CHAPTER 3: FURTHER PROCESSING AND MANUFACTURE

The activity under consideration is the further processing of minerals, and the processing and manufacturing of materials containing radioactive and nuclear substances (but not for, or from, military uses) including conversion, enrichment, fabrication or reprocessing in South Australia.

CONVERSION, ENRICHMENT AND FUEL FABRICATION

WHAT ARE THE RISKS?

23. For conversion, enrichment and fuel fabrication facilities, the most significant environmental and safety risks are posed by toxic, corrosive and potentially explosive chemicals, rather than the radioactivity of the materials.

Facilities undertaking conversion, enrichment and fuel fabrication activities use both chemical and physical processes to transform natural uranium into reactor fuel.

In conversion, enrichment and fuel fabrication facilities, the predominant risk to workers' health arises from handling uranium hexafluoride (UF_6)[1], a compound of uranium and fluorine. It is a toxic, volatile solid at ambient temperature, but is easily converted into a gas for enrichment. If it comes into contact with water or water vapour during any step of the process, UF_6 forms hydrofluoric acid (HF), a corrosive gas or aqueous liquid that is toxic by inhalation and skin contact.[2] It also forms uranyl fluoride (UO_2F_2), which is chemically toxic if inhaled or ingested.[3] The toxic effect of UF_6 exposure depends on its concentration, moisture level and the duration of contact. The chemical hazards of UF_6 are of greater concern than the radiation hazard due to the low radiotoxicity of uranium.[4]

Other chemical risks are posed by hydrogen (H_2), a potentially explosive gas, and fluorine (F_2), a reactive, corrosive gas that is toxic by inhalation or skin contact.[5] These risks are well understood and effectively managed and regulated in Australian industry.[6] Chemical safety control systems comprise: infrastructure that prevents releases, measures that mitigate consequences in the event that releases occur, and personal protective equipment for workers.[7]

The environmental risks associated with these processes stem mainly from the chemical nature of the compounds involved, not their radioactivity—the compounds have flammable, toxic, corrosive or reactive properties that can cause harm if not properly managed.[8] Many of these compounds are already used safely and managed responsibly in Australian chemical manufacturing processes and are subject to assessment under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS).[9]

Greater environmental risks stem from the possible build-up, movement and chemical nature of uranium as a heavy metal, than from the release of lighter molecules, such as H_2, which are less likely to accumulate in soil or aquifers (although these still need to be assessed).[10] If released into the environment, UF_6 reacts with water vapour, resulting in insoluble uranium compounds that ultimately settle in soil and underwater sediments.[11] While uranium is not particularly mobile, it can become soluble in oxidising conditions over long periods.[12] The chemical nature of the potentially released compounds poses a higher risk than the radiological hazard, which is low.[13]

Facilities for these further processing activities have measures in place that mitigate the consequences of the potential accidental release of hazardous substances. These include:

- routine sampling and monitoring, both inside and outside site boundaries[14]
- highly engineered storage systems for UF_6 and other hazardous materials, such as specialised, leak proof steel containers[15]
- tail gas venturi scrubbers[16]
- training and supervision[17]
- emergency response planning and coordination with local authorities.[18]

Conversion, enrichment and fuel fabrication activities produce wastes that require management to ensure the safety of workers and to protect the environment. Conversion and enrichment processes create hazardous liquid wastes.[19] Fuel fabrication produces various industrial and combustible wastes, including dewatered waste sludge and uranium materials.[20] Conversion of uranium oxide (U_3O_8) into UF_6 results in a number of impurities, including vanadium, sodium, iron and molybdenum, becoming concentrated and separated.[21] Some of these elements can be captured and may have monetary value, particularly molybdenum[22]; others are benign and can be disposed of as landfill. Each of the waste streams is managed according to strict protocols within facility licences. Techniques exist to minimise the hazardous materials in the waste produced during further processing activities, such as filtering or scrubbing gaseous discharges, and recovering and reusing the chemicals in liquid discharges.[23]

The proliferation risks of those technologies, particularly those associated with enrichment, are addressed in Chapter 7: Radiation risks.

FURTHER PROCESSING OF URANIUM

Uranium oxide (U_3O_8) cannot be used as a fuel to generate electricity without further processing. The processes that transform U_3O_8 into fuel are conversion, enrichment and fuel fabrication.

Uranium **conversion** involves the chemical change of mined and milled U_3O_8 into a gas: uranium hexafluoride (UF_6). **Enrichment** follows conversion to increase the concentration of the uranium-235 (^{235}U) isotope from its natural level of 0.7 per cent to between 3 and 5 per cent. It is necessary to enrich uranium before it can be used in most types of nuclear reactor.

The final step in preparing uranium for use in a reactor is **fuel fabrication**. This process transforms uranium back into an oxide form (UO_2) and then into dense ceramic pellets, which are sealed into zirconium metal tubes. These are then arranged into fuel assemblies that can be loaded into a reactor core.

A more detailed explanation of these processes is contained in Appendix C: Further processing methods.

