AREA 1) Potential for Expansion of Exploration and Extraction of minerals

Consider feasibility, viability, risks and opportunities, future impact upon the South Australian economy, environment and community.

Pressing issues:

1. *Volatility of uranium demand affects capital expenditure and new projects*

   Uranium, as an energy resource, is subject to similar global demand and supply rules as the other energy commodities, although environmental and geopolitical considerations are an additional driver for uranium demand. The global uranium market has a history of volatility. Following the 2011 Fukushima nuclear accident, uranium price fell more than 50% (from about 140 US$/kg to 70 US$/kg). As a result, at present uranium companies worldwide are reducing investments, capacity of existing operations, and deferring new production. Small exploration companies with limited cash are hit the most by the decrease in uranium demand, and, as a result, the investments in exploration suffer in particular. In Australia, the exploration expenditure for uranium decreased from $190 million in 2011 to $98 million in 2012, and $40 million in 2014 [1]. The same decreasing trend applies to South Australia. In South Australia, mining of uranium from the existing deposits also suffered a decrease since 2011, with production at BHP Billiton owned Olympic Dam mine decreasing from 4.012 t of U_3O_8 in 2010-2011 to 3.144 t in 2014-2015 [2]. Even more, the multi-billion dollar expansion plan for the Olympic Dam mine was put on hold indefinitely in 2012, pending the uncertainty in the mineral resources and uranium markets.

   In addition to geopolitical issues, the demand of primary uranium (uranium from mining of ores) is also reduced to an extent by competition with secondary supply sources (spent nuclear fuel, highly enriched uranium - HEU - from nuclear weapons, mixed oxide fuels and surplus stockpiles). These sources of uranium have played a significant role in the global uranium market in the last years. However, secondary supplies of uranium are projected to decrease in the future [3, 4], leading to an increased requirement for uranium mine production. South Australia is well positioned to respond promptly to any increase in the global demand for primary uranium by expanding production to meet requirements. South Australia hosts the world's largest uranium resources recoverable at low-cost (less than 130 US$/kg) [5]. South Australia also has the advantage of excellent development potential and strong record as a reliable supplier. This, combined to government incentives, should encourage the industry in increasing the expenditure in exploration and expansion of uranium operations in South Australia, and revisit all the projects which recently have been put on hold.

   Furthermore, the global demand and supply of uranium has also to be considered in the context of world's electricity consumption trends. In spite of the recent slow-down of nuclear power projects and anti-nuclear policies in some countries, nuclear power remains a key part of the global electricity mix, given its low carbon emissions and contribution to energy security. The International Atomic Energy Agency (IAEA) expects the world's nuclear capacity to increase between 44% and 99% by 2035 [6]. Australia's uranium industry plays an important part in the global electricity market, and this long term scenario should encourage exploration and development of new projects.

2. *Uranium Mining is a big share of South Australian economy*

   South Australia possesses about 25% of the world's identified uranium resources. South Australian known uranium deposits contain a total of over 2 million tonnes of uranium oxide, with an in-situ value of the resource of about A$ 80 billion (as for the commodity price in February 2016). As there are no nuclear power stations in Australia, most of South Australian uranium is exported. In the past decade (2004-2014), uranium mining has contributed more than $3 billion in export revenue to the South Australian economy. Uranium is one of the state's major mineral commodities produced, with total sales value of $370 million (4530 t) in

2014 [7], corresponding to about 3.5% of the total export. Uranium export alone (without considering copper, which is the primary mineral resource mined together with uranium) in South Australia has the same dollar value as the export of passenger motor vehicles [8].

Australian policy is that uranium can only be sold to countries with which Australia has nuclear cooperation agreement. Countries need to commit to peaceful uses of nuclear energy and have safeguards agreements with the International Atomic Energy Agency (IAEA). Australia's uranium is used in civilian nuclear power stations in the United States, Japan, France, UK, Finland, Sweden, South Korea, China, Belgium, Spain, Canada and Taiwan [3]. Negotiations also commenced with India in 2012 on bilateral safeguards agreement. The agreement to sell uranium to India is a step closer after a Parliamentary Committee cautiously supported the deal in 2015. India represents an enormous market potential for Australia. The deal could increase export revenue by $1.75 billion and would be especially lucrative for rural and remote areas [9].

