The impossible dream

Free electricity sounds too good to be true. It is.

A plan to produce free electricity for South Australia by embracing nuclear waste sounds like a wonderful idea. But it won't work.

Briefing paper

Dan Gilchrist
February 2016

ABOUT THE AUSTRALIA INSTITUTE

The Australia Institute is an independent public policy think tank based in Canberra. It is funded by donations from philanthropic trusts and individuals and commissioned research. Since its launch in 1994, the Institute has carried out highly influential research on a broad range of economic, social and environmental issues.

OUR PHILOSOPHY

As we begin the 21st century, new dilemmas confront our society and our planet. Unprecedented levels of consumption co-exist with extreme poverty. Through new technology we are more connected than we have ever been, yet civic engagement is declining. Environmental neglect continues despite heightened ecological awareness. A better balance is urgently needed.

The Australia Institute's directors, staff and supporters represent a broad range of views and priorities. What unites us is a belief that through a combination of research and creativity we can promote new solutions and ways of thinking.

OUR PURPOSE – 'RESEARCH THAT MATTERS'

The Institute aims to foster informed debate about our culture, our economy and our environment and bring greater accountability to the democratic process. Our goal is to gather, interpret and communicate evidence in order to both diagnose the problems we face and propose new solutions to tackle them.

The Institute is wholly independent and not affiliated with any other organisation. As an Approved Research Institute, donations to its Research Fund are tax deductible for the donor. Anyone wishing to donate can do so via the website at https://www.tai.org.au or by calling the Institute on 02 6130 0530. Our secure and user-friendly website allows donors to make either one-off or regular monthly donations and we encourage everyone who can to donate in this way as it assists our research in the most significant manner.

Level 5, 131 City Walk
Canberra, ACT 2601
Tel: (02) 61300530
Email: mail@tai.org.au
Website: www.tai.org.au

Acknowledgement

The Australia Institute gratefully acknowledges the generous support of the Conservation Council SA (CCSA) for funding this paper. As the state's peak environment organisation, CCSA represents over 50 environment related community groups across South Australia.

Summary

South Australia's Nuclear Fuel Cycle Royal Commission was established on 19 March 2015 and is due to report on its findings in May 2016. It is inquiring into the risks and opportunities to the economy, environment and community of the expansion or development of the nuclear fuel cycle.

Perhaps the most prominent plan has been the one championed by South Australian Senator Sean Edwards.[1] He claims to be able to bring tremendous economic prosperity to South Australia, with the almost incredible by-product of providing free electricity to the state, and with money left over to reduce state taxes.

The plan involves being paid to take spent fuel from other countries and store it in Australia. The state can then use that old fuel to power a new generation of reactors, producing tiny quantities of easily handled waste. With money earned from taking troublesome radioactive materials off the hands of countries struggling with stocks of nuclear waste, South Australia can fund next-generation reactors.

The plan sounds perfect. The reality is far from it.

The Edwards plan ignores the cost of shipping the waste to Australia, and relies on technology that has never before been deployed commercially. It hopes that unjustified and unrealistic amounts of money will be paid for the disposal of waste.

Furthermore, although the plan includes the acceptance of 60,000 tonnes of waste, only 4,000 tonnes, at most, would be reprocessed for fuel. The remaining 56,000 tonnes would remain in temporary storage, with no funds left for future generations to deal with the problem.

Even if the world fell into line just as Senator Edwards hopes, the plan fails to consider the obvious question: if Australia can generate free electricity from this spent fuel, wouldn't other countries want to do the same? The plan makes no allowances for competition.

Even if the countries of origin chose not to implement the miraculous technology proposed for South Australia, other countries could compete with Australia to provide this service. A plan predicated on monopoly profits of over 400 percent is, therefore, unrealistic.

[1] Office of Sean Edwards (3 August 2015) [1]. Transforming our Economy. Cleaning our energy. Sustaining our future.

