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# Response to Nuclear Fuel Cycle Royal Commission's Issues Paper 2

—Further Processing of Minerals and Manufacturing of Materials Containing Radioactive and Nuclear Substances—

**Contents**



## 1. Introduction

This submission addresses aspects of questions 2.1, 2.4, 2.8, 2.9, 2.11, 2.12, 2.13 and 2.14 from Issues Paper 2.

The way the questions in the Issues Paper are framed tends to bias discussion towards a favourable view of 'further processing of … nuclear substances' and encourages respondents to look for solutions to any obstacles to going down this road. There is also a danger that this framing will serve to disguise the connections between the issues. We argue that the case against further involvement by South Australia[1] in the nuclear fuel cycle is overwhelming and that this becomes clear when the issues are addressed in a comprehensive fashion. Therefore, we have taken a comprehensive approach, rather than answering each question point by point. Nevertheless, each question is covered in varying degrees of detail in the discussion.

Given that we find further involvement in the nuclear fuel cycle to be clearly undesirable, we do not attempt to respond to questions directed at facilitating further involvement. Issues related to medical and scientific isotopes are not addressed, not because they are not important, but because we regard them as a distraction from the main purpose of the Royal Commission, which is to examine the feasibility of expanding South Australia's involvement in energy-related aspects of the nuclear fuel cycle.

The following components of the questions are touched on in varying degrees of detail:

[1] The Royal Commission was established by the South Australian government and purports to relate only to South Australia, but the issues are not limited to South Australia, nor can decisions be made by South Australia alone. Therefore, although we generally refer to South Australia, it should be understood that our remarks apply to Australia as a whole.)

2.1 Could the activities of conversion, enrichment, fabrication or reprocessing (or an aspect of those activities) feasibly be undertaken in South Australia?

2.4 What are the projections for future supply and demand for conversion, enrichment, fuel fabrication or reprocessing activities? What is the evidence to support those projections? Might it be viable for one or more of those activities, or an aspect of them, to be established in South Australia in the medium or long term? What is the reason for thinking that would be so?

2.8 What additional risks for health and safety would be created by the establishment and operation of such facilities in South Australia?

2.9 What additional environmental risks would be created by the establishment and operation of such facilities in South Australia?

2.11 What security implications are created by the activities of conversion, enrichment, fabrication or reprocessing of nuclear fuel, or by further manufacturing activities, in South Australia? What is the evidence which suggests that such risks might materialise?

2.12 What safeguards issues are created by the further participation in South Australia in activities (such as the production of uranium oxide, conversion, enrichment, fuel fabrication or reprocessing) necessary for uranium to be used as a fuel in electricity generation?

2.13 What financial or economic model or method ought be used to estimate the economic benefits from South Australia's establishment and operation of facilities for the conversion, enrichment, fuel fabrication or reprocessing of, or the manufacture of materials containing, radioactive and nuclear substances?

2.14 Would South Australia's establishment and operation of such facilities give rise to impacts on other sectors of the economy? What would those impacts be? How should they be estimated and what information should be used? Have such impacts been demonstrated in other economies similar to South Australia?

Besides these questions, we are particularly concerned about the biased wording of question 2.7, which says, 'What are the processes that would need to be undertaken to build confidence in the community generally, or specific communities, in the design, establishment and operation of such facilities?' This wording presupposes that the objective is to establish and operate these facilities and that the public needs to be educated to accept them. This is characteristic of the nuclear industry's 'deficit model' approach to the public, where ordinary citizens are seen as ignorant and lacking a 'correct understanding' (White 2014).

Issues Paper 2 does not refer specifically to the Traditional Owners of the lands that are likely to be targeted for nuclear facilities, but we presume that 'specific communities' in question 2.7 is meant to include Aboriginal people. We are aware that the Royal Commission has hired a person to liaise with Aboriginal people, but, judging from his background, we fear that he sees his role as 'building confidence in the community' to accept nuclear facilities. Aboriginal people have repeatedly rejected nuclear facilities. We think it is about time their opposition was taken seriously. In this regard, we refer you to the following statement by Traditional Owners: 'Traditional Owners say NO: Statement from a community meeting held in Port

Augusta on Saturday 16 May 2015 to discuss the Royal Commission Into The Nuclear Fuel Cycle' (copy attached).

