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Report on the development of skills required for a radioactive waste management industry in South Australia

Executive Summary

This report describes the skills required to develop a state-of-the-art waste management industry in South Australia based on the scenarios described in the Jacobs MCM report "Radioactive Waste Storage and Disposal Facilities in South Australia", Feb 2016. It then goes on to describe the consequences and opportunities for the South Australian education sector.

The skills list was derived from the need to meet IAEA Standards for all stages of the development, operation and closure of waste facilities, as well as with ANSTO experience and case studies. The main findings of the skills analysis were:

- a comprehensive list of skills requirements
- most skills required for construction and operation of a geological disposal facility (GDF) for used fuel and intermediate level waste (ILW) would also be required to construct and operate an interim used fuel store (ISFS) or a low level waste (LLW) repository
- the timescale to first waste emplacement is in the order of a decade for a LLW repository or ISFS and 25 years for a GDF, with most skills required from the earliest stages and many required over the life of the projects, albeit in reduced numbers
- the required skills are a mixture of those associated with radioactivity (such as design and safety case creation, and mostly not currently present in South Australia) and those associated with conventional activities, such as environmental monitoring, mining, transport, construction, etc.

The development of a radioactive waste industry in South Australia would require significant training and development programmes to meet the skills requirements that have been identified above. The skills and training required by nuclear-related industries must be first class and should be based on strong research capabilities in training and education institutions. The report identifies nuclear education, training and research opportunities around:

- core nuclear capabilities – these would be required as additional subjects to existing STEM courses, as well as for more focused nuclear engineering and masters-level degrees
- collateral industries, i.e. industries such as cask design and manufacture, waste repository design, etc. that may grow up around the industries proposed in the Jacobs MCM report
- possible future opportunities within the nuclear fuel cycle, e.g. waste encapsulation, reprocessing of used nuclear fuel, etc.

Consultations with the three South Australian Universities showed:

- a willingness to be involved in appropriate nuclear-related education, training and research
- some existing nuclear-related research that could provide a basis for the greatly expanded regime that would be required
- strong ties to countries with extensive nuclear programmes, and hence the capability of bringing in staff with appropriate nuclear training in order to quickly ramp up the required programmes.

1. Skills Requirements

The technology for storing radioactive wastes is well understood and there are many countries (including Australia) which, by necessity, have had radioactive "waste storage facilities" for over 70 years. More recently, with the increasing inventory of used nuclear fuel globally, and storage facilities filling to capacity, there has been steady movement towards development of deep geological disposal facilities for "final" disposal of high and long-lived intermediate level wastes.

There are a large number of international conventions and agreements that have an impact on the disposal of radioactive waste both directly and indirectly. As well as the central convention – the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management - conventions related to transport of radioactive waste across international borders and liability for nuclear accidents are examples of conventions and agreements that have an indirect effect on disposal, but are relevant to this proposal.

In addition, there are internationally-accepted principles regarding the management of radioactive waste, codified in international consensus standards under the auspices of the International Atomic Energy Agency (IAEA). A number of countries have also developed national regulations based on extensions and modifications to the IAEA standards.

The Jacobs MCM report *Radioactive Waste Storage and Disposal Facilities in South Australia* (1) gives detailed proposals for state-of-the-art facilities for low-level radioactive waste (LLW), interim storage of used nuclear fuel, and ultimate disposal in a geological disposal facility (GDF) in South Australia. The proposals indicate potential for 600 operational full-time jobs, ~1500 jobs during construction, and peaking at 4-5000 full time positions through the initial establishment of the underground facilities in the years 2021 through 2025.

Many of these jobs, such as general building and construction, environmental and geological, research and assessment, project management, provision of human services, etc. will require skills that are already available in South Australia.

However, there will be many other jobs in all phases of the project that are related to the management of radioactivity. Some of these will require skills that are readily transferable and available locally. Many more of the jobs will require knowledge and experience of all aspects of dealing with radioactive materials. Most critically, there will need to be a (possibly small) core group that has previous experience in the activities which are to be undertaken, e.g. safety and licensing of a nuclear facility, and operation of a radioactive waste facility. These skills will be available elsewhere in Australia (e.g. at ANSTO and ARPANSA), or overseas. IAEA standards are the basis of Australian radiation safety regulation and so can be used as guidance for assessing the skills required to realise the proposals in the Jacobs MCM report, i.e. for filling those jobs.