The idea that an expanded nuclear industry in Australia will produce thousands of jobs and generate so much money that South Australians will be provided with free electricity is a wonderful dream. But like so many dreams, it is an impossible one.

The first section of this report outlines the key elements of the Edwards plan.

The second section of the report provides a reality check. It shows that the plan fails to deal with over 90% of the imported waste, and then exposes the chief technological and economic risks in the scheme.

The third section will consider a world in which the assumptions contained in the Edwards plan come true, and explores the possibility that other countries might go on to use the same technologies as Australia.

This paper will analyse the mid-scenario modelled in the Edwards plan – that is, 60,000 tonnes of spent fuel to be taken by Australia, with payments received of $1,370,000 per tonne – and follow the convention of using Australian dollars at their 2015 value, except where otherwise noted. Similarly, costings and claims are taken directly from the Edwards paper, except where otherwise noted.

Table of Contents

Part 1: The Edwards Plan

Senator Sean Edward's plan for nuclear development in South Australia was put forward in a submission to the Nuclear Fuel Cycle Royal Commission.[2] He claims that this development would bring jobs to South Australia, earn tremendous amounts of money, and provide free electricity to the state.

Senator Edwards has spoken publicly about his plan to the media and his constituents. In August 2015 he told the Sydney Institute that his nuclear plan is a "once in a lifetime opportunity,"[3] and that "the recycling of spent fuel is a substantial commercial opportunity. But that pales in comparison to the wider economic benefit of power almost too cheap to meter."

There are two principle elements to the program: first, South Australia will provide a repository for spent nuclear fuel from other countries, earning many billions of dollars; and second, the state will build Generation IV nuclear reactors – specifically the GE-Hitachi PRISM integral fast reactors – which are able to use that spent fuel to generate power.

TAKE OLD FUEL, MAKE MONEY

The first and key element of the Edwards plan is the idea that Australia can make many billions of dollars by importing spent fuel generated by nuclear reactors across our region.

Nuclear power programs around the world are sitting on an increasing problem: hundreds of thousands of tonnes of spent fuel lies in temporary storage. Most reactors use only a tiny proportion of the energy contained in their fuel. They can only use fresh fuel, which lasts just a few years, after which it must be removed and stored.

The problem of what to do with the spent fuel has plagued policy makers for decades.[4] Nuclear waste is very dangerous, and best-practice solutions are difficult, expensive, and – given the lengthy half-life of the material – ultimately unproven. The only countries close to having a permanent interment solution for their civilian

---

[2] Sean Edwards (2015) [1]
[3] Sean Edwards (2015) [2] The Nuclear Opportunity, presentation to The Sydney Institute, 7 April 2015
[4] Sean Edwards (2015) [1]. Page 4

waste are Finland and Sweden, with national repositories due to come online in the 2020's.[5]

In the meantime, spent fuel around the world is left in cooling ponds or above ground in dry cask storage – meant only as temporary solutions.[6]

The Edwards plan is for Australia to build our own dry cask storage facility, capable of storing spent fuel for 100 years, in order to house 60,000 tonnes of material that would be accepted over a 20 year period.

A dry cask storage facility would require $1,026 million in capital expenditure, and a further $698 million per year to operate. Over 20 years the final cost of a full facility would therefore be around $15 billion.

Senator Edwards hopes that South Australia would be paid $1,370,000 per tonne to accept this material, so 60,000 tonnes could earn over $82 billion. This would provide a spectacular profit of $67 billion, which could be spent on other activities.[7]

NEXT GENERATION... GENERATION

The second part of the plan would be to construct Generation IV reactors, and a fuel processing facility to convert part of the spent-fuel stockpile into a form usable by the new reactors.

The proposal calls for the construction of the GE-Hitachi PRISM, an integral fast reactor. This is a reactor which, if it can be made to work commercially, can take spent fuel from older reactors and, with some reprocessing, re-use it to generate electricity. While older reactors use only a small proportion of the available energy in nuclear fuel, a PRISM would use almost all of it.[8]

Not only would this be far more efficient than older reactors, allowing spent fuel to be used to provide many times more energy than originally intended, but the waste output should also be reduced to much more manageable levels.