**2. Recommendations and key principles**

(i) Our first recommendation is that the Royal Commission's analysis should be underpinned by a thorough understanding of the following key principles. The validity of these principles will become clear from the discussion in the rest of the submission.

1) When considering the feasibility of conversion, enrichment, fabrication or reprocessing in South Australia, it is important that the first reference point be the track record of the international nuclear industry, rather than rosy predictions based on technologies which have not yet been commercialised. In the case of an industry with such a long history, the past is the best predictor of the future.
2) Given the nuclear industry's history of massive cost over-runs, extreme delays, and total failures, there is no sound basis for making cost estimates or predicting when new technologies might become commercially viable. No economic model can meaningfully address such unreliability.
3) Clear distinctions must be made between theoretical feasibility, industrial feasibility and commercial feasibility. As nuclear technologies were scaled up from research facilities, to prototypes, to demonstration facilities, to industrial-scale facilities, many problems arose and costs escalated. In many cases the consequence was that theoretically attractive technologies became millstones around the necks of countries and companies that invested in them. There is no reason to believe that South Australia will escape such problems.
4) A clear distinction must also be made between the viability of established technologies about which information is openly available and which are acquired through a well-established market, and the viability of untested and restricted technologies for which South Australia is a lead customer. Scenarios for South Australia to expand into conversion, enrichment, fabrication or reprocessing have far more in common with the latter than the former type. As such, they will inevitably be high cost, high risk ventures which will not attract investors without substantial government subsidies and indemnities.
5) The nuclear industry has continued as it started with inadequate measures to protect against nuclear proliferation. Many proposals have been made to address the problems, but measures to strengthen the international security and safeguards regimes have had only marginal benefits. That is because politics has always taken priority. After 70 years, it would be naïve to expect that this situation would change in future. Under these circumstances, any moves to increase the number of countries and organisations with access to sensitive technologies and nuclear materials will increase the risks of diversion to weapons use.
6) Some people promote nuclear energy as a 'clean', 'baseload' power source and claim that it complements renewable energy and energy efficiency. This depiction of nuclear energy is inaccurate. Nuclear energy is logically, and has proved in fact to be, a direct competitor to renewable energy and energy efficiency rather than a complement to these approaches. The word 'baseload', as used by nuclear proponents in this context, should be recognised for the propaganda that it is. It is used to promote nuclear energy and coal and to discredit renewable energy. Instead of the misleading notion of baseload supply, thinking about electricity supply systems should be framed in terms of variable (e.g.

solar photovoltaic, wind) and flexible (or dispatchable – e.g. solar thermal, hydro, battery, gas) power sources, coupled with energy efficiency and demand response. The focus should be on creating a system that rewards energy services (such as space heating, space cooling, hot water, comfort, etc.) rather than energy supply per se.

(ii) Our second recommendation is that, based on the arguments provided in the remainder of this submission, the Royal Commission recommend that South Australia not engage in further processing of minerals and manufacturing of materials containing radioactive and nuclear substances.

## 3. Uranium enrichment

*3.1 Proliferation and security*

Uranium enrichment is a dual use technology and, as such, is a sensitive technology from the perspective of nuclear weapons proliferation. While we do not believe that Australia currently has any intention of acquiring nuclear weapons, it is worth remembering that up until the early 1970s Australia considered doing just that (Broinowski 2006; Reynolds 2000).

However, probably a greater concern at this time is the implications of an Australian uranium enrichment program for regional and global nuclear proliferation. Even if Australia were interested only in enriching uranium for commercial purposes, neighbouring states would be concerned about the nuclear weapons capability this gives Australia. As Australian military strategists are at pains to point out, Australia considers not only the military intentions but also the military capabilities of other countries, so naturally those same countries would view Australia's uranium enrichment program in a similar light. Some of those countries would see an Australian enrichment facility as a reason for them to develop their own uranium enrichment capability. In this regard Professor Hugh White noted:

> No matter what we think, and no matter what we say, a decision to develop uranium enrichment capability in Australia would be seen by our neighbours as a short cut to nuclear weapons. We would need to think very carefully about how they might respond (White 2007).