Sources: International Atomic Energy Agency (IAEA), *Getting to the core of the nuclear fuel cycle: From the mining of uranium to the disposal of nuclear waste*, IAEA, Vienna, pp. 4–5; Argonne National Laboratory (ANL), *Human health fact sheet: Uranium, 2005*, p. 58.

24. The risk of significant releases of radioactive materials into the environment during normal operation at conversion, enrichment and fuel fabrication facilities is low because of the nature of those materials.

Conversion, enrichment and fuel fabrication processes produce radioactive wastes, which pose a low radiological risk because of the nature of those wastes.[24] The main wastes are listed below:

- Depleted uranium—the process of enriching uranium produces a large amount of depleted uranium (DU) hexafluoride.[25] Commonly referred to as 'tails'[26], DU is a by-product of the manufacturing process and requires secure storage.[27] Under some market conditions, the tails can be re-enriched, but the volumes of DU are large and enrichers have long-term programs to 'de-convert' DU tails to a stable oxide form, recycling the resultant fluorine.[28]
- Decay daughters of uranium—very small amounts of naturally occurring radioactive elements may accumulate in the chemical process circuits of uranium conversion (and de-conversion) facilities. These are the natural decay daughters of uranium.[29] The total amount of these wastes is negligible and generally below regulatory exemption limits.[30] If the wastes exceed these limits, they are retained as low-level waste (LLW) and disposed of accordingly.
- Contaminated liquid surfactants—further processing facilities use liquids to wash materials that can become contaminated with low levels of uranium compounds. These liquids can generally be concentrated and the uranium recycled into the process circuit. During this process, protective clothing and equipment can become contaminated and are also retained as LLW.
- Contaminated filters—further processing facilities have active filtering and scrubbing systems for their gaseous and liquid discharges. These systems produce contaminated filters, which are retained as LLW.[31]

The potential rupture of a containment vessel during the handling, transport, storage and waste disposal phases of processing can lead to contamination of the facility and effects on workers and the environment.[32] The extent of these risks depends on the radioactive substances, types and extent of radiation emitted, and their physical and chemical forms.[33] Radioactive releases after a serious accident at a facility are also possible. However, the radiological consequences would be limited due to the low radiotoxicity of the uranium compounds involved.[34]

The high temperature treatment (calcining) of uranium oxides and grinding operations on uranium fuel ceramics during fuel fabrication pose dust hazards.[35] If inhaled or ingested, low-level airborne radioactive materials present health risks to workers.[36] These risks are managed by the use of personal protective equipment, ventilation and air filtration systems, alarm systems and safe operating practices[37], as well as continuous monitoring of radiation doses at each facility to ensure exposure is as low as reasonably achievable.[38] Regulatory bodies also have a role in ensuring that safety measures are effective.[39]

Uranium enrichment and light water reactor fuel fabrication plants handle uranium that is isotopically enriched in uranium-235 (^{235}U). The risk of a 'criticality incident' (an uncontrolled fission chain reaction occurring for a short period releasing radioactivity, including neutrons, which are particularly harmful to health[40]) in such a facility is very low due to an industry-wide ^{235}U enrichment limit of 5 per cent. Below such a limit criticality is practically impossible outside a reactor environment.[41] A contained and controlled criticality is safely maintained in a nuclear reactor during an operational cycle.

In addition to the regimes that manage risks associated with chemicals discussed earlier, there are established administrative, engineered and regulatory controls that effectively manage the radiological risks of further processing activities, including the waste streams. Radiation dose limits and requirements for radiation protection are set in accordance with Australian and international standards as developed by the International Atomic Energy Agency (IAEA).[42]

If conversion, enrichment or fuel fabrication facilities were developed in South Australia, limits would apply to fix maximum safe levels of radiation exposure. In addition, the design and operation of manufacturing facilities for the purposes of radiation protection would need to be licensed by the South Australian Environment Protection Authority (EPA) under the *Radiation Protection and Control Act 1982* (SA).[43]

ARE THE ACTIVITIES FEASIBLE?

25. There is no technical impediment to providing conversion, enrichment or fuel fabrication services in Australia.

Conversion, enrichment and fuel fabrication are services provided on a commercial basis in an international market.[44]

While the technology required to develop and operate conversion, enrichment and fuel fabrication facilities is sophisticated, particularly in the case of the last two, its transfer to South Australia would be technically feasible.[45] Arrangements would need to be made to acquire such technology from experienced overseas operators or vendors. The security and non-proliferation obligations that would need to be addressed for enrichment technology also would need to be considered.[46] Accessing the skilled workforce required to construct and operate such facilities would be feasible, given Australia's existing trade base and competencies in advanced manufacturing industries.[47]

The development of facilities in Australia to provide these services is prohibited by legislation. The *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) prohibits the federal Minister for the Environment from approving the construction or operation of nuclear processing facilities, except for conversion facilities.[48] Those provisions were introduced as part the anti-nuclear platforms of parties that held the balance of power in the Senate at the time.[49]

In South Australia, both conversion and enrichment activities are prohibited by the Radiation Protection and Control Act. This prohibition may be removed by proclamation by the Governor, only if satisfied that arrangements are in place to control such operations.[50] For these activities to be feasible the EPBC Act would need to be amended and, in South Australia, an appropriate proclamation made.