Put simply, the spent fuel Australia might take would be made up of a mix of materials that comes in three broad categories:[9]

> Extremely long-lived material, which is comparatively easy to handle. The reason it is so long lived is that it decays very slowly, so it isn't very radioactive.

---

[5] World Nuclear Association (2015) [1]. Radioactive Waste Management
[6] Bunn et al (2001). Interim Storage of Spent Nuclear Fuel.
[7] Note, this final figure is not explicitly provided in the plan. Author calculated.
[8] Sean Edwards (2015) [1]. Page 24.
[9] World Nuclear Association (2015) [1]. Radioactive Waste Management

> Short lived material which is, at least initially, the most dangerous. It is short lived because it decays so fast, and emits large amounts of radiation. But for the same reason it is also comparatively easy to deal with as its rapid decay can naturally make it safer within decades, or at most a few hundred years.
>
> But it is waste with a mid-range lifespan which is really problematic, decaying fast enough to be extremely dangerous, but slowly enough to be a problem for very long periods. Plutonium-240, for example, is extremely dangerous, but with a half-life of 6,563 years it still takes tens of thousands of years to decay to a safe level.

It is dealing with the middle-range material that makes permanent disposal of spent fuel so very difficult. Designing a facility that can keep it isolated for tens of thousands of years is a problem that may not have a solution. Quite apart from physical and environmental storage issues, it is not possible to predict the shape of human civilisation tens of thousands of years into the future. How do you keep that waste out of the hands of a future rebellion, or dictator, or invading force?

The PRISM, however, provides something of a solution: it uses up the mid-range material as fuel, and the resulting waste is almost entirely very short- or very long-lived, needing to be interred for a mere 300 years before it naturally decays to safer levels. This is still a serious problem, but would be a far easier proposition than dealing with middle-range waste for tens of thousands of years.[10]

According to the Edwards plan, the first two PRISMs will cost around $4 billion each. This would be more than subsequent PRISM facilities as they would be the first of their kind in the world. South Australia could then build four more, expected to cost only $2 billion each, with a final capital cost of $16 billion. Each PRISM would cost $104 million a year to run. Six PRISMs operating for their expected 50-year lifespan would cost $31 billion. So the total cost for energy generation over this period would be $47 billion.

Reprocessing the fuel to power the PRISMs would cost $617 million to set up a facility, with a small ongoing operating cost depending on the amount of fuel processed. A facility could process up to 100 tonnes per year, which is far more than Australia would use.

The tiny amount of waste produced by each PRISM reactor would need final interment, which would be provided by another new technology - borehole disposal. As very small volumes would be involved, the cost of this final disposal would be relatively minor.

[10] Sean Edwards (2015) [1]. Page 24.

In short, free electricity for 50 years would cost about $48 billion, which compares favourably with the $67 billion in expected profits from accepting the spent fuel.[11]

With the money left over, the state could increase funding to research, and even remove the state payroll tax.[12] The elimination of payroll tax would cost the South Australian budget around $1 billion a year.[13] The plan, then, might provide equivalent funding to the state for 20 years.

[11] These final figures are extrapolations from estimates included in the plan, as they are not given explicitly. Some minor expenses are omitted here.
[12] Sean Edwards (2015) [1]. Page 37.

[13] Government of South Australia (2015). Budget Statement: 2015-16 Budget Paper 3

Part 2: Wake Up Call

Edward's plan seems like an excellent deal for South Australia. Who would say no to jobs and free electricity and billions in reduced taxes? But the most cursory scrutiny exposes some serious flaws.

WASTE

The plan is to build a dry-cask storage facility, capable of securing spent fuel on the surface for 100 years. South Australia would be paid to take 60,000 tonnes over a 20 year period.