In addition to export, uranium mining also generates significant revenue through royalties ($118 million in royalties to South Australians in 2004-2014). Furthermore, uranium mining has an impact on several other sectors of the South Australian economy. The Olympic Dam mine is South Australia's single largest consumer of electricity, with typical annual electricity consumption of 870,000 MWh [22], and it is connected to the grid via Port Augusta [23]. The Olympic Dam mine also uses 35 million litres of Great Artesian Basin water each day, making it the largest industrial user of underground water in the southern hemisphere [24]. About 3 million litres of the 35 million litres extracted daily is supplied to the township of Roxby Downs.

The true impact of mining, and in the specific uranium mining, on the South Australian jobs market has been extensively debated. From one side, uranium mining is highly capital-intensive and therefore it requires more investment to create one job than in most other industrial activities. The current operational uranium mines in South Australia directly employ only few thousand people. However, uranium mining generates substantial indirect employment in other sectors of the economy. Many ancillary businesses to mining, from infrastructure to maintenance, suppliers of goods and services, hospitality, transport, etc. rely on the mining industry for their survival. Furthermore, mining provides jobs mostly in rural and remote areas, where employment opportunities are low. South Australia's unemployment rate averaged 7.5% in 2015 (the worst figures in 15 years) [28]. Should the mining industry not be supported in this period of uncertainty, more jobs would be put at risk.

3. *South Australia is a unique geological environment for uranium*

Uranium is a naturally occurring element with an average concentration of 2.8 parts per million in the Earth's crust [10]. Traces of it occur almost everywhere. Vast amounts of uranium also occur in the world's oceans, but in very low concentrations. It is more abundant than gold and silver. In some regions, the concentration of uranium increases to more than 200 ppm (in some cases up to 20%), attracting interest for exploitation and becoming a resource.

South Australia has the demonstrated geology for hosting uranium deposits, with high potential for further discoveries. South Australia possesses 25% of the total world's identified uranium resources, hosted in a variety of geological settings. Three out of the four currently operating Australian mines are located in South Australia (Olympic Dam, Beverley and Honeymoon). Majority of the uranium is concentrated in the Olympic Dam breccia-complex deposit, which is the largest known uranium deposit in the world, containing more than 2 million tonnes of uranium oxide. Significant resources however also occur in other geological formations, such as sandstone-hosted uranium deposits at Four Mile, Beverley, and Honeymoon [21]. Investigations are also being undertaken into the uranium potential of the Cariewerloo Basin by the Geological Survey of South Australia. The hematite breccia mineralisation at Olympic Dam is characterised by a very large tonnage of low-grade uranium

(~0.05% U_3O_8). Uranium is produced as a co-product with copper, silver and gold. Sandstone deposits (Four Mile, Beverley, Honeymoon), on the contrary, are of much lower tonnage but higher grades (> 0.2% U_3O_8).

The geology of South Australia is promising, and recent reclassification of all known uranium deposits in South Australia [26] highlighted a wide variety of deposits or occurrence types, suggesting significant potential for discoveries of previously unrecognised deposits or in previously unexplored regions of the state [21]. From a geological point of view, South Australia is definitely *the place to be* for uranium discoveries.

There is no other region in the world with the same abundance of uranium as South Australia. Put into perspective, there are the same uranium resources in South Australia (25% world share) than the combined resources of Canada (9%), United States (3.8%), Russia (8.9%) and China (4.9%) [27]. Despite having 25% of the world's uranium resources, however, South Australia produces only around 9% of the world's uranium (South Australia produced in 2013-14 about 4500 tons of uranium, representing 80% of Australian total production and 9% of the world's total production [21], indicating there is significant potential for long term production and expansion. The multi-million dollar Olympic Dam expansion project, which has currently been put on hold, will make it the world's largest uranium mine. Furthermore, at Olympic Dam, uranium mineralisation is intimately correlated to copper, gold and silver, and therefore it makes perfectly sense to mine the different commodities at the same time.

4. *Innovative Exploration Methods can lead to new discoveries*

Although the current scenario for uranium demand has slowed down most of the exploration activities, technology is rapidly evolving, and with it new, more efficient, and possibly game changing tools become available for minerals exploration. When searching for mineral deposits, there are different levels of exploration: regional (large scale and low resolution, generally an entire basin or region), sub-regional (more detailed, investigating the promising areas identified by the regional surveys), and local (with high resolution, in order to be able to map the orebody with the sufficient level of detail for planning mining operations). A variety of exploration methods are available, each with its own cost, time, and data resolution.