1.1 IAEA Safety Standards

The IAEA has developed a harmonised set of standards that are based on a fundamental safety objective and 10 fundamental safety principles. The safety objective and fundamental safety principles are set out in an IAEA document, *Safety Standards Series SF-1: Fundamental Safety Principles* (2), which was agreed and co-sponsored by many related organisations. The standards comprise General and Specific Safety Requirements and Safety Guides that cover the whole gamut of human interaction with radioactive materials. The hierarchy of standards is shown in Figure 1.

These IAEA Standards are the starting point for most national regulators, including the Australian Commonwealth regulator, ARPANSA, and hence for the siting, design, construction, operation, and decommissioning and closure of facilities dealing with radioactivity. For the facilities and operations outlined in the Jacobs MCM report, all of the General Safety Requirements and items 1, 5 and 6 of the Specific Safety Requirements in Figure 1 are applicable.

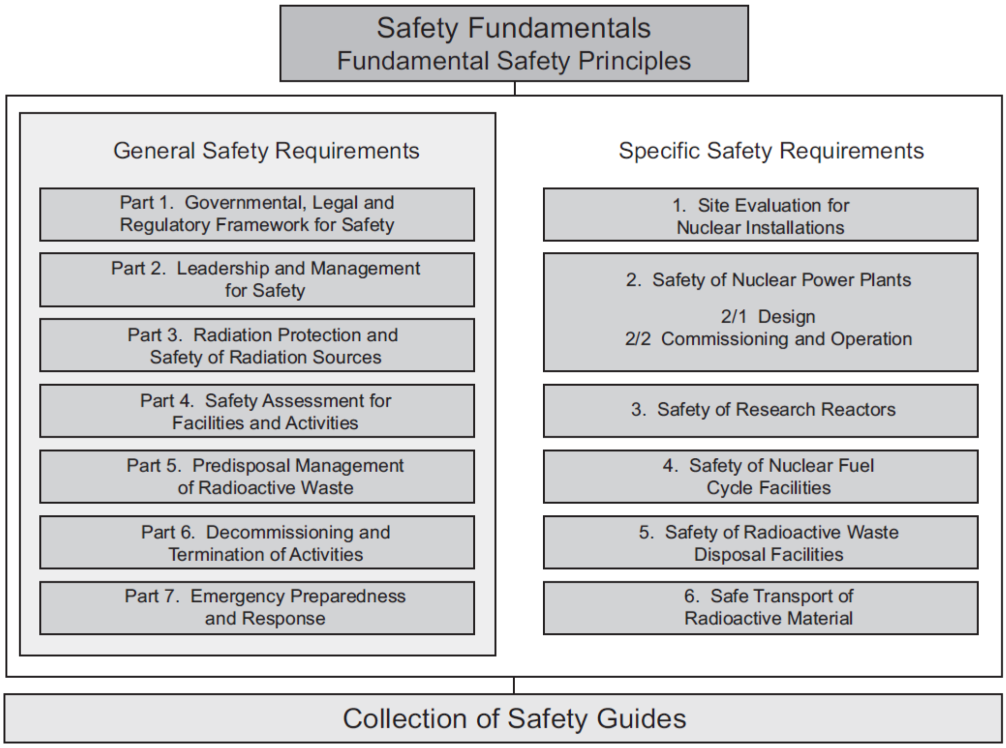

Figure 1: Structure of IAEA Safety Standard Series

The IAEA Standards allow for a graded approach to the safety case: Principle 3 of the Fundamental Safety Principles (2) states that "Safety has to be assessed for all facilities and activities, consistent with a graded approach" (para. 3.15). This is further detailed in Principle 5: "The resources devoted to safety by the licensee, and the scope and stringency of regulations and their application, have to be commensurate with the magnitude of the radiation risks and their amenability to control" (para. 3.24). In accordance with this, the General Safety Requirements (3) (4) state that the extent and complexity of safety assessment are required to vary with facility type and to be related to the potential hazard. Furthermore, the level of detail of the safety assessment performed for each step of the development and operation of a facility will vary depending on the magnitude of the risks.

This implies that for the Jacobs MCM proposal there will be a grading of the extent and complexity of the safety assessment, and hence of the skills required, from the low- and intermediate-level waste repository (least complex), through the interim used fuel storage facility to the geological disposal facility (most complex).

Although the IAEA Standards recommend such a graded approach, most of the skills necessary for the most complex proposal will also be required for even the least complex of the three proposed facilities. Rather than requiring a completely different skill-set, more complex facilities will require more people with similar training, who will address similar though different issues. For example, the engineering and materials skills required for understanding the relevant IAEA standards for designing and testing waste packages for LLW, vitrified HLW and used fuel are the same. Thus many of the skills are repeated and only a few additional skills are required for the more complex facilities.