There would then be a nuclear fuel reprocessing facility, designed to reprocess 100 tonnes of this waste per year. The economic value of this proposition is highly speculative as 100 tonnes per year is far in excess of Australia's likely needs. However, if our pioneering development of PRISM reactors proved the technology and made it affordable, then other countries might also build PRISMs, which could use the output of the processing plant.[14]

However, even assuming Australia finds a use or a buyer for the entire output of the reprocessing plant, over the 40 year life span of the facility South Australia would process just 4,000 tonnes of the imported waste.

What happens to the other 56,000 tonnes of nuclear waste?

It would remain in temporary storage. There is no long term solution costed or even mentioned in Edwards' plan. It is never discussed again.

It must be kept in mind this would be waste another country paid Australia to take, specifically because paying us was better than developing a permanent solution of their own.

As perhaps may be expected, if one country pays another to take on a massive problem, and the second country solves less than 10 percent of that problem, it could make a large short term profit. But in 100 years when the dry cask system reached the end of its rated lifespan, future generations of South Australians would be left to deal with 56,000 tonnes of high-level waste, with no money left, and no plan.

---

[14] Sean Edwards (2015) [1]. Page 12-15.

If the plan was funded only by taking the 4,000 tonnes of spent fuel it actually used, then the result would be a spectacular financial loss.[15]

The Edwards plan makes the point that Australia would not be taking waste, but only 'spent fuel'. It says: "This submission is not ... proposing the simple establishment of waste management or disposal services or the importation of radioactive wastes in any sense."

This statement is justified in the plan by the definition of radioactive waste as "...waste materials which contain radioactive substances for which no further use is envisaged."

As long as we intend to use that spent fuel, it is not, strictly speaking, waste. However, the plan provides no use for over 90 percent of the material to be accepted. It would be, in the truest sense of the word, waste. And the proposal simply ignores that waste. If there is a future use envisaged for it, it is not mentioned in the plan, nor has it been costed.

The plan earns all of its money in the first few decades, spending it all on free electricity, tax reductions and other projects over 50 years.[16] The remaining 56,000 tonnes is left to future generations to worry about, with **no money left** to deal with it.

This is a plan unlikely to be embraced by the Australian public in general, or South Australians in particular.

NEW TECHNOLOGY

> This comprehensively researched submission asserts that a transformative opportunity is to be found in pairing established, mature practices *with cusp-of-commercialisation technologies* to provide an innovative model of service to the global community. (emphasis added)
>
> Edwards' submission to the Royal Commission

Two elements of the plan - transport of waste, and temporary storage in the dry cask facility - are indeed mature. There is a high degree of certainty that these technologies will perform as expected, for the prices expected.

---

[15] 4,000 tonnes at the price of $1,370,000 a tonne = $5.4 billion. The first two PRISMs alone cost $8.3 billion.

[16] Sean Edwards (2015) [1]. Page 37. It is unclear exactly how much of the money is meant to be spent, but the plan proposes eliminating payroll tax, worth $1 billion a year. Over 50 years that will more than use up all the remaining revenue from the spent fuel taken: South Australia Budget Statement 2015-16

It should be noted, however, that the price estimates used in the Edwards plan for the dry cask storage facility draw on estimates for an internal US facility to be serviced by rail.[17] No consideration has been given to the cost of shipping the material from overseas.

Around a dozen ship loads a year would be needed to import spent fuel at the rate called for in the plan.[18] It is likely that a dedicated port would also need to be constructed. The 1999 Pangea plan, which proposed a similar construction of a commercial waste repository in Australia, made allowances for "...international transport in a fleet of special purpose ships to a dedicated port in Australia". [19]

Needless to say, building and operating highly specialised ships, or paying others to do so, would not be free. Building and operating a dedicated port would not be free. Yet none of these activities are costed in the plan.

Furthermore, beyond the known elements of transport and temporary storage, the principle technologies depended on – PRISM reactors and borehole disposal – are precisely those which are glossed over as being on the "cusp of commercialisation".

