10th March 2016

Response from the Medical Association for Prevention of War (MAPW) and the Public Health Association of Australia (PHAA) to the *Tentative Findings* of the South Australian Royal Commission on the Nuclear Fuel Cycle

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The MAPW and the PHAA wish to respond to the tentative findings of the Royal Commission.

In particular, we will be addressing two issues:

- The proposal that importation and management of international High level waste (used nuclear fuel) and Intermediate level waste represents an opportunity to generate revenue. These tentative findings do not acknowledge the major technical, toxic, safety, financial, social, regulatory and ethical risks. This proposal makes a number of assumptions and calculations that need further scrutiny, incorporating both local and international experience and existing evidence. The proposal is about short term financial gain and disregards the clear risk to current and future generations.
- Cyclotron generation of nuclear medicine isotopes

1. IMPORTING HIGH LEVEL INTERNATIONAL WASTE

Technical Issues

MAPW and the PHAA concur with the following principles established by the International Atomic Energy Agency[1]:

"Radioactive waste shall be managed in such a way:

- as to secure an acceptable level of protection for human health.
- as to provide an acceptable level of protection of the environment.
- as to assure that possible effects on human health and the environment beyond national borders will be taken into account.
- that predicted impacts on the health of future generations will not be greater than

[1] International Atomic Energy Agency, 1995

relevant levels of impact that are acceptable today.
- that will not impose undue burdens on future generations."

The commission notes that Finland and Sweden have "successfully developed long term domestic solutions" for their used fuel (high level waste) and intermediate level waste. Whilst it is noted that these two countries have an engineering and technical approach that has met licensing conditions, and have gained social consent for their location, it seems misleading and an overstatement to talk about "success" given they will not be even starting operation until early next decade. There are no operating high level waste (HLW) repositories anywhere in the world. The commission does not acknowledge the many technical failures that have occurred to date (some discussed below).

Major safety and groundwater/environmental contamination issues

According to the IAEA best practice model, disposed waste is not intended to be retrieved, and has minimal reliance on active controls such that active management is not supposed to be required and that passive mechanisms are meant to be sufficient to maintain safety. Deep geological emplacement is the IAEA's current preferred means of disposal, but its safety depends on permanent isolation of radioactive materials from the environment. Deep water contamination by radioactive waste after corrosion of waste containers is a major issue, yet good understanding of hydrogeology is lacking, especially over the very long time periods required. The Commission acknowledges that it is not possible to know the geological and climatic conditions in the distant future. The "engineered barriers" designed to work to delay exposure of the fuel to groundwater are in fact experimental, given the time frames required are stability for hundreds of thousands of years.

Major problems internationally

Groundwater contamination has already been a problem in waste storage sites. For example, after less than two decades Germany is in the process of retrieving waste from a deep geological repository because of water seepage. Three shallow repositories in the US have been closed for environmental reasons. The planned high level waste repository in Nevada has been abandoned, despite 20 years of work and over US$10 billion spent. Reasons were numerous, and included falsification of data in regard to ground water modelling. A deep repository in New Mexico will be closed for at least four years, after two separate failures comprising a fire and later an episode of radiation release. The US government report found the New Mexico facility was hampered by "failure to fully understand, characterize, and control the radiological hazard. The cumulative effect of inadequacies in ventilation system design and operability, compounded by degradation of key safety management programs and safety culture, resulted in the release of radioactive material from the underground to the environment, and the delayed / ineffective recognition and response to the release."

However, because final disposal is an untested technology, reversibility needs to be part of the design. As illustrated by the waste repository in Germany, there may be an unanticipated future need to retrieve waste materials that have been disposed of, so this capability should be a key part of the design of any waste repository. The Commission refers to a KBS- 3 multi-barrier system includes 400-500 m of bedrock fill, so clearly retrievability is not part of the example design cited.

Transport

There is also a significant risk with transport of these materials. Nuclear accidents with uncontrolled release of toxic materials have been happening for decades[2]. The spent fuel contains material that can be used to make nuclear weapons, and as such has the potential to be a target both when it is being moved, when it is being stored and when it is eventually placed.

Regulation

The 2011 IAEA document "Establishing the Safety Infrastructure for Nuclear Power Plants" notes "Standards are only effective if they are properly applied in practice."[3] The existing regulation and oversight of the Olympic Dam uranium mine site, with its sweeping exemptions from regulation, provides a stark (and salutary) example of lack of transparency and appalling abrogation of responsibility by the South Australian Government.

In turn this does little to engender confidence in the South Australian government's ability to ensure the future safety or regulation of storage and disposal, particularly of high level waste. Indeed the Royal Commission made no note of the significant problems for worker occupational health and safety raised (via an incident revealed using Freedom of Information legislation) at the Olympic Dam site that was outlined in the MAPW submission. This further reinforces the complete lack of adequate regulatory oversight in the uranium industry currently. In turn this emphasises the high likelihood of absence of adequate responsible oversight of any future waste facility.

Given this extremely poor record, it will be very difficult to build confidence in the industry.

Ethics

It is startling that ethical considerations have featured so little in the High Level Waste proposal. Leaving future generations with a large amount of toxic waste that needs to be stored for hundreds of thousands of years takes no account of their health and well-being. It is acknowledged that High Level Waste needs storage well beyond the period for which we can predict the behaviour of geological formations. We know that any additional radiation over and above background levels increases the risk of cancer and cardiovascular disease[4][5][6]

This proposal effectively ignores the health of many future generations of South Australia.

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[2] Let the facts speak www.letthefactsspeak.org 2012

[3] Establishing the Safety Infrastructure for Nuclear Power Plants International Atomic Energy Agency 2011

[4] Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, National Research Council. 2006 "BEIR VII-Phase 2: Health Risks From Exposure to Low Levels of Ionizing Radiation" http://www.nap.edu/catalog/11340.html

[5] Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries. BMJ. June, 2005. Cardis et al.

[6] Little, M. P., T. V. Azizova, D. Bazyka, et al. 2012. "Systematic Review and Meta-Analysis of Circulatory Disease from Exposure to Low-level Ion- izing Radiation and Estimates of Potential Population Mortality Risks." Environmental Health Perspectives, vol. 120, no. 11 November 2012, pp. 1503–151

Social Impacts

In the current Federal government search for a low and intermediate level domestic waste repository, there are many reports of divided communities. Misleading statements by politicians and ANSTO claiming the dump is urgently needed for ongoing nuclear medicine manufacture, a highly inaccurate government “Fact” sheet and a very ill informed and misleading telephone hotline all add to the communities’ sense of distrust and uncertainty. MAPW members have been contacted by individuals who are very distressed, as they feel very guilty believing that if they do not agree to a dump then people will die because there will not be adequate medical care. This is very upsetting for these individuals, and reflects a very misleading and badly administered campaign for site selection.

We recognise the federal process is quite separate from the Commission, and we support the need for a “world’s best practice” waste repository for domestic waste. But the very poorly run federal process does illustrate what damage can be done to a community by a campaign that lacks transparency and accurate information. There is no informed consent.