At a global level, a great deal of diplomatic and military effort has been invested into limiting the number of states with access to nuclear sensitive technologies. For example, in February 2004, then United States President George Bush announced a policy of refusing to sell 'enrichment and reprocessing equipment and technologies to any state that does not already possess full-scale, functioning enrichment and reprocessing plants' (Bush 2004). Since then the United States Government has been forced to make compromises on this policy, but the objective of restricting the spread of this technology on nuclear non-proliferation grounds remains. Therefore, resistance can be expected from non-proliferation advocates within the United States administration to Australia embarking on a uranium enrichment program.

So far only a few states have acquired uranium enrichment capabilities and most of those have gone on to acquire nuclear weapons. Those who have not gone on to acquire nuclear weapons are nevertheless viewed with varying degrees of suspicion. Iran's uranium enrichment program has been a major bone of contention for over a decade. Japan's largely unsuccessful uranium enrichment program is not viewed in the same light as Iran's—few people believe Japan has any intention of acquiring nuclear weapons in the short term—but Japan has consciously and deliberately maintained the capability to acquire nuclear weapons, as revealed in a leaked 1969 Ministry of Foreign Affairs policy document (Mainichi 1994) and alluded to by numerous Japanese politicians since then. Japan's enrichment and reprocessing programs are used as excuses by other countries (for example, Iran, South Korea and North Korea) to justify their own involvement in those fields.

It has been proposed that Australia should consider offering itself as a site for an international uranium enrichment centre and that this would be a positive contribution rather than a problem for non-proliferation. Indeed, one of the Royal Commission's expert advisors is a proponent of this idea (Carlson 2013). However, it is highly doubtful whether such an arrangement would make a useful contribution to non-proliferation, to the uranium enrichment market, or to Australia's economy.

The case of Iran shows that the alleged non-proliferation benefits of international uranium enrichment facilities are highly dubious and subject to unpredictable political circumstances. Along with France, Italy, Spain and Belgium, Iran was a member of Eurodif, an early example of an international enrichment venture. But, as a result of the Iranian Revolution, Eurodif never provided enriched uranium to Iran (Meier 2006). Nor did Iran's membership of Eurodif prevent it from establishing its own clandestine enrichment operations.

In 2007 the International Uranium Enrichment Center was established in the Russian city of Angarsk with Ukraine as a shareholder, but, in light of the ongoing conflict between Russia and Ukraine, the reliability of that international arrangement from the perspective of security of supply is also dubious. Russia is at pains to assert that the conflict has not affected its nuclear business, including with Ukraine (PlattsNuclear News Flashes), but Ukraine is clearly vulnerable to Russia's political calculations.

It turns out, therefore, that the Eurodif and the Angarsk models are vulnerable to precisely those types of international uncertainty that they are supposed to insure against. Furthermore, countries that might be concerned that their supply would be interrupted for political or other arbitrary reasons are not likely to be reassured by a facility located in Australia. In particular, those countries which might wish to establish their own enrichment facility out of fear of sanctions from the United States are likely to be sceptical of Australia's ability to act independently, given its unswerving loyalty to the United States. Hence, precisely those countries which might be interested in the security of supply that an international facility purports to provide would be unconvinced by a facility located in Australia.

Urenco is another international venture. It has provided security of supply for its three partner countries (UK, Netherlands and Germany), but failed spectacularly on the non-proliferation front. Its enrichment program was the source from which enrichment technology found its way to Pakistan and thence to other countries of concern. There is no reason to be confident that similar problems could not arise in an international uranium enrichment centre based in South Australia or anywhere else. In an age where highly sophisticated hackers are able to access top security computer networks, modern information technology poses even greater security risks than the systems that A. Q. Khan accessed to take Urenco enrichment technology back to Pakistan.

*3.2 Feasibility*

The Issues Paper effectively answers its own question regarding the feasibility of uranium enrichment in Australia when it states that the global capacity for uranium enrichment is 65 million SWUs while the current international demand for enrichment is only 49 million

SWUs. The only international uranium enrichment facilities that have been economically viable have run on a commercial basis. Alleged non-proliferation benefits, based on the assumption that participants would gain a secure supply of enriched uranium without developing their own indigenous enrichment capacity, have not been sufficient to stimulate the establishment of these facilities. Unless and until a supply shortfall is anticipated, a new international enrichment facility in Australia will not be viable.

