Lyn Angel: Good morning everyone and welcome back to our webinar on radionuclide production. Before we actually start on our second session, I would like to refer to the polling that came in at the end of the session earlier and thank you everybody, for those of you who did respond. So the first question was the ANSTO OPAL reactor is value for money to the Australian taxpayer because it overcomes barriers experienced internationally, 76.5 per cent of the respondents agree and 23.5 disagree. The second question, the increased waste footprint of export is offset by benefits and waste volume reduction technology, 80 per cent agree and 20 per cent of the respondents disagree. So thank you very much for engaging in our first session.

The second session is, before I actually commence that, I would like to reintroduce our panel members, for those of you who weren't able to join us at nine o'clock. So around the panel we have Adi Paterson, the CEO of ANSTO; Associate Professor Barry **Elison**, the Director of Nuclear Medicine Illawarra Shoalhaven Area Health Service; Professor Dale Bailey, President of the Australian and New Zealand Society of Nuclear Medicine and medical physicist at Royal North Shore Hospital; Dr Margaret Beavis, President of the Medical Association for Prevention of War; Francois Couillard, CEO of the Canadian Association of Medical Radiation Technologists and President of the Ottawa OCISO Canada and he's joining us by video conference; Dr Peter Karamoskos, representing the Australian Conservation Foundation, he's a radiologist and nuclear medicine physician at the Epworth Hospital in Melbourne; Professor Hosen Kiat, nuclear medicine physician and cardiologist at the Cardiac Health Institute; and Associate Professor Geoff Currie, Charles Sturt University, co-founder and executive of the Rural Alliance in Nuclear Scintigraphy, so RAINS. So welcome again. I'm Associate Professor Lyn Angel and I'm the non-expert moderator for the sessions today.

So this session will focus on alternate production; we've heard this morning about the reactors and now we're talking about alternate production methods for Technetium-99. There's been question raised in the public arena about whether we need the ANSTO reactor at all, given cyclotrons have been used in Canada to produce Technetium-99 directly. So the theme, to make sure we keep focused for this session, cyclotrons have been used in Canada, why can't cyclotrons replace the reactor in Australia? Where is the science now and in the foreseeable future? What would be the model in Australia for cyclotron-based production? Where is Australia in the research market? I'll remind all of our panel members who are presenting that you have a tight five-minute frame and then it would allow hopefully questions from the viewers and more discussion around the panel.

So to start this, I'm going to start with one of the key researchers in this alternative technology area, Associate Professor Geoff Currie. Thank you, Geoff.

Associate Professor Geoff Currie: Thanks Lyn. I guess that I'm the logical place to start because I've actually been doing this research with my colleagues. I've just poked up a PowerPoint presentation, just with a couple of the abstracts that have been on international conferences, a couple of them being award winning with colleagues from Portugal and Russia and Poland and a few other places, including Canada on looking at the ways that we can actually produce technetium directly with cyclotrons. So I have some considerable expertise in where we're at with this current model. So those are the couple of the abstracts that have been done. So I guess we can come back to the next PowerPoint in a second.

Some of the points that need to be made are that we've known that we can actually produce Technetium-99 indirectly via cyclotrons since the '70s, as Peter said earlier. We don't do it and there are a number of reasons why we don't do it. The same reason that we don't actually sell Technetium-99 indirectly produced in a reactor, is that you have a number of radiochemical impurity issues. The OECD report of 2010 indicated that it's actually a promising technology and that's why I'm doing research and it is a promising technology. Will it ever in the foreseeable future replace reactors? The answer is absolutely not; the Canadian experience is evidence of that. There are a number of problems that we actually don't foresee and is not actually written into the 2010 report. Some simple things like the targetry is a highly enriched Molybdenum-100 target, the only source of that is out of Russia. It's an unreliable source, you can't get it regularly and the prices have been skyrocketing. So as a result of that, it contributes significantly to the cost of production far exceeding the cost of molybdenum production in a reactor. If we're going to talk about full cost recovery, full cost recovery in cyclotrons would be three or four times higher than full cost recovery in a low enriched uranium reactor.

There are other problems as well. The experience with the Canadians, who are very optimistic and their publications are out there, six-hour bombardment, 350 gigabecs, by the time they do the radiochemical purity, because we end up with a number of radionuclide impurities in there, the TGA certainly wouldn't approve injection into humans in Australia of the current quality of product. That increases costs and while you're doing that radiochemical purity, you've got a six-hour half-life, so it's decaying. So that 350 gigabecs quickly degrades to about 120 gigabecs for export. There are people in this room who will be buying generators from ANSTO that will have generators, in excess of 100 gigabecs generators, so the idea of that kind of production at a high quality facility could supply even the Sydney basin is quite preposterous. So it would supply one, maybe two teaching hospitals in Sydney.

So what that means is that you've got to create a network of cyclotrons. We can't use the cyclotrons that exist in Australia today because they don't have the energy capacity; they're designed for producing PET isotopes, so they're not capable of producing technetium directly. There are three that are - that have the energy capacity, 16 MeV - and they're busy doing other things. So we'd have to create an entire new network. The redundancies that would need to be built into that would mean that small

communities in rural Australia might actually end up with less reliable supply or significantly less reliable supply than we currently have. You wouldn't have an after-hours service, you wouldn't be able to provide weekend emergency studies and essentially you create a two-tiered healthcare system in Australia. So with my Rural Alliance hat on, is it would be an absolute disaster from a rural perspective.

The other problem is that we actually have a system with the existing reactor that if at program times when we're doing maintenance, we actually have alternative methods for shipment because molybdenum has a 67 hour half-life. When you're looking at Technetium, if all of a sudden you've got a redundancy in, say, Wagga Wagga, then all of a sudden you can't just easily get an extra dose coming down being delivered by road from Sydney to cover that. So how do you actually cover those redundancies and of course the manpower. At the moment it's centralised to ANSTO in Sydney, to actually have the manpower for 100 cyclotrons in a network across Australia where you've got physicists and chemists and technical people to run these facilities and the daily road transport associated with that, would be enormous. So it's an impractical solution, but at the moment the science is not there. It's very optimistic, it's a fantastic opportunity for us to be doing some research in that area and I'm enjoying what I'm doing, but it's not even close to providing a commercial solution in Canada, let alone in Australia.