As mentioned earlier South Australia will have additional difficulties convincing the communities that they are suitable custodians of international waste, given the extremely poor regulation of other parts of the nuclear fuel cycle. The Roxby Downs (Indenture Ratification) Act, 1982[7] and subsequent amended bills as they apply to the Olympic Dam mine, have such extensive regulatory exemptions that community confidence will be very difficult to obtain.

The history of remediation works undertaken at Maralinga in the late 1990s also reduce community confidence in government management of nuclear materials. These were poorly done and have left a toxic region with erosion of waste sites releasing material in to the wider environment. Files released under FOI in 2011 noted that nearly a quarter of the contaminated debris pits had been eroded or subject to subsidence[8].

The tentative findings state that Australia would derive a reputational and financial benefit by assisting other countries in providing a disposal solution for used fuel. It beggars belief that Australia would have an enhanced reputation from taking the world’s longest lived and most problematic toxic waste. The financial benefits are also very dubious, as outlined in our modelling analysis below.

Proliferation and Security Risks, Accidents and Uncontrolled Release

The nuclear industry world-wide has a long history of inadequate regulation, cosy relationships between industry, regulators and political representatives, cost cutting, data falsification, concealment of incidents, human error and accidents and has clear potential for individuals or groups to cause deliberate harms. A high level waste repository will contain materials that can be used to make nuclear weapons. This represents not only a significant security risk for criminal attack, but also will create tensions with our near neighbours if they perceive Australia acquiring the materials to create nuclear weapons. High level waste creates fissile material related proliferation risks and is clearly associated with significant “dirty bomb” hazard.

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[7] www.legislation.sa.gov.au/lz/c/a/roxby downs (indenture ratification) act 1982/current/1982.52.un.pdf

[8] Phillip Dorling Maralinga sites need more repair work files show 12 November 2011 http://www.smh.com.au/national/maralinga-sites-need-more-repair-work-files-show-20111111-1nbpp.html

Financial Modelling

The Commission notes "There is no existing market to ascertain the price a customer may be willing to pay", so the financial modelling as to price is entirely speculative. Note also that the waste quantities in the proposal are also based on very dubious assumptions. An assumed 40% increase in waste generation over and above existing programmes from 'declared nuclear power plants' underpins the figures. In other words, it is assumed all declared programmes will eventuate. This is a major error, given past rates of progress from declared to actual plants. Additionally, it is assumed these reactors will be in service by 2030. This is also highly unlikely, based on the nuclear reactor construction industry's past history of major delays and cost overruns. Furthermore, China's waste should not be in the model, as is in reality it is excluded as a source of waste (because China is highly unlikely to export and is considered not accessible). This is particularly problematic for the modelling as China also happens to be the country which accounts for most of the nuclear power reactors in the future.

But perhaps the biggest error is the assumption that there will be rising nuclear electricity production for the rest of this century. We know that most reactors will reach their use by life in the next 2 to 3 decades and the replacement rate will be less than the rebuild rate, so this is a mathematical impossibility. The Commission's own report outlined the major problems with building new reactors. In fact, the annual review of the nuclear power industry predicts less than half the fleet will be left by 2040. Perhaps that's why there is also added a heroic assumption of a 60 year life span for the reactors, even though licences are only 40 years. Some are getting the extensions but that is not the norm.

The upshot is that based on more realistic assumptions the business case will lose money on a net present value (NPV) basis. Estimates suggest this may be about $50bn. The Commission presents a worst case scenario equivalent to this by assuming they only get half the 'accessible' market ie they don't capture the market, not that it doesn't exist. Combining both scenarios would result in an even greater loss. It is important to remember, most costs in this venture are fixed so they come off the bottom line regardless of the amount of waste taken.

It is very disappointing that the consultants did not factor in scenarios for the market which reflect the real world and thus provide a proper risk assessment.

The creation of a state wealth fund is highly unlikely to benefit future generations for the millennia that this waste exists. Costings provision for a separate fund "*to finance decommissioning, remediation closure and long term monitoring activities*" start in year 45, which does not engender confidence given the whole undertaking seems highly unlikely to cover the costs of construction and running costs.

The additional proposal to establish an associated research group focussed on "*the long term characteristics of used fuel and on the processes for its management, storage and disposal and possible future use*" illustrates what an unknown quantity this whole exercise is. Building a business case projecting over a century when there are such a large number of unknown factors is reckless.

Finally the modelling has been done by an engineering company with nuclear interests. This is very poor practice, as industry players have an active interest in such large projects being pronounced viable.

Please see appendix 2. for further details.

Investment

The sheer magnitude of private sector investment required will lead to major commercial pressures in almost all aspects of this process. Substantial fees and commissions associated with these transactions and contracts are already increasing enthusiasm for such a large project, in both financial sectors and potentially flowing on to the political sector. Political donations in Australia lack transparency, with many opaque foundations hiding donor identity. Where there are large amounts of money to be had by government decision making, there is always the potential for considerable financial support for the appropriate parties or individuals. In these situations the best interest of the community is seldom prioritised.

Insurance

The Commission notes "The amount of commercial insurance cover mandated by the international agreements is apparently inadequate to fully compensate victims and remediate the environment in a catastrophic scenario at a nuclear power plant…The state and federal government would become insurers of last resort". The tentative findings are not clear whether this will be necessary for the proposed high level waste dump. Any proposal that the state become the insurer of last resort illustrates the impossibility of guaranteeing against catastrophic events.

2. CYCLOTRON MANUFACTURE OF ISOTOPES

The Commission rightly notes there are opportunities to make greater use of and expand the capabilities of the cyclotron and laboratories concerned with the manufacture of radiopharmaceuticals at the South Australian Health and Medical Research Institute.

Canadians, who have been the leading exporters and best practice experts producing medical isotopes for over 50 years, are in the process of phasing out nuclear reactor production of the isotope Tc99. If the South Australian government were to adopt Canadian technology, there is potential to join them as world leaders in cyclotron isotope production. Cyclotron technology is likely to have huge demand worldwide, as it has many advantages over reactor production. Over coming decades ageing reactors will be closed, and the very poor economic returns from reactor isotope production means they are unlikely to be rebuilt. Cyclotron production is likely to be the replacement technology. Each country will need its own group of cyclotrons, as the isotopes produced have a shorter half-life and so are unsuitable for export.

It is worth noting what is happening in Canada, as they have been the acknowledged world leaders in isotope manufacture and export for many years. In 2009 Canada produced an expert and independent "Report of the Expert Review Panel on Medical Isotope Production 2009". In responding to this report the government stated 'Canada's NRU reactor has satisfied a significant portion of world demand for Mo-99; by producing at this scale, Canadians have been left to shoulder a disproportionate amount of the nuclear waste burden associated with reactor-based isotope production. This includes the significant costs associated with long-term management of the waste. The Government favours a new paradigm in which Canadians benefit from Canadian-based isotope production, supplemented if necessary from the world market, and supply is sustainable because of reduced waste and improved economics.'

They gave a number of other reasons why Canada wished to phase out reactor use. These included reliability of supply (reactor breakdowns created worldwide isotope supply shortages); investment in reactor production of medical isotopes would crowd out investment in innovative alternative production technologies; and reactor production was the most expensive option, at no stage commercially viable without major taxpayer subsidies.