To put it another way: **the commercial viability of these technologies is unproven.**

PRISM

The PRISM reactor is based on technology piloted in the US, up until the program was cancelled in 1994.[20] It offers existing nuclear-power nations what appears to be a tremendous deal: turn those massive stockpiles of waste into fuel, and reduce the long-term waste problem from one of millennia to one of mere centuries. It promises to be cheap, too, with the small modular design allowing mass production.

Despite this promise, not a single PRISM reactor has actually been built. Officials at the South Korean Ministry of Science have said that they hope to have advanced reactors – if not the PRISM then something very similar – up and running by 2040.[21] The Generation IV International Forum expects the first fourth generation reactors – of which the PRISM is one example – to be commercially deployed in the 2030's.[22]

---

[17] Electric Power Research Institute (EPRI) 2009, Cost Estimate for an Away-From-Reactor Generic Interim Storage Facility (GISF) for Spent Nuclear Fuel

[18] Using the Pacific Grebe as a model: up to 20 containers per ship, of 10-14 tonnes per container, and 60,000 tonnes taken over 20 years. See World Nuclear Association (2015) [2] Transport of Radioactive Materials; and PNTL fact sheet: Pacific Grebe

[19] Kurzeme (1999). The Pangea Concept for an International Radioactive Waste Repository

[20] Argonne National Laboratory. Integral Fast Reactor (website accessed 25 November 2015)

[21] Reuters (2012). As nuclear waste piles up, South Korea faces storage crisis

[22] Generation IV International Forum (website accessed 25 November 2015)

After decades spent developing the technology in the United States, a US Department of Energy report dismissed the use of Advanced Disposition Reactors (ADR), a class which includes the PRISM-type integral fast reactor concept, as a way of drawing down on excess plutonium stocks. It compares it unfavourably to the existing – and expensive – mixed oxide (MOX) method of recycling nuclear fuel.

> The ADR option involves a capital investment similar in magnitude to the [MOX Fuel Fabrication Facility] but with all of the risks associated with first of-a kind new reactor construction (e.g., liquid metal fast reactor), and this complex nuclear facility construction has not even been proposed yet for a Critical Decision .... Choosing the ADR option would be akin to choosing to do the MOX approach all over again, but without a directly relevant and easily accessible reference facility/operation (such as exists for MOX in France) to provide a leg up on experience and design.[23]

Nevertheless, the Edwards plan hopes to have a pair of PRISMs built in 10 years.

Crucially, under the plan, Australia would have been taking spent fuel for 4 years before the first PRISM came online, assuming the reactors were built on time.

The risk is that these integral fast reactors might turn out to be more expensive than anticipated and prove to be uneconomical. This could leave South Australia with expensive electricity and no other plan to deal with any of the spent fuel acquired to fund the reactors in the first place.

For countries that have no long-term solution for their existing waste stockpiles, the business case for constructing a PRISM reactor is much clearer: even if the facility turns out to be uneconomical, it will nevertheless be able to process some spent fuel, thus reducing waste stockpiles. This added benefit makes the financial risk more worthwhile for such countries.

Australia, on the other hand, doesn't have an existing stockpile of high-level nuclear waste. The Edwards plan would see Australia acquire that problem in the hopes of solving it with technology never before deployed on a commercial scale. We would be buying off the plan, with many billions of dollars at stake, in the hopes that we, with little experience and minimal nuclear infrastructure, could solve a problem which has vexed far more experienced nations for decades.

By the time the first PRISM is due to come online it will be too late to turn back, no matter what unexpected problems may be encountered. Australia would have acquired thousands of tonnes of spent fuel with no other planned use.

---

[23] US Department of Energy (2015). 'Final Report of the Plutonium Disposition Red Team'

Counting on the development of other PRISM reactors around the world is another gamble. The proposed reprocessing plant accounts for all of the 4,000 tonne reduction in waste over the life of the plan. Australia will have no use for most of this material – the rest must be used by other PRISMs. If PRISMs are not widely adopted, Australia will have no takers. This could leave Australia with even more than 56,000 tonnes of waste, with no planned or costed solution.