Lyn Angel: Geoff thank you very much for those insights. I'd now like to ask Dr Beavis from MAPW, I'm still getting my head around that acronym, if you'd like to state your response please.

Dr Margaret Beavis: Okay, so once again we've got a false premise in that they're implying that cyclotrons will replace the reactor now. We're not saying that, we're saying look to the future, keep up with the science, keep up with the world leaders. The OECD said that all supply chain participants should implement full cost recovery including costs related to capital replacement. Well if ANSTO says it's committed to the transparency, I haven't seen any reports, I've done a lot of Google searching around this, so I think it would be really good for ANSTO, if it's committed to transparency, to actually give us a full cost recovery model that includes building the reactor, that includes insurance, that includes decommissioning, that includes handling of the waste, because once they can give us a transparent full cost recovery model, then we can start thinking about making them accountable.

We are arguing that Australia should be partnering with Canada in taking advantage of the major advances that Canada has taken with the TRIUMF consortium. I'd like to quote from Paul Schaffer in a talk he gave last year to the Canadian Nuclear Society in which he said: many of the more than 950 medical cyclotrons around the world today operate between 16 and 24 MeV, which is the ideal range of production of 99-technetium. Since 2010, five institutions have been studying the parameters for producing 99-Technetium on three different common cyclotron models. The team has now demonstrated reliable, commercial scale process for producing 99-Technetium,

using Molybdenum-100. Geoff's point about the supply being unreliable and from Russia, well once this process becomes commercialised, then other people will be interested in producing it. So I think once cyclotrons become more common, then there will be other reactors producing this molybdenum.

I will go back to Paul Schaffer: our approach has been approved by Health Canada and the clinical trial, which is routine for getting approval for use in patients is currently underway. He then went on to say that cyclotrons are capable of providing a stable, secure and reliable supply of lifesaving diagnostic and therapeutic isotopes for years to come. There are isotopes that will require a reactor in the future, we just think there will need to be less reactors and therefore less nuclear waste and Australia should be looking into this. Other countries are supportive and are interested. The UK, the US, lots of people have done reports and reviews and I'll just quote from this one and I'm sorry to be doing so much reading, but it's good to have sources that are factual and authoritative. So this is the 2014 UK report: the model of cyclotron-based manufacture of 99-Technetium from 100-Molybdenum is one that's being developed and evaluated in Canada and the production of commercial qualities has been shown to be feasible. When compared to other technical approaches, it is concluded the direct cyclotron production of 99-Technetium is the most promising model for the UK. Compared to other approaches, cyclotron production is thought to be the most mature and it also lends itself better to co-production with other radioisotopes, because there are lots of isotopes, technetium is just the most common for use for imaging, but it's important to have a range of isotopes available.

It's worth noting that the Canadian cyclotron technology has been successfully commercialised late last year. I think indeed 10 other countries are joining with Canada to look at this research under an International Atomic Energy Agency project and these countries include the US, Italy and Japan and I question why Australia is not a part of inquiring into the advancing science of this, because these are the world leaders. In early 2015 the TRIUMF group made enough isotopes for daily supply for British Columbia on the common brand of medical cyclotron. I'd like to correct some of Geoff's numbers. Australia has 11 cyclotrons that are suitable for making Technetium. Cyclotrons, just for people that don't know, are about the size of a four-wheel-drive car, cost about $2 million. How many do you need? Well Canada is planning to have 24. Canada is 19 per cent bigger geographically than Australia, so say 20 per cent bigger for want of better numbers, there are 34.5 million people, Australia has 24 million people. So we already have 11, Canada is planning to have 24. So I think it's not right to say that we're going to have to build a whole lot more and for remote areas, clearly we would need more. Given there is a shorter half-life, you will need some to be in hospitals like Alice Springs and places like that.

I'll just go to the Canadian Government report which came out when talking about cyclotrons saying: a more distributed network of supply hubs would eliminate the single point failure - in other words, that huge chunk that goes out and the reactor producing enormous amount of isotopes goes down - that makes today's supply chain

so vulnerable. An important consideration for cost savings and an environmental perspective is that this option would largely avoid nuclear waste issues and that's really why we're all here. Investment in the development of this option is low risk because even if the Technetium-99 production technology does not prove successful, or if demand for Technetium-99 continues to drop, which it may well, the facilities would continue to be useful for other missions, namely producing positron emission tomography, in other words PET medical isotopes. Another feature of the cyclotron approach is that it has the prospect of being economically viable without the need for ongoing government support and I think that will be down the track once it's established as a competitive thing.

So once again, I'm saying that MAPW is not saying that cyclotrons are not ready to replace the reactor now and I suspect when we have cyclotrons, there will still be reactors around the world that will need to supply certain isotopes. We are saying that they look to be cleaner and they look to be a much more reliable source of technetium. We need to be partnering with Canada and investigating opportunities for cyclotron use in Australia.

Lyn Angel: Thank you very much Margaret. Now, Peter, if you'd like to spend five minutes of your time please.

Dr Peter Karamoskos: Thank you Lyn. It's interesting reading the Canadian literature and then listening to Geoff, it's almost like Geoff has hopped on to the wrong research wagon because the Canadians clearly have a lot more faith in this technology, they've poured $35 million into research and they've delivered outcomes that are just light years ahead of some of the features that Geoff has mentioned and Margie has enumerated those. The issue of the supply chain difficulties in Australia, we have to remember that Australia is a highly urbanised society; about 80 to 90 per cent of our population lives within about a four-hour drive of a capital city. So therefore cyclotron production is feasible and the issues in the regional areas can be addressed. But these are not if and whether they will be addressed, it's a matter of how and these are always challenges in the medical market. I mean just a few months ago, for example, even in the city we can have supply failures, when there was a police incident in front of the radio pharmacy that supplies our hospitals and indeed supplies most of Melbourne. Most of Melbourne on a Friday didn't have any isotopes and only one hospital which get generators, who refused to give out any doses. I mean this happens a lot of the time. There was a plane-load of generators that were missing for 24 hours. It was meant to go to one capital city and ended up in Perth and of course all the customers of the supplier then were left without isotopes for that day. Supply chain failures are inherent in a linear supply chain, which is what reactors put forward.