The approach taken here is to identify skills requirements corresponding to all of the requirements of items 1 (5), 5 (6) and 6 (7) of the Specific Safety Requirements (see Figure 1). These Specific Safety Requirements are supplemented by the relevant IAEA Safety Guide documents and by relevant case studies, including ANSTO experience. The identification of more general skills requirements, such as civil construction (port, railways, roads, etc.) and service provision, is influenced by the Jacobs MCM report and various case studies, in addition to the IAEA documents.

1.2 Timeline for Skills Requirements

An estimate of the timeline for the skills required for the proposed facilities is helpful for planning purposes. A generic timeline for a near surface facility is given in Figure 2.

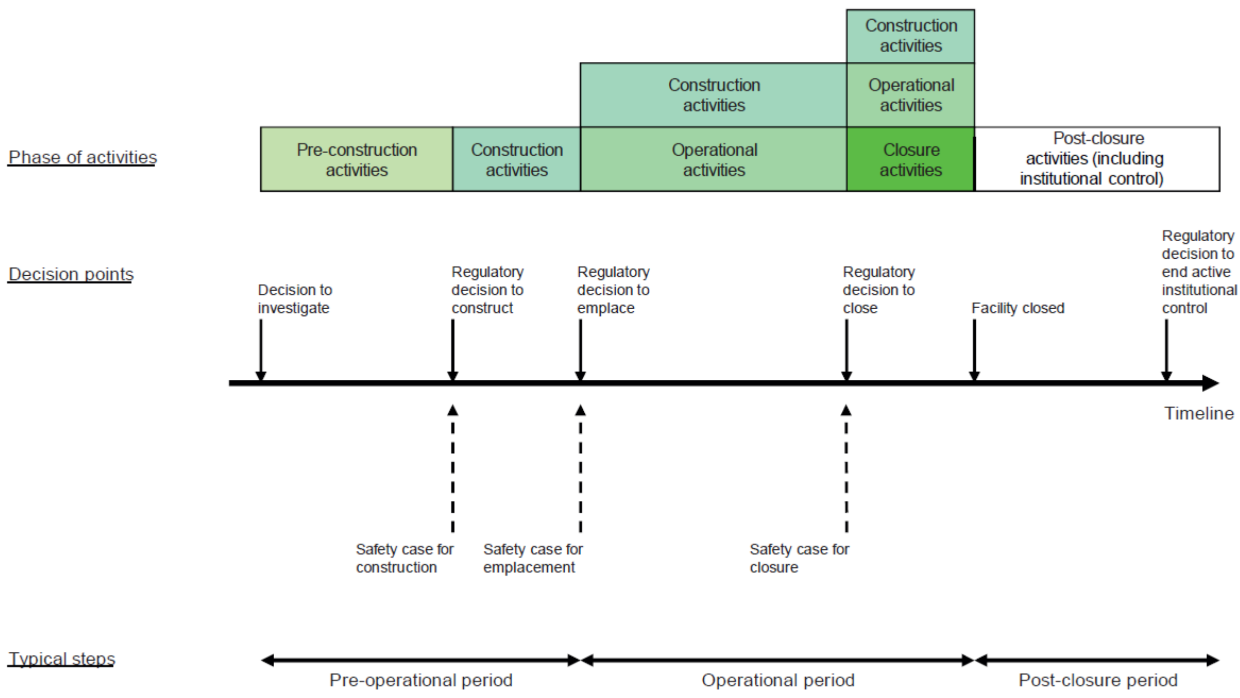

Figure 2: Timeline for near surface facility, from IAEA SSG-29 (8)

This has been elaborated upon by the Jacobs MCM report: the timelines for the Pre-Construction and Construction phases of Figure 2 for the low level waste facility and the interim fuel storage facility are given in Sections 4.3 and 3.7 respectively. The Jacobs MCM timelines assume that the programmes would run “without unreasonable delays”. They are virtually identical for both facilities:

- initial site identification and safety case to ARPANSA requirements: typically three years (years 1 to 3)
- siting work including surface-based, intrusive site investigations: 2 years (years 4 to 5)
- design development in parallel with site investigations: 2 years (years 4 to 5)
- environmental impact studies and licencing for construction: 3 years (years 6 to 8)
    - EPBC referral and license preparation
    - EPBC approval
    - safety case documentation (final) and peer review / ARPANSA approval
    - ARPANSA siting and construction licenses (based on design input)
- construction and commissioning, licensing: 2 years (years 9 and 10)
    - ARPANSA operating license
- pilot testing on site: 1 year (year 9)
- land transport and other infrastructure: 2 years (years 9 and 10)
- ready for first receipt of waste: year 11

For the interim fuel storage facility, there is the additional requirement to build dedicated harbour facilities, estimated to occur in years 6-8.