The Canadian Triumf research team had a successful pilot project in January 2015. They demonstrated a process that enables the routine production of sufficient Tc-99m (which is 85% of isotopes used in nuclear medicine) to satisfy the daily demand for a population the size of British Columbia – or 500 patients – from a six-hour run on a common brand of medical cyclotrons. Clinical trials began in early 2015. There are plans to have 24 cyclotrons operating across Canada by 2018, when they are planning to close down their reactor.

A very comprehensive 2010 OECD Nuclear Energy Agency report found reactor based isotope production requires significant taxpayer subsidies, as the cost of sale does not cover the cost of production. The report concludes: "In many cases the full impact of Mo-99/Tc-99m provision was not transparent to or appreciated by governments… The full costs of waste management, reactor operations, fuel consumption, etc. were not included in the price structure, thus providing a significant deficiency in the pricing mechanism. This is a subsidisation by one country's taxpayers of another country's health care system. Many governments have indicated that they are no longer willing to provide such subsidisation."

Clearly cyclotron production of nuclear medicine is not widely available right now, but planned in Canada in the next 3-5 years. An update this month from the Triumf group outlines current progress.

"There are a number of summaries on the technology and notable milestones listed here: <http://www.triumf.ca/node/3410>;
There are also links to a number of reports here: <http://www.triumf.ca/cyclomed99/articles-and-media>;
However, many are accepting the recent string of OECD reports as the most accurate description of the global Mo-99/Tc-99m landscape at this time. Those reports can be found here: <https://www.oecd-nea.org/med-radio/supply-series.html> - of which I would like to draw your attention to the 2014 and 2015 reports projecting supply capacity and market conditions.

"Current effort exists at two levels: 1) the Triumf team are funded at the federal level to design, test and implement an alternative production method for Tc-99m. The result has seen the team develop commercial scale Tc-99m production on three different cyclotron models (from GE and ACSI). More cyclotron types will be demonstrated shortly. Clinical trials are underway and we are proceeding toward full market approval through Health Canada (equivalent to the US FDA).

2) That said, healthcare services in Canada are provided under provincial jurisdiction, leading to a separate round of discussions with these stakeholders. While there is much support, discussions are focussing on price and reliability. Given that the technology is still new, much of our discussion has been in the form of models and projections. Progress is being made, but we are not there yet.

Files show that Australia had 14 cyclotrons in 2013, of which 9 should be capable of producing an appreciable quantity of Tc-99m. In order to move the discussion beyond models and projections, next is identifying a champion with the appropriate political connections, along with a hospital in Australia willing to serve as a test site. Once the Australian cyclotron community is able to test the technology for themselves, they will be able to make a well informed decision on the matter."

How rapidly we adopt their technology will determine how long we need to use reactor produced isotopes, and have to deal with all the resulting long lived radioactive reactor waste. Cyclotron manufacture of isotopes in Australia would markedly reduce the burden of reactor Intermediate Level Waste produced at Lucas Heights.

A longer discussion of cyclotron isotope production is attached in Appendix 1

IN CONCLUSION

MAPW and the PHAA acknowledges the Commission's findings with regard to the first three areas.

The tentative findings regarding Management, Storage and Disposal of Waste have a significant number of major limitations.

There is strong evidence that all additional radiation carries with it increased health risks. This proposal effectively gambles with the health of many future generations of South Australians, by assuming containment for hundreds of thousands of years is possible. A high level waste repository will contain materials that can be used to make nuclear weapons. This represents not only a significant security risk for criminal attack, but also will create tensions with our near neighbours if they perceive Australia acquiring the materials to create nuclear weapons. High level waste creates fissile material related proliferation risks and is clearly associated with significant "dirty bomb" hazard.

It is not acknowledged that there are no functioning high level waste facilities anywhere in the world, nor are the repeated failures and technical problems encountered by other radioactive waste facilities mentioned. The Commission does state that it is not possible to know the geological and climatic conditions in the distant future. The "engineered barriers" designed to work to delay exposure of the fuel to groundwater are in fact experimental, given the extraordinary time frames envisaged.

Transport of large quantities of High Level Waste has significant risk attached, and is not comparable to the transport of small volumes of nuclear medicine around Australia. Storage of this waste prior to deep geological placement also has a level of risk of accidental or deliberate damage. The South Australian government will have great difficulties convincing communities that they are suitable custodians of international waste, given the existing extremely poor regulation of other parts of the nuclear fuel chain.

The Royal Commission's financial modelling is deeply flawed. Stated assumptions ignore existing historical trends, with many incorrect underlying conclusions. The assumption that ways of dealing with nuclear waste will not change over the course of a century is astounding. There is a lack of independence in the firm chosen to do the modelling. Given the very large financial commitments involved, there is also clear potential that monetary benefits for involved parties (financial, technical and political) may result in undue influence on advice and decision making.

Finally, the proposal to further explore cyclotron manufacture of radioisotopes has merit, and MAPW and the PHAA welcome this proposal as it will reduce the production of radioactive waste and all the major hazards that go with it.

RECOMMENDATIONS

1. The High Level Waste proposal be abandoned.

2. The South Australian government encourage and resource research collaboration with leading experts regarding implementation of cyclotron manufacture of radio isotopes.

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Appendix 1

Medical isotope production in Australia:

Should we be using reactor based or cyclotron technology?

Updated 7th March 2016

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Executive summary

ANSTO (the Australian Nuclear Science and Technology Organisation) is currently planning to dramatically increase the use of the Lucas Heights OPAL reactor to supply a third of the world market with medical isotopes, and is constructing a new facility to be completed by the end 2016. This will result in 97% of the medical isotopes produced at Lucas Heights being sold on the export market, with 3% for Australian use.[9]

Recent advances create a choice as to whether we continue reactor manufacture, or develop cyclotron capacity in Australia.

Reactor production of isotopes has been shown to be unreliable with at times worldwide shortages of supply, due to unplanned outages. Cyclotron use would be more reliable, decentralised and both cheaper and cleaner.

Reactor isotope production and sale can only occur with significant subisidies from government. Canada, who supplies over 30 % of the world market, is phasing out reactor isotope production due to concerns about reliability, cost, radioactive waste accumulation and other issues. Cyclotrons, unlike a nuclear reactor, pose almost no accident, proliferation or terrorist risks.

Reactor use generates a significant long-lived Intermediate Level Waste waste burden which must be safeguarded for hundreds of thousands of years. Provision of subsidised reactor based isotopes may slow the uptake of cyclotron technology in many countries.

In contrast, cylotron technology is cheaper, less prone to shortages of supply, and does not produce any long lived nuclear waste. Canada expects full production of domestic isotopes using cyclotron technology in 3-5 years.

Australia would be better served in the future by following the Canadian example and using cyclotrons to produce medical isotopes.

ANSTO is a tax payer funded organisation. It should be leading the debate on this issue, and providing accurate and up to date information.

The current proposal from ANSTO to markedly increase reactor isotope production should be subject to a public inquiry, given it will have repercussions that include less reliability of

[9] http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Appendices/Australian-Research-Reactors/ accessed 13/1/2016

supply for nuclear medical care, the need for major subsidies and result in the production of waste that will impact on future generations of Australians for millennia.