Alternative mechanisms such as cyclotrons enable a distributed supply chain, where if one cyclotron goes out, another can kick in. Now all cyclotrons above 16 MeV have a capability to be used to produce technetium. Now naturally some are better than others and the higher energy the better it is and in fact the UK has bought a 19 MeV

TR24 cyclotron for SPECT and PET production recently. The issue is, are we committed? Are we going to make a policy of having a diversity of sources of technetium, because that's what the profession needs. Diversification of our sources to enable security of supply and that's the real issue here. Cyclotrons might not be right for today and Canada might have issues to address and they do, but in Australia we're not talking about flicking the switch tomorrow, we're talking about down the track and it's essential that Australia take the lead in this area and not purely relay on reactor driven technology, otherwise it will be out-innovated. Now remember, as good as the OPAL reactor is, it's not an innovative reactor. It's bought off the shelf from an Argentinian manufacturer, using techniques that have long been established. This is not innovation. If you want innovation, you go to Canada.

Lyn Angel: That's a perfect segue, thank you Peter, into our next speaker. I'd like to ask Francois, sitting again patiently, late afternoon in Canada, could you please share your insights with us? Thank you.

Francois Couillard: Thank you. I feel in a very awkward position here, you're all flattering Canada as being a great source of innovation and I'm about to maybe nuance a little bit your opinion here of Canada. So we have effectively in Canada some very, very interesting projects underway, using either cyclotron or one thing hasn't been mentioned, linear accelerators. There's actually in the centre of Canada, there's a group working on using linear accelerators instead of cyclotrons, which would provide a greater range, greater capacity even then to cyclotrons. I visited a few of these cyclotron facilities, the one in Quebec in Sherbrooke and the other one in Vancouver. The one in Vancouver got a lot of hype a few years ago at the annual meeting of the International Nuclear Medicine Society in United States where the keynote speaker was the researcher that did the work on this to produce molybdenum on the cyclotron. So he had his hour of glory. I saw him after, I tried to talk to him after his talk and people were lining up to speak to him and engage and add partnerships, people from all over the world, so lots of interest, really exciting.

What they were able to do in Vancouver is they showed that in the course of one run, they were able to supply enough technetium to supply the City of Vancouver. It's not the size of Sydney, but it's still a fairly large city by Canadian standards. So it's truly amazing work. They've done fantastic research, fantastic development. However, none of these projects has yet demonstrated an ability to produce commercial quantities of product on an ongoing basis. Let's keep that clear. None of these projects is commercial yet. They're still in the development stage, some of them have commercial partners, some don't. The commercial partners are not lining up to fund these projects in huge numbers. Why is it not there? Well there are still a lot of unknowns and as Geoff mentioned, one of the key ones is to produce their target material, they rely on Molybdenum-100 which is single source from Russia, so they're doing a lot of work right now to try to recycle this target material to reduce costs and reduce reliance on Russia. They're also looking for alternative sources of supply. So although I'm optimistic that eventually cyclotron produced technetium will be part of

the landscape, I have trust in the science and I have trust in the capacity of Canadians and other researchers around the world. It's not about to replace reactor produced technetium any time soon. It will complement the existing production, is my belief.

A few years ago, a lot of these cyclotron projects used the announcement of the closure of the NRU reactor to claim that they would save the world. There were a lot of press releases by these researchers saying with a lot of confidence that in a few years they'd be up and running and working seamlessly to replace the NRU reactor and any other reactor in the world. If you read some of their statements over the past months, six months, a year, they're really toning down their claims and tending to be a lot more prudent. Now some of you asked me to say a few words about why did Canada invest in cyclotrons and not reactors. Well actually Canada invested in reactors hugely. They invested in two new reactors that would have been solely dedicated to the supply of medical radioisotopes and why two? To have a full back-up, so each one would have been able to produce the full supply for the world and they would have had a back-up. These were mothballed several years ago because they were not able to meet the regulatory requirement. I'm not a physicist, but there was a problem, something associated to a negative power coefficient or something, that they were never able to explain, so they've been mothballed. I don't know exactly for what reason then the government decided not to invest in another reactor, but I would suspect that they've been burnt and it was too much of a political cost. So investing in smaller, innovative projects with cyclotrons seemed like a very good idea.

Now there are several other new technology projects around the world, notably in the United States, for example in Nordion, the Canadian processor, is working with the MURR reactor in Missouri on a new reactor technology. Now Nordion is very capable. They're smart people, they're putting their bet in reactor technology and they claim that they'll be producing regularly by 2018. So again, none of these new technologies has achieved any scale yet, so they cannot participate for a while in the global supply chain.

What I'd like to remind you is that it's very difficult to differentiate hype from facts in all of these projects. A lot of these are looking for secure sources of funding to support their ongoing development costs, especially the American projects and they have to look good. They have to look good in the media, they have to look good in anything you publish if they're going to continue to get money from their funders. So they do fantastic work, but fantastic work, research work, development work, does not equate to commercial success. I know, I've run operations for the largest supplier, I know how difficult it is to get in there. There are technical challenges, there is financial funding, there is heavy pharmaceutical and radiation protection regulatory burden, there's transportation and logistical challenges and once you've resolved all of these challenges, then you've got competitors that will undercut you in prices and customer service to keep you out of the market. So it's very, very difficult for any new entrants to come into this.

All that being said, Australia is very well positioned with existing facilities, knowhow, recent, reliable and safe reactor, established customer base and a solid international network. Now what will the future look like? If I had a crystal ball, I would say it will be a hybrid. There will still be reactors and there will be new technologies. So there will be small producers using cyclotrons, linear accelerators and there will still be the large global supply chain for reactors. I think there's a place for both and we need to be flexible. We don't need to argue one over the other. You happen to have this incredible source of production, capitalise on that, but at the same time, start looking at future sources, that's very smart for the future. But you have something that is the envy of the whole world, don't throw that out.