For the geological disposal facility, the generic timeline of Figure 2 also applies, but the time axis is significantly extended: Section 2.2.10 of the Jacobs MCM report estimates that routine emplacement of spent fuel/HLW in the facility would not occur until 27 years after project initiation. This estimate has been derived from overseas (Swedish, Finnish, US) experience with similar facilities.

Thus, skills requirements will extend over decades. The skills listings for the individual facilities given in the following section are indicative of when they are first required in the project timeline. However, many of the skills, for example those required for the safety case, legal and regulatory and stakeholder interactions, and overall project management skills, will be required for the life of the project.

1.3 Skills Requirements for Radioactive Waste Storage Facilities

Skills requirements are listed in Table 1 for the three types of facilities proposed in the Jacobs MCM report according to the guidance and structure set out in *IAEA SSG-29: Near surface disposal facilities for radioactive waste* (8).

For the interim used fuel store, *IAEA SSG-15: Storage of spent nuclear fuel* (9) has been used for guidance. Many of these skills are identical to those required for a LLW facility; however there are also more stringent requirements associated with the nature and form of the material being managed (e.g. shielding, criticality control, thermal cooling, security, safeguards) that will require additional skills.

For the GDF, *IAEA SSG-14: Geological disposal facilities for radioactive waste* (10) has been used for guidance. Many of the skills are identical to those for the LLW and ISFS facilities; however there are additional more stringent requirements associated with the longevity of the waste and the need to assure safety over near-geological timescales.

Table 1: Table of skills requirements

	Low-level Waste (LLW) Storage Facility	Interim Used Fuel Storage Facility (ISFS)	Geological Disposal Facility (GDF)
Legal and organisational	• skills appropriate to governmental, legal and regulatory bodies for oversight of radioactive waste disposal facilities • skills appropriate to setting and overseeing licensing regimes	• skills appropriate to governmental, legal and regulatory bodies for oversight of radioactive waste disposal facilities • skills appropriate to setting and overseeing licensing regimes • skills for driving regulatory and legislative changes to accept externally-generated HLW for interim storage	• skills appropriate to governmental, legal and regulatory bodies for oversight of radioactive waste disposal facilities • skills appropriate to setting and overseeing licensing regimes • skills for driving regulatory and legislative changes to accept HLW for final disposal
Site characterisation	• engineering geological, geotechnical, regional history, geophysical, geodetic, seismological, surveying, demographic • meteorological and hydrological modelling • risk analysis for events such as aircraft crashes, explosions, terrorist attack, etc. • geography, radiological assessment, pathways assessment • measurement of baseline levels of radioactivity of the atmosphere, hydrosphere, lithosphere and biota • skills for establishing and operating a quality assurance (QA) system for the site selection process • engineering and management skills with awareness of IAEA regulations	• engineering geological, geotechnical, regional history, geophysical, geodetic, seismological, surveying, demographic • meteorological and hydrological modelling • risk analysis for events such as aircraft crashes, explosions, terrorist attack, etc. • geography, radiological assessment, pathways assessment • measurement of baseline levels of radioactivity of the atmosphere, hydrosphere, lithosphere and biota • skills for establishing and operating a quality assurance (QA) system for the site selection process • engineering and management skills with awareness of IAEA regulations	• engineering geological, geotechnical, regional history, geophysical, geodetic, seismological, surveying, demographic • meteorological and hydrological modelling • risk analysis for events such as aircraft crashes, explosions, terrorist attack, etc. • geography, radiological assessment, pathways assessment • measurement of baseline levels of radioactivity of the atmosphere, hydrosphere, lithosphere and biota • skills for establishing and operating a quality assurance (QA) system for the site selection process • engineering and management skills with awareness of IAEA regulations • skills for determining and predicting very-long term (100,000 years) geological, seismic and meteorological behaviours • skills for assessing chemical and physico-chemical interactions between the wasteform, the container and backfill material and the disposal facility environment • skills to establish and run an underground rock laboratory, including mining • geotechnical - rock mechanics