In addition to the repeal of any prohibition, a regulatory structure would need to be developed to provide for the licensing and ongoing regulation of such facilities. This would provide prospective operators with certainty about the regulatory environment in which they would be operating.

IN WHAT CIRCUMSTANCES ARE THE ACTIVITIES VIABLE?

26. At present, the market for uranium conversion, enrichment and fuel fabrication services is oversupplied. The extent of the oversupply suggests current suppliers will be able to meet demand in the short to medium term.

The demand for conversion, enrichment and fuel fabrication services is directly related to the number of operating nuclear power plants. Demand for those services will at any point reflect the needs of power plants several years in the future.[51]

The reduction in the number of operational nuclear power plants, primarily as a result of shutdowns in Japan, has reduced demand for these services, significantly affected price and resulted in overcapacity.[52]

The precise amount of capacity oversupply is in contention.[53] While there is underutilised capacity in existing facilities, its extent is affected by secondary sources of supply[54], such as the transfer to civil use of excess military stockpiles or enriched uranium and the re-enrichment of depleted uranium.

The long-term prospect for further demand of processing activities is uncertain. Not only is it challenging to estimate the extent to which low carbon energy demand will be met by nuclear generation, but also the demand for conversion, enrichment and fuel fabrication services will depend on national policies on domestic self-sufficiency. For example, the conversion, enrichment and fuel fabrication needs of new Chinese reactors aim to be met domestically.[55]

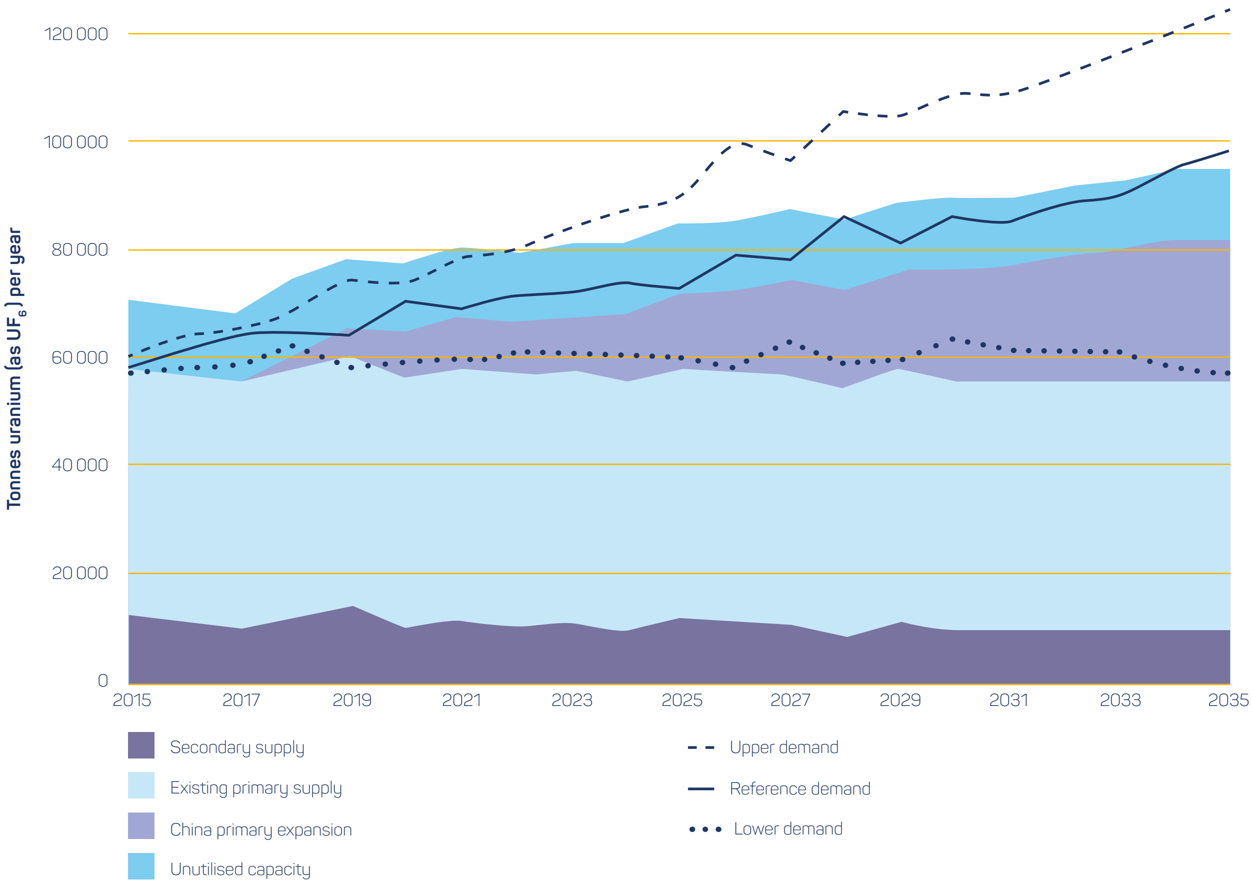

Figure 3.1: Current and projected global demand and supply for UF_6 conversion (tonnes uranium)