In 2006 the report of the pro-nuclear Uranium Mining, Processing and Nuclear Energy Review said the uranium enrichment market 'is characterised by high barriers to entry, including limited and costly access to technology, trade restrictions, uncertainty around the future of secondary supply and proliferation concerns' (Switkowski 2006, p. 4). Now, the economic prospects for a uranium enrichment industry in Australia are even worse than they were in 2006.

Arguments that a supply shortfall might materialise in future rest on assumptions about an expansion in nuclear energy generation, but high growth estimates by pro-nuclear organisations have been notoriously unreliable.[2] It is doubtful whether the much-touted nuclear renaissance was ever more than rhetoric, but the financial crisis of 2007-08 and the subsequent Fukushima nuclear accident ensured that it did not materialise. It is impossible to predict where and when the next disruption will occur, but the long investment timeframes of nuclear energy make it particularly vulnerable to the uncertainty created by events of this nature.

Some speculate that the next disruptive event has already occurred—Tesla Motor's Elon Musk's announcement in April this year of the Powerwall storage battery—and that this could spell the end of nuclear power (McMahon 2015). The full disruptive impact of this particular technological development will take time to assess, but there are good reasons to believe that the future of nuclear energy will depend on the outcome of a titanic struggle currently being played out between incumbent players invested in the old model of centralised supply-side driven electricity systems and new players committed to an emerging distributed demand-side model based on renewable energy sources.

It is important in this regard to understand that nuclear energy, as a capital intensive technology that is inflexible to changes in electricity demand, is a direct competitor to renewable energy and an enemy of energy efficiency (Cooper 2015). Once the reactors have been built, the most economical way to operate them from the perspective of their owners is to operate them at as high a capacity factor as possible. Nuclear proponents try to make a virtue of necessity by calling this 'baseload', but in fact it means nuclear generation is prioritised over all other energy sources. Renewables are squeezed out and efforts to reduce demand are resisted. This pattern is exemplified by the debacle over Japan's energy policy. Since the December 2012 change of government, the nuclear industry has regained control and has been resisting the uptake of renewable energy and the liberalisation of the electric power system, as it has done ever since the 1990s (see, for example, Ueda 2015).

There are flexible energy sources which do complement variable output types of renewable energy, but nuclear energy is not one of them. For example, natural gas, whose cost structure

[2] For example, there has been a consistent downward trend over the past decade in short-term projections for nuclear generation in IAEA's annual Energy, Electricity and Nuclear Power Estimates. This trend preceded the Fukushima nuclear accident, but became more pronounced after the accident. See also Schneider & Froggatt (2015).

and dispatchability make it a perfect fit with high penetrations of renewable energy. Of course, natural gas is a problem from the perspective of greenhouse gas emissions, but increasingly renewable energy sources, especially when distributed over a broad area and combined with demand management, are able to provide flexible response to fluctuations in supply from variable renewable resources (Diesendorf 2014; 2015).

In regard to economic benefits for South Australia from embarking on a uranium enrichment program, firstly they would be limited by the fact that the technology would be completely controlled by another country. For nuclear non-proliferation reasons, sensitive technology would be supplied on a black box basis by a country or organisation that already possesses the technology. This would limit the potential for value adding in South Australia, given that Australia does not have its own enrichment technology (having sold its laser enrichment technology to GE). Barriers to developing indigenous uranium enrichment technology are high. It has only been achieved on a highly subsidised basis, in most cases with military use as one objective. Even those countries that have succeeded nominally have not necessarily managed to make a commercial success of their enrichment programs. Japan, for example, only ever reached two thirds of its target of 1,500 ton-SWU/year for JNFL's Rokkasho Uranium Enrichment Plant. The plant's capacity fell rapidly from a peak of 1,050 ton-SWU/year in 1998 to zero by December 2010, when the last cascade stopped operating (Sawai & White 2011). Since then JNFL has commenced operating a small number of new design centrifuges, but the plant's poor operating record bears witness to the difficulty of mastering uranium enrichment technology on a commercial basis. USEC's ongoing difficulties with the American Centrifuge Project are further evidence of the technical and economic difficulties associated with uranium enrichment technology (Freebairn 2015).