Design	• engineering and modelling skills for design of packaging and disposal concepts, as well as heat flow modelling • engineering and modelling skills for design of packaging and disposal concepts - demonstrate performance under normal and less likely situations, isolation from biosphere for hundreds of years (perhaps using analogues) • skills for shielding design, criticality design • radiochemistry and radiation protection aspects of designs • engineering and design skills with awareness of IAEA regulations • skills for design and specification of transport systems to IAEA regulations, including security, physical protection, emergency response • skills for safety case QA, interactions with stakeholders	• engineering and modelling skills for design of packaging and disposal concepts, as well as heat flow modelling • engineering and modelling skills for design of packaging and disposal concepts - demonstrate performance under normal and less likely situations, isolation from biosphere for hundreds of years (perhaps using analogues) • skills for shielding design, criticality design • radiochemistry and radiation protection aspects of designs • engineering and design skills with awareness of IAEA regulations • skills for design and specification of transport systems to IAEA regulations, including security, physical protection, emergency response • skills for safety case QA, interactions with stakeholders • skills for understanding and assessing spent fuel – burnup, spent fuel integrity, chemical and physical characteristics for input to package and facility design	• engineering and modelling skills for design of packaging and disposal concepts, as well as heat flow modelling • engineering and modelling skills for design of packaging and disposal concepts - demonstrate performance under normal and less likely situations, isolation from biosphere for hundreds of years (perhaps using analogues) • skills for shielding design, criticality design • radiochemistry and radiation protection aspects of designs • engineering and design skills with awareness of IAEA regulations • skills for design and specification of transport systems to IAEA regulations, including security, physical protection, emergency response • skills for safety case QA, interactions with stakeholders • skills for understanding and assessing spent fuel – burnup, spent fuel integrity, chemical and physical characteristics for input to package and facility design
Waste acceptance	• engineering, chemical and radiochemistry skills for derivation of waste acceptance criteria • engineering skills for package design, materials testing, mechanical testing	• engineering, chemical and radiochemistry skills for derivation of waste acceptance criteria • engineering skills for package design, materials testing, mechanical testing	• engineering, chemical and radiochemistry skills for derivation of waste acceptance criteria • engineering skills for package design, materials testing, mechanical testing
Construction	• construction-related skills, i.e. those for site preparation, building, transport infrastructure, etc. • construction QA • documentation for and interaction with regulator	• construction-related skills, i.e. those for site preparation, building, transport infrastructure, etc. • construction QA • documentation for and interaction with regulator	• construction-related skills, i.e. those for site preparation, building, transport infrastructure, etc. • construction QA • documentation for and interaction with regulator • underground mining
Operation	• operational skills – loading and unloading waste packages, maintenance, etc. • training and education of operators • radiochemistry, radiation protection and	• operational skills – loading and unloading waste packages, maintenance, etc. • training and education of operators • radiochemistry, radiation protection and	• operational skills – loading and unloading waste packages, maintenance, etc. • training and education of operators • radiochemistry, radiation protection and

	monitoring, OH&S • physical protection • nuclear security, surveillance and monitoring • skills for safety case and facility QA • interactions with stakeholders • skills for management and operation of transport of LLW to IAEA regulations	monitoring, OH&S • physical protection • nuclear security, surveillance and monitoring • skills for safety case and facility QA • interactions with stakeholders • skills for management and operation of transport of LLW to IAEA regulations • transport and handing of HLW packages • nuclear materials accounting	monitoring, OH&S • physical protection • nuclear security, surveillance and monitoring • skills for safety case and facility QA • interactions with stakeholders • skills for management and operation of transport of LLW to IAEA regulations • transport and handing of HLW packages • nuclear materials accounting • underground mining
Closure	• management and closure operations, including interactions with stakeholders • radiation protection and monitoring	• largely as for LLW facility, but with less emphasis on institutional controls	• management and closure operations, including interactions with stakeholders • radiation protection and monitoring during the period of institutional control

2. Development of Skills and Research Capabilities

A key constituent of any successful nuclear industry is first class education and training. It is critical that the industry maintains an ability to appropriately apply the relevant high quality skills throughout all aspects and activities. Although the specific requirements may differ between stages of the nuclear fuel cycle, it is essential that each participating organisation is able to demonstrate that its workforce has the appropriate skills, training and education to carry out the work safely and effectively.