Collecting geological information at regional scale is the first step for new ore discoveries. Mapping the geological formations in a whole region (e.g., South Australia) and their spatial distribution allows identifying potential areas of enrichment. Searching for uranium is in some ways easier than for other mineral resources because the radiation signature of uranium's decay products allows deposits to be identified and mapped from the air [10]. A large regional survey (airborne radiometric data) was released by Geoscience Australia in 2011, covering about 95.000 km^2 of area over the Frome Embayment (SA) and northern portion of the Murray Basin. This represents the most comprehensive map of uranium mineralisation distribution in SA. The release of these data has resulted in increased activity in uranium sub-regional and local exploration over the Frome Embayment by several companies. The large scale, airborne, regional data has been integrated by sub-regional data (2D/3D seismic methods), which provide a spatial resolution down to 5m.

Every time a new deposit of uranium is discovered by geophysical techniques, it is evaluated and sampled to determine the amounts of uranium that are extractable at specified costs from the deposit, also called uranium reserves. The amount and quality of geological data is paramount. The industry needs high level of detail for accurate evaluation of the amount of resources contained, and for efficient planning of mining operations. More sophisticated techniques are progressively being introduced for this scope. Borehole logging methods (sensors placed directly into wells) such as neutron or gamma ray detection have been developed, which allow very high resolution to be obtained. As technology progresses, the tools in hands of explorers to accurately map a discovered orebody became more and more powerful. As a consequence of the introduction of new sensors, the amount of data collected in a typical survey increased exponentially in the last years, and new and more powerful data processing and modelling tools are also now available. New data analysis methods have also been used for reprocessing more efficiently existing geological databases, providing 2D/3D maps of ore deposits with increased resolution. By the use of these new technologies, economic concentrations of uranium which failed to be detected in the regional and sub-regional data can potentially be discovered in the near future.

There are some challenges for future discovery of new deposits, which only the introduction of new exploration technologies will be able to overcome. It is generally accepted that future world-class uranium deposits are likely to be located at greater depths than those already discovered. To overcome the technical challenges of locating deep, bedrock deposits will require large injections of exploration investment capital, and introduction of innovative sensors and data analysis. Few companies at present are budgeting for new expenditure in exploration for uranium. These observations reinforce the need to ensure that junior companies, which are generally efficient explorers, are appropriately assisted [8]. Within the South Australia PACE 2020 plan for accelerated exploration [25] a key work program is specifically designed to drive forward mining exploration and development, promoting multidisciplinary mineral systems analysis, new geophysical surveying, innovative modelling and data analysis. These goals are to be achieved also through the establishment of centres of excellence in South Australia. It is vital that the program is supported and regularly audited to achieve the expected benefits.

5. *Scientific Research can lead to cheaper, more efficient and environmental friendly processing of uranium ores*

In recent years, the cost of mining and milling uranium ores has increased in Australia as a result of the mining boom. The new climate of low demand for most commodities, including uranium, pushes now the industry to cut costs, but also to find innovative, clever and cheaper processes for mining uranium, at increased productivity and reduced processing costs. In order to be attractive, however, new technologies need to be proven, reliable, and, mostly, economic.

In conventional uranium mining, the orebody is accessed by open pit (e.g., Ranger, NT) or underground (e.g., Olympic Dam, SA) mining. The decision for one method over the other is driven by the distance of the orebody from the surface. Either way, the ore extracted from the mine is crushed, ground, and processed for the concentration of uranium. At Olympic Dam mine, copper and uranium are concentrated by froth flotation first, followed by acid leaching (in tanks) of uranium. Tank leaching is very efficient, but it is also capital and operating intensive. As part of the mine expansion project, alternative processing routes have been studied (research conducted at research organisations in South Australia), in order to make the concentration of uranium cheaper and more efficient. Although the expansion project is now on hold, new processing routes have been identified, and results are encouraging.