Borehole disposal

The second element of the plan is the long-term disposal of waste from the PRISM reactors in boreholes. However this technology is still being tested.[24]

According to an article in the journal *Science*, bore-hole technology has significant issues to overcome.

> The Nuclear Waste Technical Review Board, an independent panel that advises [the United States Department of Energy] DOE, notes a litany of potential problems: No one has drilled holes this big 5 kilometers into solid rock. If a hole isn't smooth and straight, a liner could be hard to install, and waste containers could get stuck. It's tricky to see flaws like fractures in rock 5 kilometers down. Once waste is buried, it would be hard to get it back (an option federal regulations now require). And methods for plugging the holes haven't been sufficiently tested.[25]

However, if estimates used by the Edwards plan are correct, and boreholes can be made to work as hoped, it would allow high-level nuclear waste to be disposed of for only $216,000 per tonne. The Edwards plan reduces this further for Australia, quoting only $138,000 a tonne, on the understanding that our own waste would be comparatively low level output from a PRISM – disregarding, as discussed above, the 56,000 tonnes left over.

Nevertheless, the figure of $216,000 per tonne is important, because that is the price at which any country with suitable geology could store high level waste. It should be noted that Australia will not have exclusive access to borehole technology. If it is proven to be as effective as hoped there is nothing stopping many other countries from using it.

The International Atomic Energy Agency (IAEA) notes that borehole siting activities have been initiated in Ghana, the Philippines, Malaysia and Iran.[26] A pilot program is

[24] Kuhlman et al (2015). Deep Borehole Field Test: Characterization Borehole Science Objectives
[25] Cornwall, W. (2015), pp.134-135.
[26] International Atomic Energy Agency (2012). Waste Technology Section: Overview of Disposal Options

underway in the US.[27] The range of geologies where boreholes may be effective is vast.

This may have serious implications for Australia's waste disposal industry, given that other countries could build their own low-cost solution, or offer it to potential customers.

However, if boreholes do not work as hoped, Australia will have no costed solution for the final disposal of high-level waste from its PRISM facilities. Australia would find itself in the very situation other countries had paid it to avoid.

PRICE

What are countries willing to pay to have their spent fuel taken care of?

This is an open question, as to date there is no international market in the permanent storage of high-level waste.

A figure of US$1,000,000 (A$1,370,000) per tonne is used by the Edwards plan, but this estimate does not appear to have any rigorous basis.[28]

The Edwards plan gives only one real world example of a similar price: a recent plan by Taiwan to pay US$1,500,000 per tonne to send a small amount of its waste overseas for reprocessing. From this, the report concludes that an estimate of US$1,000,000 is entirely reasonable.

However, the report neglects to mention several important facts about Taiwan's proposal. First, this spent fuel was to be reprocessed, not disposed of, and most of the material was to be reclaimed as usable fuel.[29] This fuel would not be returned, but would continue to be owned by Taiwan, and be available for sale.[30] If they could find a buyer, Taiwan might expect to recoup part or all of their costs by selling the reclaimed fuel to a third party.

Second, the 20 percent of material to be converted into vitrified waste by the process was to be returned to Taiwan - no long-term storage would be part of the deal.

---

[27] Arnold et al (2014). Deep Borehole Disposal Research: Geological Data Evaluation, Alternative Waste Forms, and Borehole Seals

[28] Page 30. Edwards gives two references: Bunn et al (2001) who references a leaked estimate by the Russian First Deputy Energy Minister in 1999, as well as undocumented conversations; and the Arius Association submission to the Royal Commission, which says only that it is the price "commonly quoted."

[29] International Panel on Fissile Materials (2015). Taiwan tenders spent fuel reprocessing contract

[30] World Nuclear Association (2015) [3]. Taipower launches overseas reprocessing tender

Third, and most importantly, the tender was suspended by the Taiwanese government pending parliamentary budget review.[31] This occurred in March 2015, several months before the Edwards plan was submitted to the Royal Commission.