Background

In Australia there are about 560,000 nuclear medicine procedures per year among 21 million people, 470,000 of these using reactor isotopes. Currently these are largely produced by the nuclear reactor at Lucas Heights in NSW, and imported at times when there are reactor outages (due refuelling, service and maintenance resulting in an "uptime" of 80%). Current construction underway at Lucas Heights will enable ANSTO to provide some 15 million doses per year, launching Australia as a major international supplier of Mo-99 isotope, the precursor to the most commonly used isotope in nuclear medicine,Tc-99m . Current world demand is about 45 million doses per year, so the new plant will be capable of meeting about one-third of world demand from late 2016[10].

Canada, the world's single largest producer of medical isotopes, independently reviewed its nuclear industry in 2009 and decided not to build a new reactor[11]. This review, titled "Report of the Expert Review Panel on Medical Isotope Production 2009" should be read by all members of the Australian Parliament, as it clearly spells out the many reasons why Canada wished to stop supplying over 30% of the world's nuclear medicine market.

Several reasons stood out:

- reactor based production created worldwide isotope supply vulnerabilities due to the inherent unreliability of a linear supply chain, where single point failures create unplanned outages,
- investment in reactor production of medical isotopes would crowd out investment in innovative alternative production technologies both domestically and internationally,
- Canada did not want to continue being the radioactive waste site for other countries' nuclear medicine industries,
- and at no stage was reactor production commercially viable without massive taxpayer subsidies.

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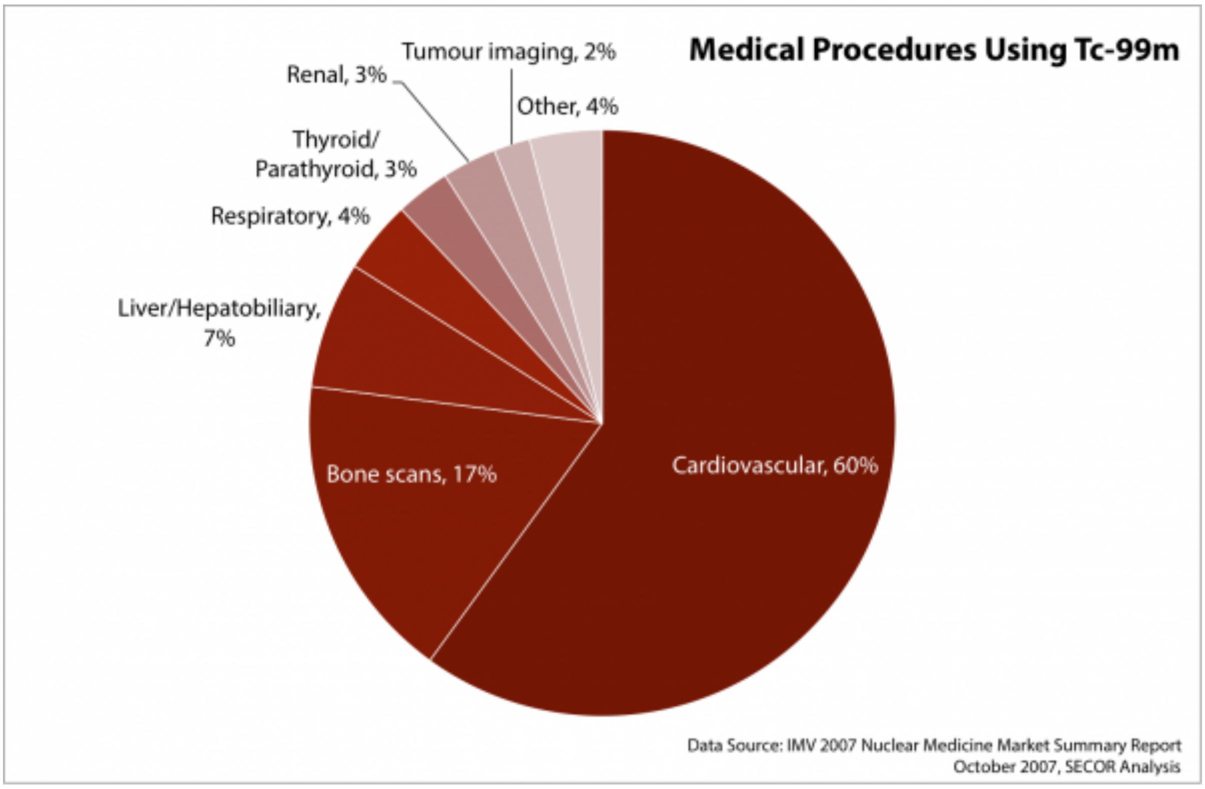
[10] http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Appendices/Australian-Research-Reactors/ accessed 13/1/2016

[11] Report of the Expert Review Panel on Medical Isotope Production 2009 Presented to the Minister of Natural Resources Canada https://www.google.com.au/search?q=Canadian+review+nuclear+isoptope+production&ie=utf-8&oe=utf-8&gws_rd=cr&ei=SE-XVvHLFMbA0gSL4YrAAw accessed 14/1/16

Why do we need isotopes?

There are multiple isotopes used in nuclear medicine, but over 85% of procedures use Technetium-99m (Tc-99m).[12] It is the world's most highly used medical isotope and is the critical component driving over 76,000 imaging procedures per day.



Nuclear Reactors and Isotope Production

Using nuclear reactors to produce medical isotopes introduces a number of challenges. [13] Most critical is reliability of supply. Aging reactors are becoming increasingly unreliable and outages contribute to ongoing shortages. More modern reactors also have unplanned outages.

The infrastructure of reactor production of medical isotopes is that of a linear supply chain, which is inherently unreliable since it is vulnerable to single point failures. Once a failure occurs in this chain, recovery is logistically very difficult until this failure is rectified. This vulnerability has been shown repeatedly over the last decade due to unplanned outages from major isotope producers.

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12 http://www.triumf.ca/cyclomed99/problem accessed 13/1/2016
13 http://www.triumf.ca/faq-medical-isotopes accessed 13/1/2016

A global shortage of medical isotopes arose in 2009 when Canada's National Research Universal (NRU) reactor at Chalk River Laboratories was shut down unexpectedly on May 14, 2009, following the discovery of a leak of heavy water. It was out of commission for 15 months. Another shortage occurred in 2011 following a shutdown of the NRU for regular maintenance. Australia's own OPAL research reactor, which officially opened in April 2007 was unable to produce sufficient medical isotopes for the domestic market until 2009 as fuel supply and engineering deficiencies were addressed.[14]

In addition, having a single central production source creates waste due to delays in shipping. Since half of the Mo-99 decays every 66 hours, much more needs to be shipped, and as a result Tc-99m ends up being wasted as it decays during shipment from far-flung reactors, to pharmaceutical companies, and finally to hospitals. Isotope-generating reactors create other by-products besides Mo-99 that persist as long-lived nuclear waste.