An emerging, cheaper, alternative to conventional mining is In Situ Leaching (ISL) of uranium. The technology is currently used at Beverley and Four Miles deposits (Heathgate Resources). ISL mining means that removal of the uranium minerals is accomplished without any major ground disturbance. The leaching solution (sulphuric acid) is circulated through an enclosed underground aquifer which holds the uranium ore in permeable sands. The leaching solution dissolves the uranium before being pumped to the surface treatment plant where the uranium is recovered as a precipitate [10]. ISL is however not applicable to all deposits, but only to deposits confined between impermeable rock formations (to avoid contamination of groundwater). ISL has economic and environmental advantages for producing uranium from carefully selected deposits when projects are properly designed and operated. Its application however requires careful understanding of the geology of the deposit, the transportation of fluids through pores and fractures, and the chemical interactions between minerals and solvent. Innovative sensors are required for monitoring the fluid pathways and the dissolution of uranium.

Significant margin for improvement is achievable through scientific research. New processes for conventional mining, and low cost and eco-friendly reagents for in situ leaching of uranium are required to boost uranium production in the difficult scenario for the commodity we are experiencing now. An ARC Research Hub for Australian Copper-Uranium has been established at the University of Adelaide with the aim of promoting scientific research. Active partnerships with local Universities are to be enhanced. South Australia hosts 3 major universities with recognised excellence in earth sciences, chemical sciences, and resource engineering [11]. Collaboration between State Government, Universities and key industry stakeholders, through innovation grants and focused research programs, can make of South Australia a global centre of excellence for uranium mining. Advances in technology may lead to more efficient mining and processing, at enhanced uranium recovery and reduced processing cost, stimulating new initiatives and investments.

6. *Environment and Safety of Uranium Mining*

Among the different stages of the nuclear fuel cycle, conventional uranium mining has the lower environmental risk. The level of radioactivity in the naturally occurring uranium ores and in the mining tailings is low (few parts per million). Generally speaking, uranium mining is no different from other kinds of mining unless the ore is very high grade (which is not the case of South Australian mines). Only after the processes of milling and chemical extraction, a uranium concentrate is produced (U_3O_8, uranium oxide, also called *yellowcake*) with higher radioactivity levels and high environmental and health hazards, and therefore requiring specific handling, storage, and transportation protocols. Risks of catastrophic failure in the nuclear fuel cycle are generally associated to the use of uranium in power stations, and not to uranium mining.

Mining is generally considered a temporary land use, and upon completion the area with any waste rock, overburden, and covered tailings needs to be reclaimed for other uses, or its original use [10]. On completion of the mining operation, tailings are returned to the underground mine, to the pit, or to a tailings dam, in which case tailings are covered by few metres of clay and topsoil to resist erosion. This is to reduce both gamma radiation and radon emanation rates to levels near those normally experienced in the region of the orebody, and for a vegetation cover to be established.

In situ leaching (ISL) of uranium presents some higher hazards than conventional mining, since toxic leaching solution, containing the dissolved uranium, is circulated underground, and any uncontrolled flow has the chance of contaminating the surrounding environment. At established ISL operations, after mining is completed the groundwater quality must be restored to a quality standard determined before the start of the operation so that any prior uses may be resumed. Upon decommissioning, ISL wells are sealed, or capped, process facilities removed, any evaporation pond revegetated, and the land can readily revert to its previous uses [10]. Although there are early examples of North American ISL projects which failed to restore groundwater quality at the end of operations, causing environmental damage [12, 13], the technology is nowadays more advanced, risk mitigation procedures are in place, and no major accidents related to ISL have been recorded so far in Australia. Furthermore, the water quality at the Australian sites is very poor to start with. At Beverley and Honeymoon the original groundwater in the orebody is fairly saline and too high in radionuclides for any permitted use.

Health risk to workers is also strictly monitored by the existing regulations and practices. Precautions taken during the mining and milling of uranium ores to protect the health of the workers include [10]:

- Forced ventilation systems in underground mines to ensure that exposure to radon gas and its radioactive daughter products is as low as possible and does not exceed established safety levels.

- Dust control, because the dust may contain radioactive constituents and emit radon gas.
- The use of radiation detection equipment in all mines and plants, often including personal dose badges.
- Imposition of strict personal hygiene standards for workers handling uranium oxide.