Within the industry, this ability to perform is often referred to as *nuclear competency* and has been defined by the IAEA (11) as "the ability to put skills and knowledge into practice in order to perform a job in an effective and efficient manner to an established standard". Factors contributing to a person's competence include the person's prior experience, aptitudes, attitudes, behaviours, skills and qualifications.

The UK nuclear industry and regulator (12) uses the term SQEP (suitably qualified and experienced personnel) to describe "competent" people within the industry:

> "*It is essential that all personnel whose activities have the potential to impact on nuclear safety are suitably qualified and experienced (SQEP) to carry out their jobs. This includes both those who directly carry out operations and others such as directors, managers, designers, safety case authors etc. whose roles, if inadequately conceived or executed, may affect safety in less visible ways – for example, through introducing latent technical or organisational weaknesses. The licensee should therefore put in place robust arrangements for identifying its competence needs and assuring these are met and maintained.*"

The UK has invested significant effort and resources into filling a perceived nuclear skills gap. Figure 3 illustrates the definition of competence now employed by the UK National Skills Academy: Nuclear (NSAN) (13).

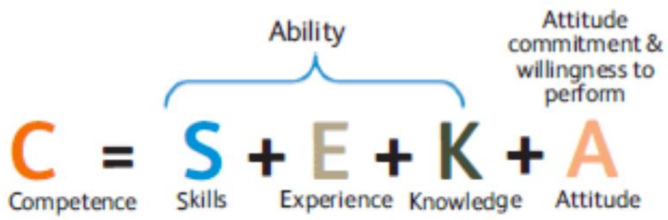

Figure 3: National Skills Academy: Nuclear – Standardised competency requirements across the industry

These descriptions of the human capital requirements of a 21st century nuclear industry illustrate that their demands go far beyond the provision of nuclear education. Although the provision of world class nuclear knowledge through education will be vital, it must be accompanied by a world class training and research capability that can provide the experience critical to the creation of the fully competent personnel necessary for the industry to succeed.

The relevant considerations, and potential consequences and opportunities for the South Australian education sector, including skills development and research capability necessary to support a storage/direct disposal industry in South Australia, are described below.

2.1 Core Nuclear Education, Training and Research Capability

2.1.1 Basic nuclear safety training

Safety, security and, where fissile material is involved, safeguards are key components of any nuclear enterprise, and the integration of these nuclear "3S's" is increasingly important for new nuclear industries (11). But of these three, it is the development of skills related to nuclear safety, and the associated nuclear safety culture, that is of primary importance to the industry, the regulator and the public. Thus, the core nuclear education, training and research capability needed to support any nuclear industry revolves around the safety of the industry and its operations.

Indeed, basic compliance-based nuclear training is now usually mandatory for any involvement in the nuclear industry. As noted above, the UK has taken a proactive stance and is developing a "Triple Bar" entry requirement for individuals working in and with the industry (15). There are two versions of the Triple Bar: one for existing sites, which is specific to people working on operational or decommissioning sites; and one for new-build sites, which contextualises the training specifically for a new-build agenda. The three training areas within the Triple Bar are:

1. Basic Common Induction Standard: provides individuals with what is required for compliance for entry to a nuclear site;
2. Basic Nuclear Industry Context: provides individuals with an awareness of the nuclear industry and why they need to comply; and
3. Basic Nuclear Industry Behaviours: provides individuals with an awareness of how they need to behave to promote and encourage a nuclear safety culture.

2.1.2 Core nuclear competencies

Beyond this basic training, there is a need for competency-based nuclear engineering education such as that recommended by the IAEA (16). A competent nuclear engineer can be produced through varying contributions of formal academic programme and industry training, but it is important to recognise that neither education nor training on its own can produce the high level of competence required. It is recognised that a robust nuclear engineering course is the sum of many subjects.

A typical core curriculum (16) consists of courses in: reactor physics, the nuclear fuel cycle, thermal hydraulics, nuclear materials, radiochemistry, radiological protection, safety, security and safeguards, dynamics, control and instrumentation, nuclear instrumentation, reactor systems and engineering, communication, team working, basic business/economics, and project management.

Although some of these subjects may seem superfluous if the engineer is to be employed in a nuclear industry focused on the back end of the nuclear fuel cycle as considered here, in practice if that industry is to include the storage and/or disposal of used fuel then only the courses in reactor systems and engineering would be partially irrelevant.