Not only was the Taiwanese government proposing a completely different process to the one proposed by the Edwards plan, **they weren't willing to pay for it anyway**. So the use of the Taiwanese case as a baseline example for the price Australia might hope to receive to store waste simply does not stand up to scrutiny.

The plan does briefly mention that the US nuclear power industry has set aside US$400,000 a tonne for waste disposal – to cover research, development and final disposal.[32] This much lower figure is disregarded for no apparent reason, making the mid-scenario's assumption of a price more than double this, at US$1,000,000, seem dubious. Even the pessimistic case considers a price of US$500,000 a tonne, higher than the US savings pool.

As will be discussed in the next section, the question remains: if borehole technology works as intended, and at the prices hoped for, why would any country pay another to take their waste for $1,370,000 a tonne, when a solution exists that only costs $216,000 a tonne, less than one sixth of the price?

If South Australia led the way to prove the viability of the borehole disposal method and took on the risks associated with a first of its kind commercial operation, many other countries should be expected to use the technology for their own waste, or could offer those services to others. This alone makes the idea that other countries would pay $1,370,000 a tonne highly unlikely.

LONGTERM RISKS

Political and financial stability is an almost universally accepted requirement for any country planning to set up an international waste repository.[33] The Edwards plan notes our stability in governance and finance as factors in our favour.[34]

Untreated high-level waste requires storage for tens of thousands of years.[35] Even if Australia processed 100 tonnes of waste every year indefinitely – and the Edwards plan did **not** model the costs of this – it would still take six-hundred years to work our way through the 60,000 tonnes of spent fuel that would be taken under the plan.

---

[31] World Nuclear Association (2015) [4]. Taiwan reprocessing tender suspended
[32] Page 30; see also the US Nuclear Waste Policy Act (1982)
[33] Arius Association (2015). Arius Association (2015). Comments of the Arius Association
[34] Sean Edwards (2015) [1]
[35] World Nuclear Association (2015) [1]. Radioactive Waste Management

Even if environmental factors are disregarded, the political and financial dimensions are fraught with uncertainty. How many countries have gone six hundred years without political instability? How many have gone so long without a rebellion, or invasion, or a serious financial downturn?

Six-hundred years ago, Henry V executed the Southampton Plot traitors and went on to defeat France at the battle of Agincourt, Portugal took Ceuta from the Moors, and the Swiss Confederation annexed Aargau. We have not the slightest idea what will be happening in Australia in six hundred years.

Yet, according the Edwards plan, we are expected to leave this spent fuel on the surface in dry casks, accessible to possible rebels, invaders, or dictators of the future. We would leave it, with all the money spent in the first 50 years, to future generations who may not have the financial means to safely deal with it.

And with the money gone in the first 50 years, the problem could expand to an almost unimaginable degree. If South Australia cannot afford to run a 600 year program of reprocessing, use and disposal, the unprocessed leftover waste will be dangerous for tens of thousands of years. Human civilisation itself has not lasted so long.

Quite apart from whether today’s generation can be trusted to responsibly deal with the 56,000 tonnes of waste the Edwards plan seems to have forgotten about, we have to ask ourselves what hostile parties might do with it. On such a long time scale, the possibility that some hostile group might gain access to a surface waste site is very real.

This is part of the tremendous difficulty in developing a long-term plan for waste storage. It is one reason countries with spent nuclear fuel might be willing to pay Australia to take it in the first place.

It is not something a realistic plan would ignore.

Part 3: Changing perspective

The Edwards plan relies on a fatally flawed business model which ignores a fundamental element of our economic system: competition. Even if we blithely accept the technological risks associated with PRISM reactors and deep borehole disposal, the scheme would still fail economically.

To succeed, the plan requires the successful development of unproven technology, but ignores the possibility that these same developments might change the economic situation. It ignores any perspective but the Australian one.