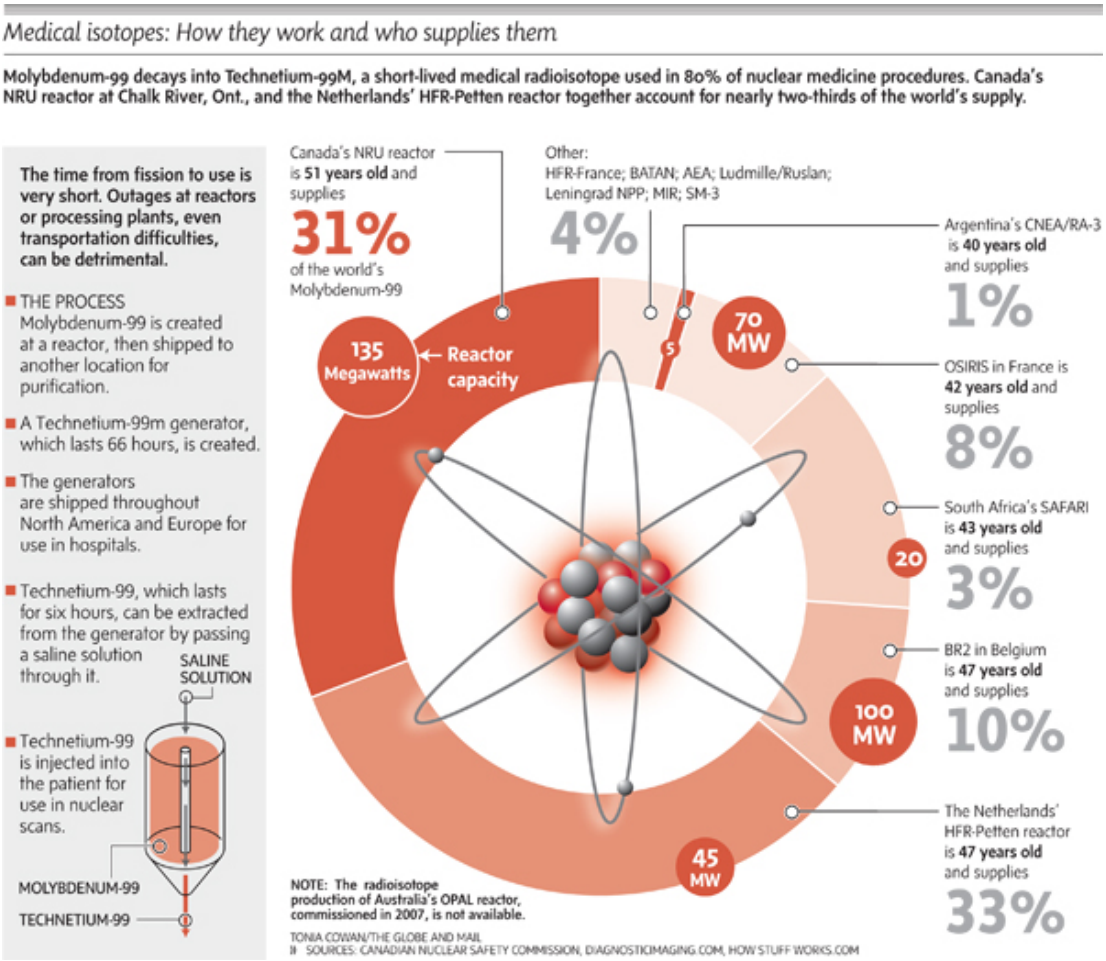
Historically, Tc-99m has been produced in a select number of nuclear reactors around the world. These reactors produce large quantities of molybdenum-99 (Mo-99), which undergo radioactive decay to form Tc-99m within special generators as they are shipped and stored at local hospitals.

Only a few reactors around the globe are capable of producing Mo-99 at an appreciable amount, and many of these reactors are ageing and require more frequent shutdowns for maintenance and repairs.

A Nuclear Energy Agency/OECD report from 2015 titled "The Supply of Medical Radioisotopes"[15] outlines a number of differing supply scenarios between 2015 and 2020, particularly in reference to Technetium-99m which is 80-85% of medical isotopes used. It notes that demand has fallen over 10% in the last year, from 10,000 6-day curies per week to 9,000 6-day curies per week. It states "*The reasons behind market demand being now lower than previously estimated are not fully clear*." They suggested increased efficiency of use, some reduction in the average injected dose and some changes in clinical procedures. Despite this observed drop in demand, they continued to model 0.5% increase in demand for mature markets, and 5% increase in demand in developing markets. This persistent growth modelling was done to "*maintain continuity*".

This report acknowledges the important role of alternative technologies; *"From 2017 the additive irradiation capacity from 'alternative technology' projects primarily in the US is progressive and quite substantial throughout the period, indicating that the additive capacity of 'alternative technology' will support overall security of supply during the 2017 to 2020 period."*

[14] http://www.world-nuclear-news.org/newsarticle.aspx?id=14530 accessed 15/1/2016
[15] https://www.oecd-nea.org/med-radio/supply-series.html accessed 7/3/2016



Sources of Tc-99m from conventional nuclear reactors, courtesy the Globe & Mail.

Australia currently produces just over 1 % of global supply of Tc-99[16]

For many years, Canada's NRU reactor supplied approximately one third of the world's demand of Mo-99 for Mo-99/Tc-99m generators used in hospitals for diagnostic nuclear medicine. The NRU shutdowns in 2009 and 2011 created major problems in supplying Tc-99m to nuclear medicine sites in many countries, including Canada, and illustrated the existing system's single point of failure vulnerability. The Canadian NRU reactor is scheduled to close in 2018. New reactor and non-reactor based projects are coming on line in the 2015-2020 period in Europe, North and South America and the far East[17].

The Canadian Government Expert Review Panel on Medical Isotope Production in 2009 considered building a new reactor when examining options for future isotope supply, but concluded:

> *"Research reactors are shared facilities that have all the benefits associated with multi-use facilities, including the benefit of costs being spread over a large base of activities. However, this is the most expensive of the options, with high capital and*

[16] http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Appendices/Australian-Research-Reactors/ accessed 13/1/2016

[17] https://www.oecd-nea.org/med-radio/supply-series.html accessed 7/3/2016

operating costs. Costs associated with the processing facility, training, licensing requirements, security, and waste management are also very significant.

Revenue from isotope production would likely offset only approximately 10–15% of the costs of the reactor".[18]

A 2010 OECD/Nuclear Energy Agency report titled "The Supply of Medical Radioisotopes- An economic study of the Molybdenum-99 supply chain"[19] found reactor based production of Mo-99/Tc-99m requires significant taxpayer subsidies, as the cost of sale does not cover the cost of production. This study was very comprehensive, and in its opening acknowledgements states:

"This report would not have been possible without input from a significant number of supply chain participants and stakeholders including all major reactor operators, all major processors, generator manufacturers, representatives from radiopharmacies and nuclear medicine practitioners. The input from the supply chain participants was essential for completing this study, and the NEA greatly appreciates the information provided by interviewees."

The report goes on to conclude: "In many cases the full impact of Mo-99/Tc-99m provision was not transparent to or appreciated by governments who were financially supporting research reactors' 99Mo production. The full costs of waste management, reactor operations, fuel consumption, etc. were not included in the price structure, thus providing a significant deficiency in the pricing mechanism. This is a subsidisation by one country's taxpayers of another country's health care system. Many governments have indicated that they are no longer willing to provide such subsidisation.