Lyn Angel: Thank you Francois.

Francois Couillard: Sorry for the long-----

Lyn Angel: No, no, that's been very helpful actually. Thank you very much, Francois. Now I'm going to ask Dale if you can have your claim.

Professor Dale Bailey: Thanks Lyn. I'm a physicist, so I thought I'd just start with a little physics for the viewing audience. Reactors make Molybdenum-99. That decays with a half-life of 67 hours. It decays to technetium which is what we use in the diagnostic studies. Technetium's got a half-life of six hours, so with a 67-hour half-life from molybdenum, that can be shipped to a hospital once a week and that can be then extracted, have the technetium extracted from it, as required. So it's highly desirable to put the source of the technetium generation into the hospital department so that if the person comes into the emergency department with chest pain at 3:00am and there's a lung scan, the on-call team can provide it. Same thing on the weekend and we offer a full 24/7 service in our hospital. So if you move to a different model where you make technetium at a cyclotron somewhere and transport it, you wouldn't be able to do that at three o'clock in the morning, you probably wouldn't do it on the weekend. You would have to be transporting enormous amounts of technetium by road, using vehicles, pollution and dealing with Sydney traffic and all the other problems that we have and it just becomes an impractical thing to move that much technetium around.

Geoff represents the regional parts of Australia where although, as Peter rightly points out, we cling to the coastlines and live in metropolitan areas, but there's still a very large number of nuclear medicine practises in the regions; we have something like 250 different facilities in Australia and they are scattered well and truly throughout the countryside. If you think about, say, Orange, Dubbo, if we were supplying with cyclotrons from Sydney, you've got the considerable time of transfer from the original site to the diagnostic facility and that would mean that the decay along the way, then you're losing radioactivity all the time. So really it doesn't make any sense to transport technetium unless you're making it in your backyard and you can make it at three o'clock in the morning, you're much better to have the generator sitting there that can

just be eluted, where you just pass saline through it and out the bottom we get the diagnostic agent, so it's a much better model.

Now also, nuclear medicine is really very naïve about the source of where we get our isotopes from. If a technology came along which was clearly superior to reactor produced and there are issues with reactors, of course, everyone just talks about, that's what we know. But if there was a demonstrably superior technology, nuclear medicine would be all for that. We don't mind where it comes from, as long as we've got the juice to supply the patients.

Lyn Angel: Thank you very much, Dale. Adi, your comments please.

Dr Adi Paterson: Thank you very much. I never ever expected in my life to be with my fellow community of people who are against war and against the proliferation of nuclear technologies and hear somebody say that they want the market to control the supply of Molybdenum-100. Molybdenum-100 is a stable isotope, 9.83 per cent of molybdenum is Molybdenum-100, but how does Russia make it? They use the same technology that is used to enrich uranium, to enrich Molybdenum-100. So I've just heard for the first time somebody thinks that the market is going to develop various technologies, be they gas technologies or centrifuge technologies or other technologies to enrich materials and make this generally available to the world so that you can have a reliable supply of medical isotopes, while at the same time criticising reactors which are low enriched uranium for being part of an apparent concern about nuclear warfare. It's shocking.

Basically Molybdenum-100 has been produced in exactly the same sorts of facilities as enriched uranium, in order for those countries to understand the properties of those materials. So as much as I like the elegance of the work that is being done on that, there's a reason that the supply chain is very weak and it's only nuclear weapons states that have this type of enrichment technology which is not under the control of safeguards that they can produce these materials. So I think we should think really, really carefully before we rapidly go into enriched materials of this type in order to produce nuclear medicines. Having said that, the experimentation is elegant and the chemistry has advanced a lot and the potential for use is actually quite exciting for small island states if you can have a safeguarded approach to the production of the enriched isotope. If you're a small island state, you're not going to easily get reactor-based supply but putting those supply chains in, getting the airlines to agree, get everybody to agree, that stuff is really difficult. But if we could have a safeguarded approach to small island states, for example, or remote countries, to have this type of technology to them, I'd be extremely comfortable to say that ANSTO would be right at the front of that charge.

Why don't we look at this technology we do? As I've indicated, ANSTO operates the largest accelerator in Australia, the Australian Synchrotron, it's an electronic accelerator. That means we know a lot about the photon techniques that could be

used to make Mo-99, we run three cyclotrons, so that means that we know about the energy range for the cyclotrons that can be used. By the way, as the energy goes up from the physics, the growing in of other forms of technetium which you don't want in is actually a very serious problem, which means that the production times for these particular cyclotrons are going to remain high, I think. So I really do think we need to reflect. When you're promoting solutions, we need to look at the whole supply chain and I think that there's a dangerous presupposition that the market can supply low-cost Mo-100 in order to supply this market. Now I hope there's some reflection on that and some internal questioning of whether we're just really criticising an existing set of technologies but not really embracing the consequences of the ones that we're talking about.

Having said that, I do hope that some of the photon techniques that Francois talked about, some of the other technologies with the linear accelerators also look promising to me, I think there's a reasonable expectation that in densely populated urban environments, within 20 years or so, we'll have reliable supply out of accelerators and I think that will be a great thing. It'll provide an alternative, it'll provide redundancy and so on. But there's no plausible scenario where these accelerator-based techniques should replace existing, established capacity because basically if you do the math for Australia, just to supply our network on a reasonable basis with the known costs, at the moment you would have the cost of an OPAL reactor with all of the other overheads just for the nuclear medicine. In the case that I think we're trying to make is the OPAL reactor, this is one of the missions. The many other missions help pay for that resource and to make it economic. There's no economic case for accelerator-based production in the short term, however I think for communities and countries that don't have that capacity, where they're isolated from the reactor provision, we should be working hard in the consortia that are developing internationally to do it. But I would not be a proponent of a market solution to Molybdenum-100 production just being left to the vagaries in the market; I think it would be a dangerous thing.