Typical core competences (16) that would emanate from a masters level course in nuclear engineering with appropriate training and industrial experience components would be the ability to:

- conduct mathematical analysis and numerical simulation, and theoretical and experimental investigations in nuclear engineering;
- conduct mathematical simulation of processes in nuclear components and systems;
- apply standard methods and computer codes for design and analysis;
- perform radiation protection and measurement experiments, and analyse resulting experimental data;
- have a commitment to safety and an understanding of safety culture (including, for example, risk analysis and management, human factor engineering, and human–machine interface);
- understand the regulatory process and the role of the regulator in nuclear facility licensing and operation; and
- participate in the design process of the principal system and components of nuclear facilities, accounting for environmental and safety requirements, and incorporating new requirements and technologies.

Despite the focus on nuclear engineering here, relatively few of the personnel employed in nuclear facilities have specific nuclear engineering degrees. Nuclear engineering as an activity is typically undertaken by physicists, chemists, mathematicians and experts in virtually all of the main engineering disciplines. Indeed, the prosecution of a radioactive waste and used fuel storage and/or direct disposal industry as described in the Jacobs MCM report could well be delivered without the instigation of an undergraduate nuclear engineering course in South Australia. Of far greater importance is the introduction of nuclear physics, engineering and chemistry concepts and knowledge into relevant STEM-based degrees, as this would provide the broad human capital base necessary to support a nuclear industry in South Australia. Specific nuclear competencies could then be achieved through focused masters-level courses that also provide both practical experience and industrial training.

Thus, it is likely that the optimum way to support a radioactive waste and used fuel storage and/or direct disposal industry in South Australia will be through a whole-of-state approach that encompasses both collaboration as well as competition in the South Australian tertiary education sector.

2.1.3 Research

The development of world-class nuclear engineering education, as in any subject, is best achieved in an institution or environment of relevant world class nuclear engineering research. In the present context that would require the development of a world class research capability on the siting, technical evaluation, construction, and operation of a radioactive waste and used fuel storage and/or direct disposal industry.

In addition to the core nuclear competence areas listed above, the scale of the industry envisioned in the Jacobs MCM report (1) would require state-of-the-art expertise, obtained through research, in geological and hydrogeological assessment and prediction, road and rail investment optimisation and impact, transport safety and logistics, environmental and ecological monitoring, and large scale civil construction. Many of these activities are also highly relevant to the mining of naturally occurring radioactive materials (NORM) such as uranium and thorium and are likely to already exist in Australia, if not all in South Australia.

Other, more focussed topics for research that could be envisaged are:

- alternative forms of disposal
- alternative forms of processing, e.g. mobile compaction and packaging
- use of used fuel as a low-grade heat source
- future uses of waste products
- geological emplacement techniques
- degradation of used fuel, either in storage or after emplacement in a repository
- isolation/reduction of long-lived transuranics etc.
- innovations in long-term storage systems
- security and anti-intrusion systems
- volume reduction techniques

2.2 Nuclear Education, Training and Research Capability Enabling Collateral Industrial Opportunities

The establishment of a radioactive waste and used fuel storage and/or direct disposal industry of the scale described in the Jacobs MCM report would be globally significant, and could lead to very substantial opportunities for South Australian high technology industries. The operator of an optimised radioactive waste and used fuel storage facility would likely aim to develop an optimised strategy for transport and storage before, or instead of, the development of a deep geological disposal facility.

For example, whilst it is possible to use shielded flasks and casks for both transport and storage, the threshold criteria for each stage are different, particularly with regard to weight. Thus, an optimised strategy that utilised differing storage solutions could be cheaper, safer and more efficient. Although there are a number of national and international standards for radioactive waste and used fuel transport and storage containers, the number of suppliers is relatively small and most are medium-sized companies.

With appropriate R&D-based innovation driven towards an optimised solution, opportunities for the development of high technology companies specialising in the design, testing and construction of transport flasks and casks could be significant. Such enterprises would be aligned with South Australia's well-trained manufacturing based workforce, but would need support from high quality nuclear engineering research into radioactive waste-form conditioning, advanced manufacturing, nuclear materials durability, flask and pressure vessel structural integrity, nuclear quality assurance, and radiation protection.

The opportunities for such companies would arise early in the development of a used fuel storage and/or direct disposal industry. It may be that early entry to the market would be best achieved by collaborating with existing international suppliers as a route to developing a truly credible indigenous industry. Indeed, as gaining approval for nuclear flasks and casks from regulators can take some time, the first entry to this market might well be best achieved by setting up advanced manufacturing facilities operating to nuclear standards to produce presently-available licenced products.