A second reason why a uranium enrichment program would not be economically beneficial is because it would fall on the wrong side of the above-mentioned struggle between the old and the new. In time we expect the new energy model to prevail. This would be a desirable outcome for both the environment and human welfare. Those regions which find themselves on the right side of history will reap the economic rewards. However, those that find themselves locked into antiquated, cumbersome, expensive and polluting systems will lose on all scores. South Australia has a far greater comparative advantage in wind and solar energy than it does in nuclear energy. It would be the height of folly to allow nuclear interests to obstruct these industries as they have in other countries (and as the coal industry has obstructed them in Australia).

## 4. Conversion and Fuel Fabrication

We believe there are no grounds for coming to more optimistic conclusions than those reached in 2006 by the Uranium Mining, Processing and Nuclear Energy Review on the feasibility of these aspects of the nuclear fuel cycle. In regard to conversion, that report concluded as follows:

> Establishment of conversion in Australia is only likely to be attractive if it is associated with local enrichment, partly due to transport costs, the complexity associated with the handling of toxic chemicals and constraints applying to Class 7 Dangerous Goods (which also apply to $U_3O_8$) (Switkowski 2006, p. 36).

An earlier study reached a similar conclusion:

> As part of the UEGA project, and also as a separate activity associated with the South Australian Government, the prospect of uranium conversion in Australia was also studied in the 1970s. The study concluded that uranium conversion would be viable only if associated with an enrichment project (Carlson 2013, p. 2).

As discussed in section 3 above, enrichment is not viable in South Australia, so, based on the above quotations, nor is conversion.

With the exception of Canada, the only countries with operational commercial-scale facilities for conversion to UF6 for use in uranium enrichment are located in countries with their own uranium enrichment facilities. Canada had the advantage of relatively early entry at a time when demand for nuclear fuel was still expanding, as well as lower transport costs (at least to enrichment plants in the United States), so its commercial success cannot be automatically applied to Australia. In any case, Switkowski's 2006 report observes that the cost of conversion 'is the lowest fraction of all of the steps in the nuclear fuel cycle' (p. 34), so the value added would not be great.

Furthermore, there have been several accidents involving uranium conversion facilities (Depleted UF6 Management Information Network; Vargo 1999). The materials involved are inherently toxic, radioactive and fissionable, so entering into the uranium conversion business would increase the risks to the South Australian public, especially to workers at those facilities.

In regard to fuel fabrication, there would be no advantage in importing enriched uranium to fabricate into nuclear fuel for subsequent export. The World Nuclear Association (WNA) states, 'Currently, fuel fabrication capacity for all types of LWR fuel throughout the world considerably exceeds the demand. It is evident that fuel fabrication will not become a bottleneck in the foreseeable supply chain for any nuclear renaissance' (WNA 2015). The only possible situation where it might conceivably be feasible for South Australia to develop a fuel fabrication plant would be to supply reactors within Australia, but it is unlikely that even that would be viable without heavy government subsidies. Furthermore, as we argue in our submission in response to Issues Paper 3, 'Electricity Generation from Nuclear Fuels', construction of nuclear power plants is undesirable on many grounds, including economic grounds.

Like uranium conversion facilities, nuclear fuel fabrication facilities also have inherent dangers. For example, the 1999 criticality accident that occurred at the JCO re-conversion facility in Tokai Village in Japan related to the fuel fabrication process. It was the most serious nuclear accident in Japan until the Fukushima accident and it occurred at a facility that was considered safe. It resulted from lax work practices, pressures to meet tight deadlines, and a captive regulatory authority (Citizens' Nuclear Information Centre). Shocking as the incompetence and negligence were, it would be foolish to assume that South Australia is immune from such problems.

## 5. Reprocessing

### *5.1 Proliferation and security*

Like uranium enrichment, reprocessing is a dual use technology and therefore a sensitive technology from the perspective of nuclear weapons proliferation. The purpose of the main process currently used (Purex) is to separate plutonium and uranium from the other elements in spent nuclear fuel. The IAEA recognises any isotopic mixture of plutonium (less than 80% $^{238}Pu$) as a 'direct use' nuclear material (IAEA 2002, p. 23). In other words, it can be converted directly into material for a nuclear weapon. Furthermore, separated plutonium is not 'self-protecting'—that is, it is not radioactive enough to prevent thieves from handling it. It must, therefore, be secured to prevent diversion to military use. The security apparatus involved is complex, expensive, opaque, and is likely to infringe on civil liberties.

