Energy Institute, 2015, Economic Impacts of The Indian Energy Center, http://www.nei.org/CorporateSite/media/filefolder/Policy/Papers/Economic-Impacts-of-the-Indian-Point-Energy-Center.pdf?ext=.pdf