The development of such an industry would pay increased dividends should a deep geological disposal facility be subsequently developed, as bespoke waste-form and used fuel conditioning, packaging and storage solutions will need to be designed and manufactured. The development of a suitable site, and the design and implementation of a system delivering environmental and ecological isolation operating in tandem with a robust engineered barrier system, would lead to a world-leading facility and can only be achieved through interaction with a supporting world-class research capability.

At present, Australian expertise and research capability able to support nuclear engineering, transport/storage packaging, waste-form development, waste-form conditioning and system durability lies predominantly with ANSTO at its Lucas Heights facility in Sydney. However, with the development of a substantial waste and used fuel storage and/or direct disposal industry, there could be opportunities to shift the focus of its capability in these areas to a South Australian venue, potentially in collaboration with a South Australian University or a South Australian federal research agency (e.g. Geoscience Australia, CSIRO).

2.3 Nuclear Education, Training and Research Capability Linked to Future Opportunities within the Nuclear Fuel Cycle

Australia has a rich history in the development of innovative solutions to radioactive waste management, particularly through the development of Synroc. Synroc is a kind of ‘synthetic rock’, invented in 1978 by Professor Ted Ringwood of the Australian National University. It is based on a group of geochemically-stable natural titanate minerals which have been shown to immobilise uranium and thorium for billions of years. Most of the elements present in HLWs can be locked into the mineral crystal structures. ANSTO continued the development of Synroc for over 30 years. Today, Synroc can take various forms depending on its specific use and can be tailored to immobilise particular components in ILWs or HLWs. ANSTO is currently building the world’s first operational Synroc plant to treat the waste from its expanding radiopharmaceutical production.

In the future, potential customers for a nuclear fuel cycle back-end service could require:

- storage of used fuel for a finite period before return
- indefinite storage of used fuel without further treatment
- encapsulation of used fuel constituents in Synroc
- the reprocessing of used fuel, most likely using a PUREX technology, resulting in uranium and plutonium being extracted for use in MOX fuel, and wastes that would be immobilised in Synroc
- the reprocessing of used fuel, without separation of uranium and plutonium, for use in Generation IV fast reactors

Although in the majority of countries there is little present interest in or demand for closing the nuclear fuel cycle, it is possible that this could change over the life of the proposed industry. It would therefore be sensible to undertake sufficient research and development on these topics to enable Australia to remain aware of possible opportunities. This is another area where collaboration with ANSTO would be advantageous.

It should be noted that unless used fuel is stored indefinitely in an intact form, there are opportunities for state-of-the-art long term waste-form solutions such as Synroc in all of the potential programmes. Thus, there are clear opportunities for South Australian universities to undertake state-of-the-art research into the design and implementation of such waste forms. Again, this could usefully be undertaken in collaboration with ANSTO.

2.4 Consultation with South Australian Universities

The ideas and conclusions contained within this report were shared with the three major South Australian universities. Due to the tight timelines involved in the production of this report, this consultation was not comprehensive, and further discussions with the universities are encouraged.

All three universities were considering the interim report of the Royal Commission and considering their potential responses to the opportunities identified.

ANSTO observed that the University of SA and Adelaide University in particular mentioned strong ties to countries with extensive nuclear programmes and nuclear expertise, namely France, the UK and Japan. Each recognised the potential to use these ties to bring in expertise in order to supplement their existing courses in such disciplines as environmental management, mechanical, civil and chemical engineering, safety management and monitoring, project management, etc. with nuclear-related course material. In addition, such expertise would provide associated research capabilities and links to the nuclear research bodies of their home countries. This would enable a rapid build-up of relevant training and research capability in South Australia.

The third university, Flinders, was able to point to a wide range of relevant research capabilities already in place on such topics as:

- low dose radiobiology relating to biological effects of doses of radiation relevant to radiation workers and the public
- various radioanalytical methods and nuclear forensics, including analysis of environmental radiation in a variety of matrices
- selecting and testing suitable geological sites for disposal of radioactive wastes
- groundwater-related issues
- political, cultural and policy issues including international relations
- legal and policy aspects: planning and environmental law and regulation, as well as native title
- international law aspects of natural resource management

All three universities recognised that the creation of such high-tech industry of global significance would be a significant fillip for STEM research and education in South Australia, with the potential to attract international researchers and industry. The recent commissioning of a medical cyclotron at the South Australian Health and Medical Research Institute and the continuing support of the uranium mining industry in South Australia means that a radioactive waste storage industry would add to the state’s nuclear credentials.

3. References

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