Data sourced from World Nuclear Association, *The nuclear fuel report: Global scenarios for demand and supply availability 2015-2035*, 17th edn, 2015, p. 117, fig. 6.3

CONVERSION

Conversion services are presently provided by a small number of major suppliers in Canada (Cameco Corporation), France (AREVA), Russia (ROSATOM) and the United States of America (ConverDyn).[56]

In 2015, the World Nuclear Association (WNA) estimated that production capacity in excess of demand was about 22 per cent, as shown in Figure 3.1. Secondary supplies are available from the waste streams of earlier enrichment, which contain uranium and can themselves be enriched. Other secondary sources include reprocessed uranium and inventories held by Russia and the US Department of Energy.[57] These supplies are estimated to be equivalent in quantity to overcapacity from primary sources.

The WNA estimates suggest that increased use of existing capacity would meet growth in demand to at least 2033.[58] This estimate is consistent with the International Energy Agency's view of the projected growth in nuclear power plants that would arise if the policy commitments made before the 2015 United Nations Climate Change Conference were implemented.[59]

ENRICHMENT

Enrichment services are currently provided by organisations in Germany, the UK and Netherlands (URENCO), France (AREVA), Russia (ROSATOM) and the USA (URENCO).[60] Other, smaller suppliers in China (China National Nuclear Corporation) and Japan (Japan Nuclear Fuel Limited) are mostly used to meet domestic demand.[61]

Demand is met primarily by enrichment plants, with secondary supplies sourced from the down-blending of highly enriched uranium released from military stockpiles, the re-enrichment of depleted uranium fuels, and the underfeeding of centrifuge plants. A combination of factors, including the 2011 Fukushima Daiichi accident, premature shutdown of power stations in Europe and the USA, and inventories held by traders, has led to an accumulation of primary enrichment capacity and enriched uranium inventories.[62]

The current level of oversupply in the enrichment market is approximately 18 to 25 per cent.[63] WNA demand forecasts in 2015 suggest that current enrichment capacity (measured in separative work units or SWU) could meet demand until 2025, as shown in Figure 3.2. Beyond this period, the WNA forecasts that prospective capacity in China would meet growth in demand.

FUEL FABRICATION

Fuel fabrication services are currently provided by companies across 16 nations in Asia (China, India, Japan, Kazakhstan, Korea), Eastern Europe (Romania, Russia), Western Europe (France, Germany, Spain, Sweden, United Kingdom), North America (Canada, USA) and South America (Argentina, Brazil). The main fabricators across these countries are typically reactor vendors and include AREVA, Westinghouse and Mitsubishi. The market includes a significant number of organisations that have developed fabrication capacity to meet local demand, such as the utilities company KEPCO in Korea and entities in India and Pakistan.[64] Fabricators that are also reactor vendors, which previously only produced fuel for their own reactor design, are increasingly producing fuel for competitors' reactor designs.[65]

Overcapacity for fuel fabrication services cannot be described in the same terms as conversion and enrichment. This is because fuel fabrication services do not produce a commodity, but a manufactured product. Suppliers compete by offering improved performance through improved fuel designs. Therefore, the existing overcapacity, estimated to be more than double current requirements, is not simply due to a fall in demand; it is also because multiple suppliers have the capacity to produce a diverse range of fabricated fuel designs suitable for a range of reactors.[66]