Lyn Angel: Thank you Adi. Now that has actually finished the more formal presentations from the panel and we've now got some opportunity for other panel members to join into the discussion. Peter, if you've just got a comment first.

Dr Peter Karamoskos: Yes, picking up from what Adi mentioned. Adi said that he wouldn’t believe in a market solution to sole control production of isotopes, but I thought it was all about cost recovery and making sure that we've got financial sustainability, so I just put that question out there. But with regards to the Molybdenum-100 that comes from Russia, firstly there's not enough volume of molybdenum to really pose a proliferation danger in Russia. Furthermore, LEU is not necessarily proliferation resistant. I'm not suggesting the five per cent enrichment level, I'm suggesting the infrastructure that goes to providing LEU, it's not long ago that Iran produced a research reactor for which it said it was going to produce isotopes that was 19.75 per cent enriched, still LEU, for isotope production and it almost came to war. So really,

you can't divorce your reactor from the infrastructure that enriches the uranium. So that's two things.

Dr Adi Paterson: Can I just-----

Dr Peter Karamoskos: Can I just finish?

Dr Adi Paterson: Yes.

Dr Peter Karamoskos: So I just want to mollify your concern. The other thing is, it seems surprising that Adi would condemn Russia as a proliferation threat yet at the same time several years ago, Australia was prepared to ship its uranium to Russia to fuel its reactors. Now it's stopped doing that, not because they were concerned about proliferation dangers, but because it was part of the sanctions against Russia for invading Ukraine. So let's not be too morally outraged here and create this sort of confected sense of outrage. I think that needs to be put into context.

Lyn Angel: Thanks Peter. Adi.

Dr Adi Paterson: To be absolutely clear, I did not say that I didn't think the economics of cyclotrons would work. Making a particular narrow point, the technology that is used to enrich uranium for positive benefit to society and nuclear medicine can be used badly, as we all know. That's consensus, it's been in Australian consensus. What I think the public needs to know is that Molybdenum-100 would be made using those techniques and the statement was made that the market will sort out the production of Molybdenum-100 but the techniques used are the techniques that we don't want people to get out into the general domain. So the market can't solve that.

Dr Peter Karamoskos: But this is not what we said-----

Lyn Angel: Thank you Adi. Now Peter, I'm just going to turn to Barry.

Dr Barry Elison: I'd like to make a couple of points. First of all, I don't think there's any doubt that we should encourage cyclotron research for production and we're way down, we're far away from that. I think it's very important that our listeners and viewers understand that we may have 11 cyclotrons in this country, but there's probably only one, maybe two that might be able to do something. Please, let's not get silly about it, our local hospitals wouldn't even talk to the person next to it, never mind use a cyclotron for research. So let's just put that away, it's absolute nonsense. I don't care how many cyclotrons we have, if they're owned by a hospital, they belong to the hospital and they will not be used in that process, so let's not be silly about that; we don't have enough cyclotrons, we don't have enough voltage.

I think the other thing, I've spent a lot of time working in remote centres, I'll quote Dubbo, Port Macquarie and when I first started in Wollongong, Wollongong was almost a remote centre. You cannot provide services in remote centres unless you have a cyclotron there. It ain't going to happen, let's be absolutely realistic. Rather, let's say

we need regular, reliable supply from a reactor for our remote population and they should not be treated any differently from those that choose to live in the city. Thank you.

Lyn Angel: Thank you Barry. Hosen, did you have a comment as someone who hasn't been involved with the formal part of it at this point?

Professor Hosen Kiat: I tend to agree with Barry that transparency across healthcare both in public and private is absent or virtually absent and there's really no point of focus on one aspect of healthcare in Australia. There is no accountability of how viable a department of cardiology of North Shore is, versus Westmead; none. There's no comparisons between how effective private cardiology compared to public cardiology service; none. So why would we need to even focus on just one $140 million shortfall when the whole Medicare public system is probably in billions of dollars? There are no comparisons, so as a clinician academic, incidentally, I also know that such transparency doesn't exist in universities either and universities certainly are heavily federally funded and subsidised. Where are the transparencies of how good the money has been used? I think that's the main crux from the first discussion that I would like to contribute, because I have that input into the clinical aspect and academic aspect.

As far as the isotope is concern, modalities are generally complementary, they're not ubiquitous for certain diagnoses. If you are a patient with only a fifth of your heart function working, you want every comparable and complementary facility to double check, triple check that the subsequent treatment is truly the viable treatment and therefore it is not one technique versus the other, it is really the complementary aspect of the technique. As far as the bread and butter tests, technetium certainly is brilliant. For $200 I will know whether I can operate if I'm a urologist on a prostate or whether I should treat the patient with a bone scan. That's it, it's so simple, no other test can override that, that's the bread and butter. Myocardial perfusion imaging with technetium is the most evidence based viability and prognosis proven modality. No other test has superseded that and it's bread and butter. So for all these reasons, I think these modalities will continue to exist because they have different weighting in different aspects of diagnosis and treatment.

Lyn Angel: If I can just comment from the patients' perspective, I'd certainly want to know that provided all the risks and benefits have been looked at carefully patient by patient, that I was going to get the best or for any of my family, that was available at the time, given that we need to really continue to keep researching to keep seeking what the best might look like. So I'd like to, Dale first thing, then Margaret. Thank you Dale.

Professor Dale Bailey: Adi, ANSTO were involved in bringing the first medical cyclotron to Australia, a 30 MeV machine, I believe, installed in Sydney and after it

used up its useful life, it was decommissioned. What happens to a cyclotron when it reaches end of life? Where is it now? Where's that cyclotron?