Overall, it is clear that there is a market failure in the 99Mo supply chain. This market failure has contributed to a supply chain that is economically unsustainable. This pricing structure has resulted in a lack of investment in current and new infrastructure to reliably supply 99Mo."

[18] **Report of the Expert Review Panel on Medical Isotope Production** 2009 Presented to the Minister of Natural Resources Canada https://www.google.com.au/search?q=Canadian+review+nuclear+isoptope+production&ie=utf-8&oe=utf-8&gws_rd=cr&ei=SE-XVvHLFMbA0gSL4YrAAw accessed 14/1/16

[19] https://www.google.com.au/search?q=The+supply+of+medical+isotopes+An+economic+study+of+the+Molybdenum+supply+chain&ie=utf-8&oe=utf-8&gws_rd=cr&ei=d2yYVr-uE8zP0ATX_KegBQ accessed 15/1/2015

Cyclotron isotope production

A cyclotron is an electromagnetic device (about the size of a four wheel drive car) used to accelerate charged particles (ions) to sufficiently high speed (energy) so that when it impinges upon a target the atoms in the target are transformed into another element. [20] In other words, it uses electricity and magnets to shoot a narrow beam of energy at elements, e.g. molybdenum-100, a natural material, and this produces technetium-99.

A cyclotron differs from a linear accelerator in that the particles are accelerated in an expanding spiral rather than in a straight line.

The Canadian approach

In 2009 the Canadian Government Expert Review Panel on Medical Isotope Production recognised that cyclotron technology could readily be adapted to produce isotopes.

Drawing from expertise in physics, chemistry, and nuclear medicine, the team of Canadian researchers (Triumf Cyclomed99 group[21]) set out to develop a reliable, alternative means of production for a key medical isotope Technetium-99m (Tc-99m). In early 2015 they announced they had developed technology that uses medical cyclotrons already installed and operational in major hospitals across Canada to produce enough Tc-99m on a daily basis. They also successfully addressed issues for several other less commonly used isotopes.[22]

This production method for Tc-99m can be used by retrofitting various brands of conventional cyclotrons already in use in hospitals and health centres across Canada. They have had successful pilot projects producing commercial quantities of isotopes in three different cyclotron models (from GE and ACSI). More cyclotron types will be demonstrated shortly. They state proposed upgrades to existing medical cyclotrons and production sites can be done quickly and cost effectively. This allows for rapid deployment of the technology which can be scaled to meet regional demands.

Depending on the machine capability, a large metropolitan area could be supplied by a single dedicated, or a handful of partially dedicated, medical cyclotrons. By enabling regional hospitals to produce and distribute isotopes to local clinics, widespread supply disruptions can be avoided.

[20] http://www.triumf.ca/faq-medical-isotopes accessed 13/1/2016
[21] http://www.triumf.ca/cyclomed99 accessed 15/1/2016
[22] http://www.triumf.ca/cyclomed99/articles-and-media accessed 13/1/2016

The Canadians also believe cyclotrons create new opportunities to export technology to international partners and across multiple business sectors. Other uses exist for nearly all aspects of this technology, with potential applications that have benefits toward other aspects of nuclear medicine, molecular imaging and non-related fields.

By the completion of the project, the research team will be producing Tc-99m on three different brands of medical cyclotrons at a commercial scale. Production and distribution of this most commonly used isotope from a regional supply hub will de-centralize the process, helping to avoid future isotope shortages.

Clinical trials began in 2014 and are proceeding toward full market approval through Health Canada (equivalent to the US FDA).[23] In Canada there are plans to have 24 cyclotrons operating by 2018. But it is likely to be several years before cyclotron production is able to fully substitute for the reactor based isotope production. The Canadian example is useful given some similarities in population, geographic size and city size.

Worldwide many hospitals in major urban centres operate cyclotrons. There are currently over 950 small medical cyclotrons manufactured by several companies (ACSI, GE, IBA, Siemens, Sumitomo, Best, etc.) installed around the world. Approximately 550 of these machines operate above 16 MeV and are capable of producing appreciable quantities of Tc-99m. Existing cyclotrons would need to be upgraded to maximize beam current onto a single target. It is important to note that cyclotron production still needs considerable work to become mainstream.

Cyclotrons in Australia[24]

A new medical production facility in Australia is the twin PETNET cyclotrons at Lucas Heights. These are small cyclotrons dedicated to making fluorine-18 for FDG synthesis.

Two small cyclotrons are operated commercially in Melbourne by Cyclotek while others are based at the Royal Prince Alfred Hospital (NSW), Peter MacCallum Cancer Institute (VIC), Austin Health and Medical Imaging Australia (VIC), Royal Brisbane Hospital (QLD), Wesley Hospital (QLD) and Sir Charles Gairdner Hospital (WA). Another will be integrated into a new building complex at the Macquarie University Hospital in NSW. It remains to be seen how many of these will be sufficiently powerful to adopt the Canadian retrofit technology to produce isotopes in a decentralised way. Australia should look to partner with the Canadians to jointly progress and implement the cyclotron technology.

[23] http://www.triumf.ca/cyclomed99/how-it-works accessed 13/1/2016
[24] http://www.ansto.gov.au/NuclearFacts/AboutNuclearScience/ReactorsandAccelerators/Cyclotrons/ accessed 13/1/2016

It is interesting to note that the current ANSTO web page states:
"*A recent report (2010) from the OECD Nuclear Energy Agency indicates that non-reactor technologies for Mo-99 production are still decades away from fruition, and expresses strong doubts as to whether they could ever substitute for reactor technologies. A 2010 article in the European Journal of Nuclear Medicine and Molecular Imaging comes to the same conclusion*". [25]

Clearly in 2016 this is not the case. It is surprising and concerning that the enormous and very well publicised technological advances made in Canada are not acknowledged. It is also surprising given the 2015 OECD/NEA report "The Supply of Medical Isotopes" acknowledges the significant and rapidly growing role of alternative technology projects, and notes their contribution to world supply is modelled as progressive and quite substantial from 2017 on.

It is important that ANSTO provides up to date and balanced information to government and the public, so that it is not perceived as behaving like a vested interest.

Conclusion

Australia's proposal to increase production of isotopes at the OPAL Lucas Heights reactor comes at a turning point in the technology. We have a choice as to whether we continue reactor manufacture, or develop cyclotron capacity in Australia.

Reactor production of isotopes has been shown to be unreliable. On a number of occasions it has resulted in worldwide shortages of supply, due to the unplanned outages that have occurred. Cyclotron use would enable more reliable decentralised isotope production, which will be both cheaper and cleaner.

Reactor production and sale can only occur with significant subisidies from the government (i.e. taxpayers). It is more costly than cyclotron manufacture. Subsidisation of other countries' health systems at a time when Australia is already financially constrained seems ill advised.