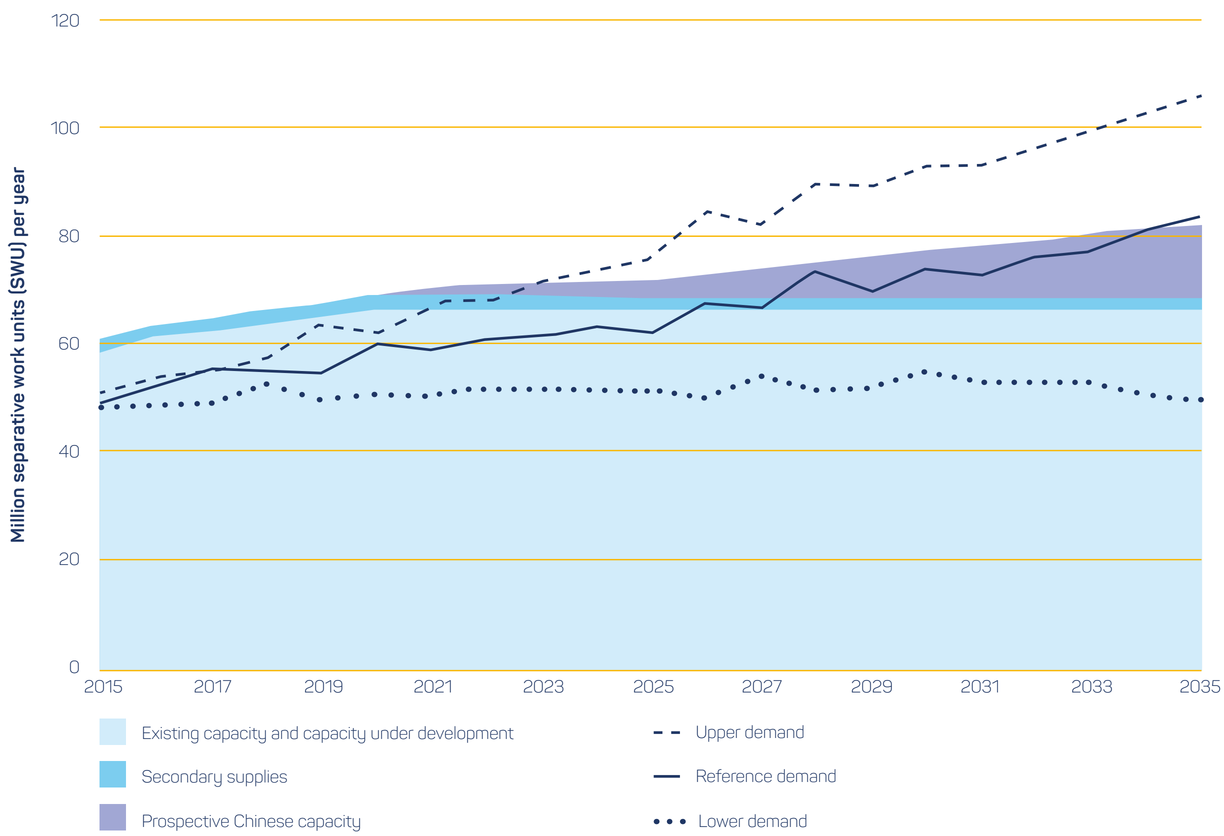

Figure 3.2: Current and projected global demand and supply for enrichment services

Data sourced from WNA, *The nuclear fuel report*, p. 136, fig. 7.5

27. An Australian operator seeking to supply conversion, enrichment or fuel fabrication services would face significant barriers to entry.

Because Australia does not produce nuclear energy, any facility to further process uranium would supply only international markets. This is significant because all facilities providing conversion, enrichment and fuel fabrication services are in countries that have a domestic nuclear energy industry. The largest and most dominant providers of each of those services are sustained by supply to substantial nuclear energy programs in their own countries in addition to meeting international requirements.[67]

The absence of a domestic nuclear energy market in Australia is but one challenge to the development of further processing services in South Australia.

The markets for these services are characterised by a small number of global service providers that operate specialised facilities.[68] Incumbents have significant advantages:

- Current commercial enrichment technologies are owned and controlled by two principal global suppliers, URENCO and TENEX. It would be necessary to reach licensing arrangements with one of them at a price which allowed the activity to be conducted profitably. Furthermore, the licensing of that technology in the case of URENCO and TENEX requires international legal agreements to be reached with the governments that own that technology. In the case of URENCO, an arrangement to establish one facility took more than five years to be reached.[69]
- Links between fuel fabrication technology and the technology of a reactor vendor mean that at present all fuel fabrication facilities are owned by reactor suppliers, with the sole exception being one fabricator closely cooperating with a vendor.
- The vertical integration of some suppliers that provide further processing services diminishes the capacity of an entrant to secure contracts for any one service.
- Production, particularly enrichment, can be expanded at existing facilities. A facility can be expanded by adding further cascades, avoiding the cost of establishing and licensing a new facility.
- Long-term contractual arrangements for the supply of most services are in place and privately negotiated. This is the case for many arrangements for further processing, and universal for the supply of fuel fabrication services.[70]

In addition to facing these challenges, new entrants would also face the challenge of acquiring skills and other capabilities, developing infrastructure, and licensing facilities and products. In the case of fuel fabrication, it would be necessary to undergo the expensive and time consuming process of obtaining safety certification of fuel designs from licensing authorities in customer countries.

An operator might seek to provide more specialised services than those directed at nuclear energy. For example, developing fuels for research reactors or target plates for medical isotope production would not face the same barriers. In those cases, an arrangement with a domestic operator to meet requirements such as security of supply might sufficiently alter the normal circumstances faced by a new participant to permit entry.

28. Financial assessments concerned with the potential viability of a new entrant point to, at best, marginal investment outcomes for further processing facilities based on proven technologies and a limited range of positive investment outcomes for facilities based on proprietary or unproven technology.

As further processing services are provided on a commercial basis, assessment of their viability is best undertaken by an investor with relevant knowledge and experience in that market. There can be no substitute for such analysis. However, because further processing activities are prohibited and cannot be licensed in Australia, no commercial operator is likely to undertake such an assessment.

To address viability, financial assessments of potential profitability of facilities established in Australia were undertaken for the Commission.[71]

Those assessments concluded that further processing facilities based on current and proven technologies were at best marginal investments and, in many cases, had negative returns.[72] Positive returns were indicated for facilities that used proprietary or unproven technologies, although significant investments would need to be made to demonstrate and commercialise those technologies. Those conclusions, and the analysis undertaken, are described in detail in Appendix D: Further processing—analysis of viability and economic impacts.

Those assessments proceeded on the basis that new facilities without any market advantage needed to compete with existing operators. That means the assessments do not answer whether a facility would be viable if established in partnership with an existing operator or if it had market power due to a unique, attractive offering.