Dr Adi Paterson: So there are parts of the cyclotron which can be retained for intellectual property reasons. There was a lot of development of targets in Australia and very, very clever and effective targets. So we've retained all of that intellectual property and we retain that targetry. I'm hoping that as cyclotron applications become cheaper that we might be able to reintroduce that. Second thing is you get what we call the cold parts, the parts you simply decide to either sell off for scrap or take parts of it, in some cases and move them into other facilities. Then finally, cyclotrons get activated during the course of their life. That activation is what we call a short to medium term waste problem, it gradually decays away and during that time, we store the cyclotron, as we store the other nuclear waste that we have, in secure facilities and we monitor that decay until it's fully decayed away. Then there is typically some contamination issues as well, so we have to monitor that contamination. So it's treated, it starts off as an intermediate level waste, just as our liquid wastes do when they come out of the production of Mo-99. Then it gradually decays down to low and then it eventually is able to be disposed of as a non-nuclear waste. Very similarly, the waste that we've brought back from France, we've managed to secure an agreement that they give us the 300-year waste not the 100,000 year waste, so that was a very good negotiation on our part to minimise the risk to the country over the long term.

So the cyclotrons also have some challenges in terms of what modalities you're using and which particular isotopes you're using because the patients themselves become reactive for a period of time, whether it's reactor based or so on. So what we are trying to do in Australia with all of the isotopes we select, both for our cyclotrons and for our reactors, is look for the ones that have co-products at their absolute minimum level. Now one of the worries that I have with technetium produced in cyclotrons, the higher energy you use, the more technetium that is not Technetium-99m but other forms of technetium that is there. Because the enriched Moly-100 which we've been talking about is not enriched to a very, very high, it's just above 98 per cent. So two per cent of the material is actually longer-lived isotopes. We're not quite sure where that goes in the body. So really want we want to do is think from the patient perspective, think from the rational economics perspective, but overall from a waste perspective, the total volume of waste over the lifetime of the reactor, something that is quite difficult to understand, but I'll bring it back to the patient. Every Technetium-99m dose that goes into a patient, diagnosis, saves their life, there's about half a teaspoon of waste. I think that half teaspoon of waste is worth it.

Professor Dale Bailey: But the cyclotrons themselves are a radiation, radioactive waste problem as well, not a disposal problem.

Dr Adi Paterson: Oh absolutely and once you're transporting as well, if you take transport, production, use in the facilities, I think you would have a significant increase in the overall what I call system risk if you had a large number of cyclotrons.

Professor Dale Bailey: Yep.

Lyn Angel: Thanks Adi, Margaret.

Dr Margaret Beavis: I think the numbers that I understand are that there were nine in 2013 that had sufficient power to generate - were to be converted to produce technetium and my latest update is that there are 11. $2 million per cyclotron, once the technology is proven, I think they could go into some of the more regional areas and that wouldn't be a problem, because $2 million in terms to a regional hospital is quite a feasible thing to do, especially if we're spending $140 million a year subsidising the reactor currently. Also, as I said earlier, most countries in the world import their isotopes. If there are remote areas that need isotopes, we can continue to import them from other countries. The question that's underpinning this entire webinar is the nuclear waste problem that Australia has and what we're going to do about it. We're trying to say we need an inquiry to say that we need to work out what is best for future waste management production and then also about how we're going to manage our waste. So I think they're important issues. It's a false argument to say it's either or. We can have cyclotrons in Australia and still import technetium as we need to for remote areas.

Lyn Angel: Thank you Margaret.

Dr Adi Paterson: I'd just like to reflect on the $2 million.

Associate Professor Geoff Currie: Yeah, it's totally wrong.

Dr Adi Paterson: The $2 million is the core cost of the machine. The best way to estimate the cost of a cyclotron facility is to take the energy, if it's 16 MeV, the facility will cost about $16 million, if it's 24 MeV, it'll cost about $24 million. So to suggest that the core cost of the asset is the full cost of a cyclotron facility is simply wrong.

Dr Peter Karamoskos: That's not correct, PETtraces are $2 million, I got that directly from GE. Yes, there are facility costs on top of that. If you want to go the-----

Professor Dale Bailey: Peter, that's totally wrong.

Dr Barry Elison: That's rubbish.

Associate Professor Geoff Currie: $5 million----

Professor Dale Bailey: Every hot cell that you put in for processing is a minimum of about $300,000.

Dr Peter Karamoskos: I said and that.

Professor Dale Bailey: You couldn't get out of a facility install on a greenfield site for less than about $6 million, that's with PETtraces.

Dr Peter Karamoskos: That's not $16 million.

Dr Barry Elison: That's a small one, a PETtrace is much-----

Dr Peter Karamoskos: But that's what we're talking about, $16 million.

Professor Dale Bailey: Well no, that's-----

Dr Barry Elison: No, you can't. You've got to have 16 MeVs to produce cyclotron.

Dr Peter Karamoskos: PETtrace is 16.5 MeV.

Dr Barry Elison: Okay, thank it's going to cost you $16 million.

Dr Peter Karamoskos: Why $16 million? You just said $6 million.

Dr Barry Elison: Because of the hospital, the build. I didn't say six, I'm saying 16.

Professor Dale Bailey: You need metre-thick concrete around it.

Dr Margaret Beavis: That doesn't cost $16 million, a metre-thick concrete doesn't cost $16 million.

Associate Professor Geoff Currie: We actually have quite an extensive group of expertise that have actually built these facilities.

Dr Peter Karamoskos: Well you're being done, you're being done.

Associate Professor Geoff Currie: You're not going to get the capital for $2 million. The other issue is, is that when you say there are 11 cyclotrons, there may be 11 cyclotrons in Australia, but all these cyclotrons are built for PET, so they're-----

Dr Margaret Beavis: Yeah, they'll need conversion.

Associate Professor Geoff Currie: No, they can't.

Dr Barry Elison: No, they can't be converted.

Associate Professor Geoff Currie: No, they can't be converted to a higher-----

Dr Margaret Beavis: Well, the Canadians are talking about converting.

Dr Peter Karamoskos: Canadians are producing this using the PETtrace cyclotrons.

Associate Professor Geoff Currie: PETtrace is 16 MeV and so we have three cyclotrons in Australia of 16 MeV, the one at ANSTO at Camperdown, the one at Macquarie University and there's one in Adelaide and they're the only three that are capable of producing technetium.