In addition, reactor use for the production of isotopes creates a significant waste burden. 97% of the increased reactor isotope production is planned to be for international sale, so Australia will be left with the reactor waste from this international use. This waste is long-lived Intermediate Level Waste which must be safeguarded for tens of thousands of years, as well as shorter-lived Low Level Waste which requires formal disposal.

[25] http://www.ansto.gov.au/NuclearFacts/AboutNuclearScience/ReactorsandAccelerators/Cyclotrons/ accessed 13/1/2016

Provision of heavily subsidised reactor based isotopes internationally is also likely to slow the uptake of cyclotron technology in many countries.

In contrast, cylotron technology is cheaper, less prone to shortages of supply, and does not produce any long lived nuclear waste, and will be commercially feasible in the near future. Cyclotrons, unlike a nuclear reactor, pose almost no accident, proliferation or terrorist risks.

To develop cyclotron manufacture in Australia, a suitable research team needs a champion with the appropriate political connections, along with a hospital in Australia willing to serve as a test site. Once the Australian cyclotron and medical community are able to test the technology, it will be possible to make a well informed decision.

ANSTO is a tax payer funded organisation. The information it provides to the community via it website is significantly outdated. It should be leading the debate on this issue, and has a responsibility to provide accurate and up to date information.

The decision to markedly increase reactor isotope production should be subject to a public inquiry, given it will have repercussions that include the need for major subsidies, less reliability of supply for nuclear medical care and result in the production of waste that will impact on future generations of Australians for millennia.

Appendix 2

AN ANALYSIS OF JACOBS MCM ECONOMIC MODELLING

This economic modelling has many flawed assumptions. These include:

1. **Political and Social factors**
   It is assumed that countries with substantial accumulated burdens of HLW will be more reluctant and have less incentive to develop a spent fuel permanent disposal site than Australia. This assumes there will be more political and social resistance than in Australia, which has no HLW burden nor foresees a nuclear power industry to produce it. This defies any logic, particularly given Australia's long history of resistance to finding a new location for even a low/intermediate level waste storage facility.

2. **Financial Incentives**
   There is an assumption that a country, which has a large burden of spent fuel to dispose of, and which will conceivably develop a spent fuel disposal facility, will then have less economic incentive to attract other countries' HLW than Australia, in an industry which has high fixed costs and relatively low variable costs. In other words, a nation which already needs to dispose of its waste will not only have a greater economic incentive to develop its own repository, but once it does so, will also have a greater economic incentive to take others' HLW. The price needed for such a country to take waste would be significantly less given economies of scale and existing infrastructure. Competition would result in Australia's market share and price paid both being significantly reduced.

3. **Economic modelling assumptions**

   a. The modelling assumes the current reactor fleet (438) includes operations of Japanese NP reactors (48) despite 46 of these in ongoing long-term outage post-Fukushima, with a total net capacity of 371GWe (Nuclear Power Reactors in the World, IAEA 2015)

   b. In addition, it ignores the reality that the nuclear industry is in decline. The 391 operating reactors—excluding 'Long Term Outages' (the IAEA is not keen to call the Japanese reactors 'Long term shutdown' so still calls them operational despite them being shut down for five years) - are 47 fewer than the 2002 peak of 438. World wide, total installed capacity peaked in 2010 at 368 GW before declining by 8 percent to 337 GW, which is comparable to levels last seen two decades ago. Annual nuclear electricity generation reached 2,410 TWh in 2014—a 2.2 percent increase over the previous year, but 9.4 percent below the historic peak in 2006.

   c. The modelling assumes the current fleet is continues at the current level, with current units under construction and planned by 2030 adding to this capacity. This ignores a number of basic realities:
      i. It does not take into account the ageing reactor fleet and decommissioning requirements, thereof leading to an inevitable decline in reactor units by 2030 and almost certainly beyond that.

   ii. Using IAEA figures for nuclear power plants (NPP) under construction and planned by 2030 (68 and 96 respectively ie total 164) it assumes they all eventuate. This clearly does not reflect the historical experience of the nuclear power industry, where one in eight construction starts have been abandoned or suspended since 1977 and many-fold more planned reactors were never commenced. In other words, assuming all construction starts and planned reactors eventuate is a highly optimistic scenario, completely ignoring past experience.
   iii. The average life of a NPP as of 2015 is 30 years. IEA 2014 World Energy Outlook states 38% of today's capacity is due to retire by 2040 equivalent to 200 reactors. The modelling assumes rates of NPP establishment that again ignore the lived reality. The model assumes:
      1. all units under construction (68) connect to grid by 2021 and capacity increases by 1.5GW requiring 15 grid connections per annum, **4 x rate of grid connection in previous decade.**
      2. by 2030 188 units (178GW) would be needed to maintain status quo, **5 times the rate of grid connection in the last decade.**
      3. license extensions for reactors older than 40 years (ie licenses extended to 60 years). Using input from only those approved (mainly USA) implies an addition of 21GW by 2020 and 160GW (169 units) to replace shutdowns to maintain status quo by 2030.

However, it must be noted that license extensions outside of the USA are not certain (not all units are eligible and not all upgrades to maintain the units for another 20 years will be commercially viable, YET, Jacobs MCM assumes all units will have 60 year license extensions without question).

d. Although Jacobs MCM claims to be exercising conservative assumptions by only considering reactors currently being constructed or planned by 2030 to its estimates, its waste projections extending beyond then assume complete replacement of the current nuclear reactor fleet (including additions planned and under construction to 2030) at least once again and probably twice for many which are due to retire in the next two decades. It thus assumes that the reactor fleet will expand by ~40% and maintain this scale to 2090 despite no evidence to suggest any certainty of this projection. It thus is an arbitrary optimistic guess not supported by any IAEA or IEA data. This assumption also runs completely contrary to the findings of the SA Royal Commission itself in regard to nuclear power plants. If building a nuclear power plant is not a good idea for Australia at present, then why do we accept the assumption that other countries will continue to build them even faster than they have in the past? Given the current rapid increase in renewable energy sources and storage options, and the time frames involved, these assumptions lack credibility.

4. The revenue due to spent fuel disposal is based on the LCOE (levellised cost of electricity) assessments by the OECD based on estimates of cost to dispose of spent fuel (SF) by the generating country. Jacobs has then used this as a basis for willingness to pay (WTP) to have a third party dispose of it. This is the baseline used ($USD1M). It then states potential for enhancement of this baseline amount since it would free up expansions of NP programs in the host countries due to diminished opposition, and decrease cost to build since finance would be cheaper since one liability would be dealt with. The assumption that cost to dispose of HLW, ie WTP, has any degree of accuracy in the absence of a history of a functioning deep geological repository is highly problematic. It is no more accurate than a

best guess and as such requires appropriate discounting to account for the risk inherent thereof.

5. More fundamentally, the same WTP and enhanced economic incentives used to justify this business model are equally valid for a nation with a HLW burden but in the converse ie if there is money to be made by disposing of others' waste then there is money to be saved (billions of dollars apparently) to dispose of one's own waste. In other words, the argument is self-extinguishing. Indeed, the very argument that there is a multibillion dollar business of disposing of the world's HLW which no-one else has deduced, much less the countries involved in its generation, except we clever Australians who have none of it and clearly have superior insight is ludicrous.