The analysis:

- addressed the profitability of standalone conversion, enrichment and fuel fabrication facilities; the combination of conversion and enrichment; and a vertically integrated operation providing all three services
- addressed different technological or process options for each further processing service—both dry and wet conversion processes, gas centrifuge and laser enrichment, and, in the case of fuel fabrication, fuels for both light water and heavy water reactors
- undertook estimations based on facility capacities similar to those currently operating internationally
- developed life cycle cost estimates for developing each of the further processing facilities and its supporting infrastructure in South Australia
- assessed revenues based on prices that were the long-term average for the supply of conversion and enrichment services, and on published reports of agreements for fuel fabrication services.

The financial analysis found, as shown in figure 3.3, that:

a. There are some limited circumstances in which a standalone conversion facility in South Australia could be viable.

A conversion facility using a wet process is not viable in most future scenarios and marginal in some.[73] It would be viable if the price for conversion services were at or above the long-term average of A$21 per kilogram of uranium. A dry conversion facility is potentially viable under a wider range of prices than wet. However, dry conversion is used commercially in only one international facility.[74]

b. A centrifuge enrichment facility is not likely to be viable in South Australia as a standalone activity.

An enrichment facility using gas centrifuge technology would not be viable under a wide range of scenarios.[75] This is the case even if prices reverted to their long-term historical average of A$182 per SWU by 2030.

Despite substantial private investment, laser enrichment technology has not yet been demonstrated to be feasible on a commercial scale.[77] However, if it could be delivered

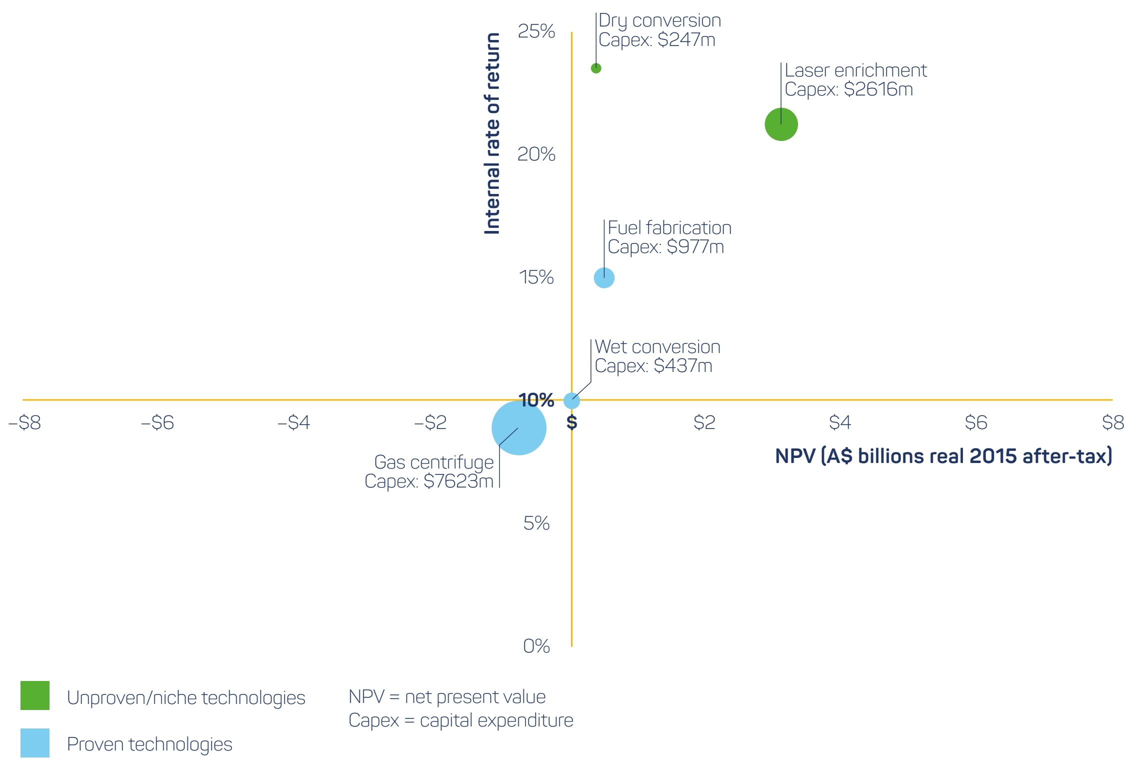

Figure 3.3: Commercial viability of standalone further processing facilities[76]

at approximately half the capital cost of gas centrifuge enrichment, as has been asserted in evidence to the Commission[78], it would have considerable value as a disruptive technology.

This would require substantial additional investment in research, development and the demonstration of commercially unproven technology. The Commission has not included these costs in its viability analysis.

c. Fuel fabrication facilities could be commercially viable, the more profitable being those concerned exclusively with fabricating fuel for light water reactors.

A fuel fabrication facility established in South Australia could generate a positive return on investment if such a facility could capture approximately 9 per cent of the market for fabricated light water reactor fuel[79]. Capturing this share would depend on South Australia establishing a unique selling proposition that it does not currently have.