Dr Peter Karamoskos: PETtrace 800 series.

Associate Professor Geoff Currie: So to come back to the science of it, is that because you criticise that me being on the wrong bandwagon for the research, this is

the actual research that is actually productive. The Canadians are on the wrong side of the equation. All of that science that I quoted that you felt that I was on the wrong - that's actually from the Canadian experience; it's published, it's published in the *Journal of Nuclear Medicine*, the most prestigious of our journals. Those barriers and limitations come from irradiating with 24 MeV. If you come back to 16 MeV, that's where, as Adi said, you end up with less contaminants in the process, you end up with less output, but it's actually a cheaper production process because you don't actually have the purification process. So when you actually say a higher energy-----

Dr Peter Karamoskos: That's not true, that's not true.

Associate Professor Geoff Currie: It is true.

Dr Peter Karamoskos: No it's not, no.

Associate Professor Geoff Currie: So you actually said higher energy is better at it, it's not. It shows a lack of understanding of the actual science around cyclotron production. If the purpose of this is actually get an expert panel of people together to actually inform the public about what the real science is, then we need to be speaking about the science we understand.

Dr Peter Karamoskos: But Geoff, you're not correct.

Associate Professor Geoff Currie: That clearly indicates that the science is not right.

Dr Peter Karamoskos: You're not correct, you're not correct. Read the papers. I can show you.

Associate Professor Geoff Currie: I have read the papers.

Dr Peter Karamoskos: No you haven't, no you clearly haven't, clearly haven't.

Dr Adi Paterson: I think it's fair to say that you're a publishing scientist in the field.

Associate Professor Geoff Currie: That's exactly right.

Dr Adi Paterson: I thought that.

Dr Peter Karamoskos: Well, I see your name about eighth on the list there, Geoff.

Lyn Angel: Actually, I'm going to interrupt, Peter.

Dr Peter Karamoskos: How much of it actually-----

Dr Barry Elison: Oh no, no that's not fair, that's not fair.

Lyn Angel: Peter, I'm going to interrupt this. We do have a question from the viewers. Dave Sweeney actually asked a question for Adi, did the Australian community and the full range of stakeholders get to make comment on ANSTO's plan to greatly increase isotope production? In short, who said yes, when and after what process?

Associate Professor Geoff Currie: Just for clarity, Dave Sweeney is anti-nuke for Australian Conservation Foundation.

Lyn Angel: Thank you.

Associate Professor Geoff Currie: Peter's here representing him.

Lyn Angel: Thank you. Adi.

Dr Adi Paterson: I think it's an excellent question. The process of deciding that we would have a replacement research reactor ran from the latter part of the 90s. It was approved in early 2000s, the reactor was constructed and began operating in 2006. Throughout that period, it was envisaged that Australia would continue to play the domestic supply role and would look to potentially increase that into a global supply chain. It was very much part of the discussion when I joined ANSTO in 2009, we had a project at the time which was called the Mega Moly project, it was already on the cards; it had been widely discussed with our stakeholders and the board and with the ministers at the time. So the expansion of this facility was absolutely consistent with the mirror image we had in Canada, in the Netherlands, in Belgium, where these countries, which can in some senses see as periphery countries, they're not the biggest of the countries, have taken on the burden of developing these sorts of technologies. Really interesting to me that cyclotron technologies have mainly developed in these peripheral countries, in Belgium, in Sweden, in Canada. So this seems to be a particular niche that countries of our size and with our strategic intent to be a global player in nuclear medicine, that's no different to somebody developing a drug in Melbourne around diabetes or something else, wanting it to be a global drug, not just an Australian drug.

Lyn Angel: Thank you for that. We do have another question. Cameron asks: what is the comparative level of waste from cyclotron production per unit activity versus reactor production? Perhaps Adi or Geoff might be able to respond to that.

Dr Adi Paterson: It's quite a complex question to answer because the apportionment of the different parts of the cycle are important. I, for example, if we were to take Molybdenum-100, I don't know what the waste streams for that look like because they haven't been quantified. But I think that it would be fair to say that the cost of waste in a nuclear medicine production facility that is reactor based is going to be higher than the cost of production and the waste component of a cyclotron facility. That's simply not even really discussable. The real issue is, how much does the whole lifecycle cost and reactor produced Molybdenum-99 is the cheapest isotope by a factor of 5:10 of any diagnostic isotope that is available anywhere in the world and the waste cost is a very small proportion of the total cost of the isotope. So I would argue that any replacement technology should be evaluated on the full cost recovery basis and I think that's the rational, economic basis of doing it.

Dr Peter Karamoskos: I think the question was talking about the volumes of waste, not the cost.

Dr Adi Paterson: The volumes are tiny. I think when you say waste, people think often of things like landfill sites and so on. You're talking about if you think of a really big Bunnings store, Australia's nuclear waste site for nuclear medicine production would be significantly smaller than your average large Bunnings store. That's just a feel for what the waste will be over the next 40 years.

Dr Barry Elison: That's a good perspective.

Dr Adi Paterson: Yeah.

Lyn Angel: Look, I didn't think we'd actually use all of the time constructively, but thank you so much, we have. So I'd like to try and summarise and then get some consensus around a few points before we break for our next session. So clearly cyclotron production for technetium is not a new technology. It can be done, but it does seem very clear that nationally and internationally there are still some major challenges around that in terms of the quality, the efficiency, the cost and quite significant challenges remain. So while there are obviously benefits to the cyclotron production, it's not ready for commercialisation at a national level at this stage.

So there are three areas I'm going to try and get the consensus on. Cyclotron production of Technetium-99 can't at this time or in the foreseeable future, so we're not talking about 15, 20, 50 years ahead, replace reactor production in terms of costs, efficiency, reliability or flexibility. Is there general consensus from the panel around that point?

Dr Margaret Beavis: If you take out the foreseeable future, yes.

Dr Peter Karamoskos: We can't do it now.

Dr Margaret Beavis: So we agree, we can't do it now?

Professor Dale Bailey: Five to 10 years.