6. Furthermore, if the economic argument was valid in principle, there would be many entrants into the third party disposal market. Yet there are none. Even Finland and Sweden, which have deep geological repositories for their own NP programs, have not engaged in international waste disposal. Yet economically, according to the Jacob MCM proposal, it would make sense to do so. Maybe the experts in the field know something Australian proponents don't.

7. Of course, the disposal of HLW for many millennia involves more than merely an economic argument and an NPV calculation, but the externalities involved of the moral and ethical burden on future generations who do not yet exist. They will not reap the economic rewards of our generation who have generated these liabilities. It is not possible to place an economic value on this yet it is vital we do not discount it to zero.

8. Another externality to consider is the huge plutonium content of spent fuel Australian will possess and the inevitable incentive to reprocess the waste recycle the fuel, leading to proliferation liabilities. A plutonium stockpile would be a major hazard and burden. Fissile material related proliferation risks and the dirty bomb risks associated with high level waste are real and again not taken into consideration.

APPLYING NEW MODELLING WITH A REVISED ASSESSMENT OF VOLUME OF WASTE
We provide two new models (See tables 1-8):

1. **Accessible market (B)** The estimate of volume of HLW to be handled by a facility over the period has been revised correcting for the shortfall in NPP until 2030 on the basis of IAEA and IEA data and projections. The other Jacobs MCM assumptions have been kept constant, ie:
    a. Full replacement of existing (corrected downwards) NPP as they retire over the ensuing period beyond 2030, at least once
    b. 60-year operating license renewals for all units
    ALTHOUGH,
    c. Exclude relatively marginal contribution by ILW disposal. The business case almost entirely relies on the disposal of HLW

2. **Accessible market (C)** A second scenario, whereby following 2030 there is a further replacement rate of NPP over the ensuing 15 years similar to that proposed for the 15 years to 2030 ie a further deficiency of 44 to 52 reactors and then a static number requiring continual replacement.

Until 2030 the replacement rate of NPP will be less than the shutdown rate so there will be a significant shortfall by 2030- ie less reactors than Jacobs MCM states. Jacobs MCM's underlying assumption is that the number of existing reactors will increase by the ones under construction (68 NPP) plus the ones planned (97 NPP) whilst in addition maintaining the overall existing fleet (~438 NPP) in action. What the numbers from the IAEA and IEA state is that **the rate of retirement of NPP exceeds the rate of replacement** (construction and planned) so I am saying assuming (B) there is this gap by 2030 – very likely, this is the deficiency in HLW to be available. After that, I assume things are constant. However, in (C) I assume the same rate of retirement continues and the same rate of construction/planning leading to another deficiency in reactors overall and therefore waste to be available. After that the following modelling assumes constancy in reactor numbers. The less HLW produced the smaller the market available to a proposed business importing it.

Summary

The Jacobs MCM economic modelling is highly implausible in its projections for the numbers of operating reactors in the future. It ignores current rates of grid connections for new reactors - both planned and under construction. The lifespan of reactors is assumed at 60 years when the current average life span is 30 years. It makes unjustifiable assumptions about the viability and use of NPP beyond 2030. When the modelling is corrected for likely and more certain assumptions, it provides negative net undiscounted cash flows for all 25% market capture scenarios, and the Accessible market C scenario at 50% market capture, involving losses of tens of billions of dollars. The net present values are negative at a discount rate of 10% for all scenarios below the Jacobs baseline scenario (accessible market A) and below. This means the project's commerciality relies on excessively optimistic and erroneous assumptions.

Modelling involving +50% increases in costs (suggested by Jacobs MCM) will make even more scenarios loss making both in an undiscounted cash flow basis and net present values.

It is perhaps not surprising then that Jacobs MCM states a fairly glaring disclaimer on P10:

> In no part of this report does Jacobs, either explicitly or implicitly, make any recommendation or endorsement of the viability or otherwise of the Project.

If Jacobs MCM is not prepared to standby its figures and conclusions, why should Australians, who will be left with the burden of the world's HLW for hundreds of thousands of years, have any confidence in it?

	Reactors operational			Reactors under construction			Reactors planned (assume by 2030)		
Country	No.	Capacity	Waste/annum HLW (19 tonnes/Gwe)	No.	Capacity	Waste / annum HLW	No.	Net Capacity	Waste/ annum HLW
ARGENTINA	3	1627		1	2500				
ARMENIA	1	375							
BELARUS				2	2218				
BELGIUM	7	5927							
BRAZIL	2	1884		1	1245				
BULGARIA	2	1926							
CANADA	19	13500							
CHINA	23	19007		26	25756		39	27520	
CZECH REP.	6	3904							
FINLAND	4	2752		1	1600				
FRANCE	58	63130		1	1630				
GERMANY	9	12074							
HUNGARY	4	1889							
INDIA	21	5308		6	3907		4	3094	
IRAN, ISL. REP.	1	915					3	2160	
JAPAN	48	42388					9	12419	
KOREA, REP. OF	23	20717		2					
MEXICO	2	1330		5	6370				
NETHERLANDS	1	482							
PAKISTAN	3	690		2	630				
ROMANIA	2	1300							
RUSSIA	34	24654		9	7371		22	5715	
SLOVAKIA	4	1814		2	880				
SLOVENIA	1	688							
SOUTH AFRICA	2	1860							
SPAIN	7	7121							
SWEDEN	10	9470							
SWITZERLAND	5	3333							
UAE				3	4035		1	1345	
UK	16	9373							
UKRAINE	15	13107		2	1900				
USA	99	98639		5	5633		16	9237	
VIETNAM							2	2000	
(IAEA Nuclear Power Reactors in the World 2015)	**432**	**371184**	**7052**	**68**	**65675**	**1248**	**96**	**63490**	**1206**
Excluding highlighted countries	**202**	**156381**	**2971**	**27**	**25285**	**480**	**19**	**21018**	**399**
Adjusted for accessible market assumptions (SARC)26%	**112**	**125482**	**2384**						

Figure 1: Nuclear reactors in the World 2015 (IAEA, 2015)

HLW (tonnes)	**All NPP**	**Accessible market (A)(~26%) Jacobs MCM**	**25%**	**50% Accessible market**	**75%**
Current inventory	390,000	89,979		44989.5	
by 2080	870,615	226,360		113,180	
Reactors under construction inventory (2030-2090)	74869.5	19466.07		9733.035	
Reactors planned inventory (2030-2090)	72378.6	18818.436		9409.218	
TOTAL	**1,017,863**	**264,645**	**66,161**	**132,322**	**198,483**

Figure 2: Estimates of HLW (tonnes) based on IAEA data (note slight differences in totals due to construction and planned reactor derived amounts differing)

Waste form / availability	**Total available now from current programmes**	**Total available by 2080 from current programmes**	**Total available by 2090 from assumed new programmes**	**Total available by 2090 (pre rounding)**
Spent nuclear fuel (SF) in tonnes heavy metal (tHM)	**89,979**	**226,360**	**50,160**	**276,520**
Intermediate level waste (ILW) in cubic metres (m^3)	***269,471***	***624,030***	***158,400***	***782,430***

Figure 3: Jacobs MCM (SARC submission, 2016)