29. Overall, given the barriers to entry, market oversupply, uncertainty around future growth and limited range of positive investment outcomes, there would be no opportunity for the commercial development of further processing capabilities in South Australia, assuming they were in competition with existing suppliers. The position could be different for an existing supplier seeking to expand its operations.

The analysis undertaken for the Commission suggests that even if prices for each of these services were to return to their long-term averages, bearing in mind the barriers to entry and at best the marginal viability of proven technologies, there is not likely to be any opportunity for further commercial processing activities in South Australia. That position would be different if:

a. substantial growth in the demand for services from nuclear power stations being developed in Asia could not be met by existing global or domestic capacity

b. demonstration of the feasibility of a technology (for example, laser enrichment) substantially reduced the cost of establishing a facility

c. an alternative competitive advantage was demonstrated relative to existing suppliers (for example, security of supply, non-proliferation and/or fuel leasing arrangements).

Although the first two of these scenarios are not presently probable, neither are they implausible. The third would depend on pursuing waste storage and disposal options addressed in this report and, if they were successful, would represent a realistic opportunity. Capitalising on the opportunity created by any of those circumstances would depend on reaching an agreement with the holder of the technology, either under licence or in partnership, to support a new facility in South Australia.

30. Proximity of uranium mining would not, by itself, present a competitive advantage for conducting processing activities. However, the concept of fuel leasing has the potential to alter that position.

It does not appear that transport costs of uranium oxide concentrate are such a significant component of the costs of conversion, enrichment and fuel fabrication services as to provide a competitive advantage. As such, close proximity to where uranium is mined does not itself justify the development of domestic conversion facilities. An Australian facility would benefit only from avoiding the cost of transporting UOC to a converter located elsewhere, presently in Europe or Canada. This cost advantage is estimated to be less than 3 per cent of the cost per kilogram of the UOC.[80] However, this potential advantage would be offset by the disadvantage that an Australian conversion or enrichment facility would experience in having to transport its output – a specialised activity – to fuel fabricators in the northern hemisphere. Whether there is any remaining advantage would require identifying specific customers, and assessing a range of other factors, which are too uncertain to be the subject of this analysis.

The Commission's financial analysis of further processing activities did not take account of the potential effect of a fuel leasing service. Such a proposal might affect the growth in demand for further processing services by providing a unique service that combines used fuel management and further processing. Such a service would be particularly valuable for customers with substantial used fuel management challenges. This would significantly alter the market share and price assumptions underlying the financial analysis. Fuel leasing is discussed in Chapter 5.

REPROCESSING

31. Reprocessing of used nuclear fuel has proven to be a risky technology to introduce, and its commercial viability has been undercut by the availability and low cost of uranium. Without nuclear power generation, a used fuel reprocessing facility would not be needed in South Australia, nor would it be commercially viable.

After several years of being used, nuclear fuel is discharged from the reactor core. At this point, there are two pathways for the fuel. The first, reprocessing, involves the separation of plutonium (Pu) from the irradiated uranium.[81] The other is to temporarily store, and later dispose of, the used fuel in a deep geological repository.

In the standard method of reprocessing, known as PUREX (plutonium and uranium recovery by extraction), the used fuel is cut up and dissolved in hot nitric acid and the plutonium and uranium are separated from fission products and heavy by-products.[82] Both are subsequently converted to oxide powders. Both the plutonium and uranium can be recycled and manufactured to produce uranium oxide or mixed oxide (MOX) fuels for use in a limited number of reactors.[83] A further description of aqueous reprocessing and other methods is given in Appendix C.

Reprocessing has been undertaken only in countries with nuclear power programs. The countries currently engaged in reprocessing are France, Japan, Russia, India and the UK.[84]

Reprocessing has proven to be highly expensive and technically complex. The cost of extracting and reprocessing the plutonium for use as nuclear fuel is greater than the cost of new uranium.[85] There is a sufficient global supply of uranium at low cost for existing and committed reactors.[86]

Regarding the technical complexity, two countries with highly sophisticated nuclear industries and considerable expertise, Japan and the UK, have faced significant difficulties in successfully developing commercial reprocessing facilities. Japan's Rokkasho reprocessing plant has been under construction for more than two decades. To 2013, the estimated start-up date had been postponed 20 times.[87] The facility is now expected to be operational in 2018.[88] In 2011, the Japan Atomic Energy Commission predicted that the construction and operating costs of the facility over 40 years would amount to about US$120 billion, approximately 10 times the cost of interim storage.[89] The UK's recent reprocessing plant, the Thermal Oxide Reprocessing Plant (THORP), faced a number of challenges in its operation[90] and never operated at its intended capacity. THORP will cease reprocessing by 2018 due to falling domestic customer demand and following the completion of existing international contracts.[91]

A number of responses to the Tentative Findings suggested a more favourable view of reprocessing should have been taken in light of future reactor developments.[92] The long-term prospects of those technologies are addressed in Chapter 4: Electricity generation, and in Appendix E: Nuclear energy — present and future. Those responses do not alter the view that a new reprocessing facility based on current technology would not be economically viable under current and likely future market conditions.[93] For these reasons, and without the development of domestic nuclear power generation, there would be no need to develop a reprocessing facility in South Australia. Given this finding, the environmental risks associated with the activity do not require further consideration. The proliferation risks associated with reprocessing and separated plutonium are addressed in Chapter 8: Non-proliferation and security.