Existing plutonium stockpiles represent a major security and proliferation threat. However, as Mohamed ElBaradei bluntly put it, 'The nonproliferation regime is starting to come apart at the seams' (ElBaradei 2009). Little has happened since ElBaradei's remark to change that assessment, and, as discussed below, advanced fuel cycle proposals that purport to address the problem will not become a reality during the first half of this century if ever. Many solutions have been proposed, but those which do not include refraining from separating more plutonium will only exacerbate the problem.

*5.2 Precedents*

While traditional reprocessing is not such a difficult chemical process, addressing security, safeguards and safety issues makes commercial scale reprocessing an extremely complex and expensive process. Attempts by the UK and Japan to establish commercial programs have been singularly unsuccessful. It is claimed that France has a successful reprocessing program, but it has been very expensive and is heavily subsidised, including through its military program, and would not have survived as a purely commercial venture.

France's domestically owned plutonium has been used in its light water reactors and fast breeder reactors. The latter were supposed to be the prime user of separated plutonium, but they have been a commercial failure. For example, 'The French Superphénix, the largest sodium-cooled reactor ever built, was designed to demonstrate commercialization. Instead, it operated at an average of less than 7 percent capacity factor over 14 years before being permanently shut' (Makhijani & Boyd 2010, p. 6-7; Von Hippel 2010, p. 10). Use as MOX fuel in light water reactors has been successful from a technical perspective, but '[t]he cost of France's MOX fuel program far exceeds the value of the resulting savings in low-enriched uranium fuel … Recently, a National Assembly Commission of Enquiry recommended that France's Court of Auditors, its equivalent of the U.S. Government Accountability Office, carry out a cost-benefit analysis of France's MOX fuel program' (Von Hippel & MacKerron 2015, p. 13). Indicative of the poor economics of reprocessing is the fact that 'since 1995 the state electricity utility EDF has assigned in its accounts a zero value to its stocks of separated plutonium, as well as to its stocks of reprocessed uranium' (Schneider & Marignac 2008, p. 41).

The United Kingdom's reprocessing program has been an unmitigated disaster. Its Thermal Oxide Reprocessing Plant (Thorp) in Sellafield cost £2.85b to build. When it started commercial operation in 1993, 20 years after it was first proposed, it was already unviable (Buchan 1993). It has since been plagued by scandals, accidents and faulty equipment. It was already way behind in meeting its targets when a leak containing highly radioactive nuclear fuel dissolved in concentrated nitric acid was discovered in 2005. The quantity of leaked liquid, which contained about 20 tonnes of uranium and plutonium fuel, was enough to half fill an Olympic-size swimming pool (Brown 2005). Since then, technical problems, including with evaporator equipment designed to reduce the volume of liquid high level waste, have slowed reprocessing to a snail's pace. Reprocessing contracts due to be completed in 2010 are now not expected to be completed until 2018 and no new contracts are foreseen. Meanwhile, the Sellafield MOX plant, which was supposed to turn the separated plutonium into MOX fuel, was closed after the Fukushima nuclear accident having cost the British taxpayer £1.34b while producing almost no MOX fuel—13.8 tonnes over 8 years compared to a projected output of 120 tonnes a year (Connor 2011).

But compared to Japan's reprocessing program, the UK's program has been a shining success. It is 30 years since the governor of Aomori Prefecture and the mayor of Rokkasho Village accepted a request from the Federation of Electric Power Companies to establish three nuclear fuel cycle facilities in Rokkasho (a reprocessing plant, a uranium enrichment plant and a low-level radioactive waste disposal center) and 22 years since construction of the Rokkasho Reprocessing Plant commenced. Originally scheduled for completion in 1997 at a cost of 760 billion yen, the estimated cost has since tripled to 2.24 trillion yen and the total cost of construction, operation and dismantling the plant is estimated to be 11 trillion yen (Sawai 2005). As of October 2014, the projected start up date had been postponed 21 times and there is no reason to expect that it will begin commercial operations in March 2016 as currently planned.

*5.3 Feasibility*

It is important to understand the lessons of these failures, which include drastic overruns of construction schedules, gross underperformance, and wildly optimistic cost estimates.