Dr Margaret Beavis: I think you need to cross out the foreseeable future.

Dr Barry Elison: Put a time on there, three years?

Lyn Angel: Well there needs to be a time limit.

Dr Peter Karamoskos: There needs to be a policy. Whatever we want, if we want reactor production uniquely, then that's a policy decision that come to fruition.

Lyn Angel: Yeah, I think that probably would be a given, but we are trying to talk about the science and what we are faced with at the moment.

Dr Peter Karamoskos: Policy determines science.

Dr Adi Paterson: Calibration point would be-----

Lyn Angel: Well not necessarily.

Dr Margaret Beavis: Yeah, it does, absolutely it does.

Lyn Angel: That's a different discussion, I might add.

Dr Peter Karamoskos: It does because if you have policy-----

Dr Barry Elison: Hang on, let's go back to basics-----

Associate Professor Geoff Currie: Ten years, is everyone happy with 10 years?

Dr Barry Elison: Let's go back to-----

Dr Margaret Beavis: No, absolutely not. This is like Kodak and the camera. It's a matter of this technology will go ahead, the speed of which it will go ahead, we'll have to wait and see, but it's coming. So I think it's a matter-----

Dr Barry Elison: Well hang on, no, no, there's no consensus to say it's coming, no. There's no consensus to say it's coming, absolutely.

Dr Peter Karamoskos: But it is coming.

Dr Barry Elison: Where? Where's it coming?

Associate Professor Geoff Currie: Well the fact is, there may be other technologies like linear accelerators that actually surpass the cyclotron.

Dr Margaret Beavis: Yeah, it will come.

Dr Barry Elison: It's being researched, if something is being researched-----

Dr Margaret Beavis: You've read the research?

Dr Barry Elison: If you're researching something, you're researching something. You can't say because you're researching something the outcome will be X, Y and Z. The results of the research will inform what we're going to do. If you say that we're going to do it, it's rubbish.

Dr Margaret Beavis: It's been commercialised, it's been authorised by health and it's doing clinical trials.

Lyn Angel: Can I be very clear about research in this I do know about, if you are working to research for an outcome that is already being planned, it would be very faulty research.

Dr Barry Elison: Exactly.

Lyn Angel: So I think we need to keep that very, very clear in our minds.

Dr Barry Elison: Research will inform-----

Dr Peter Karamoskos: How are research funds directed then? Through policy.

Lyn Angel: I'm not talking about policy here now, I'm talking about good research.

Dr Barry Elison: Research will inform policy. The word is research.

Lyn Angel: So in terms of the agreement about it not being here for the foreseeable future, whether it be one, two, three or five years, I think probably that would be a reasonable statement to make.

Dr Peter Karamoskos: In Australia you're talking about.

Dr Adi Paterson: I think also and what I've said very clearly is that there are exciting dimensions to this technology and they will be applicable.

Lyn Angel: Yes.

Dr Adi Paterson: There's no doubt about that. But there are some really big questions as well.

Lyn Angel: So the second-----

Dr Peter Karamoskos: So you're saying Australia, Lyn, you're talking about Australia?

Lyn Angel: Well I guess our situation, I think probably globally, but particularly Australia, let's focus on the Australian context. The second point that I wanted to put out there was that cyclotrons can't produce a solution for the other radionuclides produced in the reactor.

Professor Dale Bailey: That's consensus, yep.

Dr Margaret Beavis: We have said clearly that you can have cyclotrons and like most of the world, import as need be some-----

Professor Dale Bailey: There's many that can't be imported.

Dr Margaret Beavis: Well-----

Lyn Angel: But in terms of the production of, let's forget about the import/export discussion about this point.

Dr Margaret Beavis: Well I think it's really an important part of it.

Lyn Angel: We're talking about whether or not they're going to be able to replace all the things that reactors currently do.

Dr Peter Karamoskos: Well that wasn't the discussion. There is a paper by the American Association of Physicists in Medicine that shows how you can, whether it's economic or not is another question.

Dr Margaret Beavis: Remains to be seen.

Dr Peter Karamoskos: But you can.

Lyn Angel: Well a lot of this has-----

Dr Adi Paterson: I think what we can agree is that Iodine-131 would become really difficult and I think that the (Tcm 177) would, in its modern form, its high specific activity form would be essentially impossible.

Dr Margaret Beavis: Again, we could import it.

Professor Dale Bailey: No, no, no.

Associate Professor Geoff Currie: That's the point, you can't.

Dr Barry Elison: If you can't do it now, you won't do it then.

Ari Paterson: Volumes are not high enough globally, that's why we're trying to lead the world in the (Tcm 177) for the treatment of cancers and why shouldn't we try to lead the world.

Dr Peter Karamoskos: Well that's a choice.

Associate Professor Geoff Currie: That's the point, ANSTO is a significant part of the health and wellbeing of every Australian.

Dr Margaret Beavis: Well no, you've overstated that case many times, Geoff, I won't go to the why with you on that, but that's been overstated a lot.

Lyn Angel: So the third point I'm going to put out there for consensus, cyclotrons are a technology that as leaders globally in nuclear science, Australia should be investing research efforts in the Technetium-99 production and I would put too that there could well be some serious discussion around potential partnership with industry and a university such as CSU who does actually have one of the world - are the national leaders in this research and the department seems a logical next step. So the suggestion or the consensus around continuing that research, at the same time to explore whether there may be better technologies, but alongside of what's happening in the reactor.

Dr Barry Elison: No question.

Ari Paterson: I think we would broaden from cyclotrons though, we'd have to say accelerator based.

Lyn Angel: Other technologies.

Dr Barry Elison: That's a good question, got to be consensus.

Dr Margaret Beavis: I think exploring Australia, if you could adjust that to accelerators and possibly the suggestion of the partnership, leave that open to the best researchers in the country.

Lyn Angel: Alright, look thank you so much for your contribution. We're going to close this and have a 10 minute break and we'll be reconvening in 10 minutes. So I'll see you all at about 10 past 11. Thank you very much.

END OF RECORDING (59:09)