NUCLEAR MEDICINE

32. The Australian Nuclear Science and Technology Organisation (ANSTO) already operates a research reactor and associated facilities for manufacturing molybdenum-99 in Sydney. Considering the cost of duplicating this infrastructure and the nature of the market, it would not be profitable or cost-effective for South Australia to engage in this activity.

The use of radioactive isotopes for imaging, diagnosis and the treatment of illness and disease, broadly known as nuclear medicine, plays an essential role in modern medical practice.[94] Radioisotopes are targeted at specific tissues to help detect and monitor health issues, or to deliver doses of radiation to selected areas to treat disease without damaging surrounding healthy tissue.

Radioisotopes for medical procedures are produced in either a reactor or cyclotron, depending on the type required. The majority of the most commonly used medical radioisotopes are produced in only a small number of research reactors around the world.[95] Because most isotopes decay swiftly after production, location of production and transportation are critical issues.[96]

Currently, the most commonly used radioisotope in diagnostic procedures is technetium-99m (^{99m}Tc), which is produced from the decay of its parent isotope, molybdenum-99 (^{99}Mo).[97] In Australia, this is produced exclusively in ANSTO's OPAL research reactor in Sydney.[98]

Figure 3.4: The cyclotron at the South Australian Health and Medical Research Institute

Image courtesy of SAHMRI

ANSTO is constructing a new nuclear medicine manufacturing plant, which will significantly expand its capacity to manufacture ^{99}Mo: it plans to triple production to meet increasing Australian and some international demand.[99] The radioisotope ^{99m}Tc can be produced using non-reactor technologies; however, unlike research reactors, they are unable to do so efficiently and in sufficient volumes to meet demand.[100] Noting that ^{99m}Tc has a short half-life (six hours), production must be close to where it is used.

South Australia imports ^{99}Mo for medical procedures from ANSTO.[101] At present, there is no demand in Australia for a second reactor for medical purposes.[102] There would be significant barriers to establishing a reactor in South Australia for this purpose, not least the expense and complexity of the required infrastructure.[103]

33. There are opportunities, complementary to ANSTO's activities, to make greater use and expand the capabilities of the cyclotron and laboratories concerned with the manufacture of radiopharmaceuticals at the South Australian Health and Medical Research Institute (SAHMRI).

South Australia's cyclotron, a particle accelerator, is located at the SAHMRI (see Figure 3.4). It produces a range of radioisotopes in relatively small volumes for medical applications within the state.[104] It is also used for research and development of new techniques and products in the field of nuclear medicine.[105] It has capacity for further utilisation.[106] Manufacturing radiopharmaceuticals using the cyclotron produces very small quantities of short-lived wastes, which are managed on site and regulated by the South Australian EPA. South Australia has significant expertise and skill in this field, within hospitals, universities and at the Molecular Imaging and Therapy Research Unit at SAHMRI.[107]

There is a range of opportunities to expand the cyclotron's current capabilities that could be realised with further investment.[108] These lie in the research and development of new techniques for manufacturing radioisotopes for medical applications, the skilling of Australian and overseas technicians, and research to develop new imaging techniques and therapies. They relate to[109]:

a. producing and handling positron emission tomography (PET) isotopes, by assessing the manufacture and diagnostic effectiveness of new or prospective positron emitters

b. undertaking new, commercially focused trials on promising radiopharmaceuticals of both diagnostic and therapeutic types

c. developing new micro-dosimetry tools and methods for verifying the effectiveness of therapeutic radiopharmaceuticals—this has commercial potential because it facilitates the licensing of new drugs that use radionuclides

d. examining how to commercially produce the alpha and beta emitting radionuclides that are emerging as components in new and promising therapeutic radiopharmaceuticals.

Expansion of the cyclotron's capabilities could be realised gradually. Incremental steps could include[110]:

a. installing a beam-splitting system with increased targets to facilitate further research and experimentation into prospective and novel areas of nuclear medicine, including tracers, proton therapy and targeted alpha therapy

b. developing a unique expertise and training capacity on an international scale in these novel areas of nuclear medicine, potentially within an on-site training centre

c. developing infrastructure to enable the commercial manufacture of iodine-123 (^{123}I) for use in specialised imaging and diagnosis. Following closure of the Australian cyclotron that supplied this isotope, it is currently imported from Canada.[111] As well as import replacement, there is scope to export to the Asia–Pacific market

d. developing a range of novel research and development programs using the enhanced cyclotron capabilities.

Investments in such infrastructure could enable South Australia to develop an internationally recognised centre of expertise in nuclear medicine research. Collaboration between the SAHMRI, South Australian universities, other research organisations and the private sector would be central to the successful development of such a centre. A plan would need to be developed to address the strategies required to realise such opportunities.

NOTES

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