The first lesson is that, in regard to the nuclear fuel cycle, what may sound convincing in theory does not necessarily work in practice, especially not on an industrial scale. A related lesson is that estimations of cost and start-up times made by promoters of these projects have no credibility. The return on the colossal amounts invested in the nuclear fuel cycle programs of the UK and Japan has been virtually zero. With such a history, economic estimates presented by people proposing that South Australia invest in nuclear fuel cycle technologies should be recognised for the PR that they are. Decision-makers crave facts and figures on which to base their decisions, but they must resist the temptation to rely on figures provided by nuclear proponents.

It is not necessary to use sophisticated economic models to recognise that projects with such a high chance of failure on such a large scale are not viable. However, even for those reprocessing program that have actually worked, they turn out to be much more expensive than a once-through approach to dealing with spent nuclear fuel (Mecklin 2015; Rosner, et. al. 2015).

A further lesson is to be extremely sceptical of suggestions that South Australia can succeed where countries with far more experience in the field have failed. Australia has very little experience with the back end of the nuclear fuel cycle. This lack of experience breeds a naïve support for alternative forms of reprocessing: pyro-processing, 'integrated' fuel cycles, and partitioning and transmutation of actinides. These technologies, combined with Generation IV reactors, have gained a following in Australia in recent years, but they are nowhere near becoming a commercial reality. It is important to recognize that as Generation IV reactors are still in the experimental stage and have not been commercially built, any projections about them are pure speculation and not based on facts and evidence. Judging from the experience with existing reprocessing facilities, it would be foolish to assume that just because these alternative technologies sound plausible on paper they will not face as great or greater obstacles to commercialisation.

This conclusion is based not only on the above review of past history, but also on detailed analyses by official expert bodies. For example, the Blue Ribbon Commission on America's Nuclear Future reached the following conclusion (bold italics in the original text):

> ***no currently available or reasonably foreseeable reactor and fuel cycle technology developments—including advances in reprocessing and recycling technologies—have the potential to fundamentally alter the waste management challenge this nation confronts over at least the next several decades, if not longer*** *(Blue Ribbon Commission 2012, p. 100).*

Another report which provides a realistic assessment of the potential of so-called advanced fuel cycle technologies was published in April this year by France's Institute for Radiological Protection and Nuclear Safety (IRSN). In regard to reprocessing for molten salt reactors, one of the unproven technologies favoured by nuclear proponents in Australia, it makes the following comment:

> [T]he feasibility of the concept and the associated reprocessing has not yet been established. This is particularly significant given that some very specific problems are associated with the concept (containment of liquid fuel, choice of materials, corrosion by the molten salts, reprocessing of the salt, processing of the ultimate used salts, etc.). It therefore seems that these prospective technologies, which represent a complete break with the current technologies, will probably not be accessible until at least the second half of this century given the major developments and technological breakthroughs needed (IRSN 2015, p. 209).

The web site on which the report is published is pessimistic about the prospects of the advanced fuel cycle technologies under consideration. It states (bold in original):

> **On the basis of its examination, IRSN considers the SFR system to be the only one of the various nuclear systems considered by GIF to have reached a degree of maturity compatible with the construction of a Generation IV reactor prototype during the first half of the 21st century;** such a realization, however, requires the completion of studies and technological developments mostly already identified (IRSN 2015 press release).

In regard to the SFR system (sodium cooled fast reactor)—the only one said to have any short- to medium-term prospects—it is important to remember that commercialisation of this type of reactor has been claimed to be just around the corner since the 1960s, but has receded like a mirage ever since. Even more unsuccessful than France's experience with SFRs (see above) has been Japan's debacle. Japanese nuclear policy makers originally proposed commercialising SFRs by about 1980 (Japan Atomic Energy Commission 1961), but that target receded further and further into the future, until by 2005 the target for commercialization had slipped to 2050 (Japan Atomic Energy Commission 2005). Predictions of early commercialisation of SFRs should, therefore, be taken with a large grain of salt.

Some point to Russia, China and India, but there is limited data available on their programs. It is known that Russia's fast breeder reactor program has been plagued by sodium leaks and fires. 'Russia's *BN-600* has experienced a respectable capacity factor but only because of the willingness of its operators to continue to operate it despite multiple sodium fires' (Von Hippel 2010, p. 10). The Fukushima nuclear accident is testimony to the dangers of cutting corners on safety, and the Soviet Union experienced disasters of its own. In any case, it is inconceivable that Australia would turn to Russia for sensitive technology of this nature.