As a result of this code of practice, the total effective dose of radiation for monitored uranium mining workers in Australia is only 2.5 mSv per year (with a maximum of 10 mSv), against 1.5 mSv per year of the average population (which represents exposure from natural sources). These values are well below the limit of 20 mSv per year set for nuclear industry employees and uranium miners [14]. The level of radiation in the populated areas near uranium mines around Australia is also monitored, and it is well below the law limits. Compared to other commodities, uranium mining requires more care and attention, but no major risk to both the environment and the community is to be seen with an expansion of uranium mining in South Australia as long as the current codes of practice are implemented and operations are strictly audited.

7. *Community Perception of Uranium Mining*

One of the most pressing issues for the uranium industry is to provide the community with objective information about the impact of uranium mining and processing on the environment, society, and the health hazard. A lot of misleading information, both pro and anti-uranium, has been released over the years, which generated controversy. Several uranium mine plans have been put on hold due to some combination of community opposition and economic circumstances (e.g. Bigrlyi / NT, Yeelirrie / WA, Lake Maitland / WA, Kintyre / WA, Olympic Dam / SA). In South Australia, the environmental approval of the Olympic Dam mine expansion was legally challenged in 2012 (case was then dismissed) [15], and more than 400 anti-nuclear activists joined the protest at the Olympic Dam site [16]. Even the original development of the mine, in 1983-84 attracted public opposition from Australia's anti-nuclear movement [17].

There is general concern about the environmental and health impact of uranium mining. Ensuring that information is transparent from one side, and that the legal framework protects the rights of the community and of traditional owners, is crucial. The legal framework in South Australia with respect to uranium mining is possibly the most advanced. Particular care is taken in ensuring that measures are implemented to protect the environment and the community over the entire cycle of operations. Traditional land owners' rights also have to be respected. In 20011, the South Australian Roxby Downs Indenture Act, which rules the operation of the Olympic Dam copper-uranium mine, was amended to also ensure compliancy with the SA Aboriginal Heritage Act [19].

South Australia has demonstrated experience with technologies for safe mining and processing uranium ores, developed from the state's uranium mines using different ore beneficiation processes. Uranium mining in South Australia started back in the 30s, when ores were mined at Radium Hill and Mount Painter to recover radium for medical purposes, and continued through the Olympic Dam project in 1988 (a joint venture of Western Mining Corporation and PB Minerals, now owned and operated by BHP Billiton), Beverley and Four Miles (Heathgate Resources Pty) from late 2000, and Honeymoon (Uranium Ore) in 2011. The South Australian industry developed significant know-how, skilled workforce, and reputation for safe mining of uranium.

8. *Policy and law landscape for sustainable mining*

The Australian Government supports the development of a sustainable Australian uranium mining sector in line with world's best practice environmental and safety standards [3]. The South Australian Government also has made clear that it openly and actively supports exploration for uranium in South Australia [18]. This puts South Australia ahead of other states such as NSW and Queensland, who waived only in 2012 long lasting bans on uranium exploration and mining. The South Australian Government has streamlined the project approvals process, improving transparency in order to increase industry and community confidence. The regulatory framework promotes efficiency in mining operations, as well as safety and protection of the environment. No uranium exploration or mining is allowed without rigorous technical assessment. Uranium exploration and mining in South Australia is governed by:

- Mining Act 1971 and Mining Regulations 2011 made under the Act.
- Radiation Protection and Control Act 1982.
- Roxby Downs (Indenture Ratification) Act 1982.
- Environment Protection and Biodiversity Conservation Act 1999.

The Act and the Regulations require licences for both exploration and mining prior to any work being commissioned. Considerations must be included for each approval type. These have also to include a Program for Environment Protection and Rehabilitation before any mining activity commences.

Mining methods, tailings and run-off management and land rehabilitation are also subject to Government regulation and inspection [10]. For instance in Australia the Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing was published in 2005, and updated in 2015.

The Environment Protection Authority (EPA) is responsible for the administration of the Environment Protection Act 1993 and the Radiation Protection and Control Act 1982. The Department of State Development has a memorandum of understanding with the EPA to support the consistent and efficient environmental regulation of mineral resources.

The South Australian government also works with the Commonwealth in ensuring adherence to the EPBC (Environment Protection and Biodiversity Conservation Act 1999).

The Australian regulatory framework for the uranium industry is widely recognised as being effective and representing world's best practice. Export licences are granted under strict Commonwealth legislation that ensures that uranium is used solely for the generation of electricity.

The Foreign Investment Review Board (FIRB) examines foreign investment proposals to ensure the investment is in Australia's interest.

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