*5.4 Environmental impact*

Other than where there are major accidents, reprocessing is the area of the nuclear fuel cycle with highest releases of radioactivity. In regard to France's La Hague reprocessing plant, Schneider and Marignac (2008) note:

> The limits on radioactive discharges to the atmosphere and ocean from the La Hague reprocessing plant are two to four orders of magnitude larger than those for a 1300 MW reactor at the Flamanville site, just 17 km (10 miles) down the coast (p. 27).

They go on to observe that 'La Hague is currently the largest man-made source of radioactivity releases to the environment' (p. 41). Of course, that was before the Fukushima nuclear accident.

Thus, contrary to the spirit of the London Convention (Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972), large quantities of radioactive material are routinely dumped into the marine environment through liquid waste pipes. The impact of marine and atmospheric releases on human health is disputed, but there is evidence of an increased incidence of childhood leukaemia around the La Hague plant (Guizard et. al. 2001).

We do not have references for research results on actual impacts of reprocessing plants on fishing industries, but many neighbouring districts and countries express their concern (for example Ireland (Breaking News 2003) in regard to Sellafield in the UK and Iwate Prefecture in regard to Rokkasho in Japan (Sawai 2006)). The devastating effect of the Fukushima nuclear accident on fisheries throughout Japan, but particularly in the Tohoku region, demonstrates the damage that radioactive contamination of the marine environment can do to this industry, both as a result of elevated readings of radioactivity in fish and other estuarine and marine products, as well as through reputational damage. (See, for example, Kyodo 2015 for information on international restrictions on imports.)

Some claim that reprocessing reduces the volume of radioactive waste, but Schneider & Marignac (2008) find that 'with past and current operating practices, there is no clear advantage for the reprocessing option either in terms of waste volumes or repository area' (pp. 3-4). As discussed above, including the quote from the Blue Ribbon Commission, there are no grounds for believing that in the foreseeable future advanced fuel cycles will solve these problems.

Finally, the inherent risk of catastrophic accidents at reprocessing plants should not be forgotten. The Norwegian Government takes this risk seriously and commissioned a report into the potential impacts of an accident at Sellafield. The report found:

> The environmental consequences for Norway following a hypothetical accident at Sellafield – with a release of 1 % of the total assumed inventory contained in the B215 HASTs – will according to our model predictions be severe, particularly in connection to sheep and goat production (Thørring et al 2010, p. 23).

Serious accidents have occurred in the past at reprocessing plants, including at the Savannah River and Tomsk plants. The explosion at the Tomsk plant in 1993, in particular, led to 'major releases to the environment' (Institute for Radiological Protection and Nuclear Safety 2008, p. 3). These accidents relate to Purex plants. Nuclear proponents in Australia are wont to treat the failings of the current mainstream nuclear technologies as irrelevant to the future, but it is naïve to assume that unproven technologies will be any safer than existing technologies. The materials they are dealing with are as inherently dangerous and the processes are at least as complex, so unpleasant surprises should be expected.

## 6. Conclusions

The fuel cycle activities proposed in Issues Paper 2 should all be rejected on economic, environmental, safety, and non-proliferation grounds. The poor record of the nuclear industry and its failure to live up to its promises of cheap, reliable and safe operation should be the main yardstick for judging future performance.

The economic risks involved in establishing nuclear fuel cycle industries have always been born by the state, which in turn passes them on to taxpayers. It would be irresponsible to divert scarce tax dollars to establish industries that have such a high risk of failure.

South Australia can do much better than pin its hopes on the outdated energy model on which the nuclear industry is based. It is already leading the way in renewable energy, which has far more job-creating potential than capital intensive nuclear energy (Diesendorf, M 2015, p. 22). The Royal Commission must recognise that the biggest threat to South Australia building on its leadership position in Australia to become a world leader in renewable energy and energy efficiency is for it to hitch its fortunes to the broken wagon of the nuclear industry. It must discard the glossy PR brochures of the nuclear spin doctors and read the signs and the trends that are showing the way to the future.

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