But, for arguments sake, let's consider a world in which the ambitious technological and other assumptions in the Edwards plan are proven to be correct and the plan 'succeeds'.

THE PERFECT WORLD

Imagine the following came to pass:

PRISM reactors can be built for only $2.1 billion each.

Borehole technology is used to safely store waste for only $216,000 a tonne.

Dry cask storage is appropriate to use indefinitely.

According to the Edwards plan, a fuel reprocessing plant could earn around $300 million a year, if there were PRISM reactors available to buy the output.[36] This would be the return on a facility that cost $617 million to build, and $70 million a year to run.[37]

Consider, then, a hypothetical potential customer, a nation with a supply of spent fuel. This country has five options to choose from:

1. Send the material to Australia at a cost of $1,370,000 a tonne.
2. Put it in dry cask storage, pending some future use, at $250,000 a tonne.[38]
3. Permanently dispose of it in boreholes for only $216,000 a tonne.

[36] Sean Edwards (2015) [1]. Page 13
[37] Sean Edwards (2015) [1]. Page 31-32
[38] Ibid. Around $1 billion to build the facility, and $698 million a year for 20 years to fill it, with a small ongoing caretaker expense, gives ~$15 billion for 60,000 tonnes, or $250,000 per tonne.

4. Build a reprocessing plant to sell fuel to PRISM facilities around the world, **earning a profit** of over $2,000,000 a tonne.
5. Build PRISMs and use the spent fuel to generate their own electricity.

When we look at the options available to this hypothetical country, option one – the option that the Edward's plan assumes will be chosen – would appear to be the least attractive from a financial perspective.

If the PRISM and deep borehole technologies are successfully developed and are as cost effective as the Edwards plan claims, they would be exactly what would make Australia's own offering uncompetitive.

Let us assume, however, that options 2-5 are impossible for our client nation, for geological or political reasons. We then need to look at competition risks from third parties.

Imagine a third country which has a comparable industrial base to Australia and some stable geology suitable for deep borehole interment. This nation sees Australia's plan to earn profits of between five and ten times the cost of disposal and investigates how it can get some of this windfall profit for itself.[39] It reads the Edwards plan, and realises that Australia owns none of the technology used and has no unique competitive advantage. It builds its own PRISMs, its own reprocessing facilities, and its own boreholes. It offers to take waste at a mere 200 percent profit.

Which country is more likely to get customers: the one charging $1,370,000 per tonne, or the one charging a fraction of that rate?

It is clear where this would lead. It only takes only one competitor to eliminate a monopoly and see the price fall to a competitive rate. This is straight-forward economics.

The Edwards plan assumes massive and unrealistic profits would be sustained for decades with a complete lack of competition and in defiance of far cheaper alternatives. This is not a sound basis for any kind of economic plan.

The Edwards plan risks failure at the first technical hurdles, but as this analysis shows, even if it succeeds technologically it still fails economically.

Even if all the technical assumptions are correct, even if the world lines up just as we could hope, that perfect world is one in which we do not have a business.

[39] $1,370 per kilo paid, with $138 per kilo to inter PRISM waste; or $214 to use boreholes for untreated waste; or ~$250 to put the waste into temporary storage and then forget it exists.

NO GOOD OUTCOME

The free energy utopia depends on two new, as yet unproven technologies: PRISM reactors, and cheap borehole disposal. The Edwards plan appears to rely on these technologies not only being successfully developed, but remaining entirely in Australian hands. Competition is certainly not addressed in the plan.

It would be more realistic to assume that other countries would act on the same opportunities, if indeed they arose.

To implement the Edwards plan, Australia would need to spend around $10 billion to set up temporary storage, a reprocessing plant, and a pair of PRISMs. We would also need to import and store spent fuel.

Furthermore, the importation of spent fuel would likely require a dedicated port and a fleet of specialised ships, and this is not costed in the plan.[40]

The plan calls for spent fuel to begin to be imported and loaded into the dry-cask facility six years after the commencement of construction. It plans for the first PRISMs to be completed four years later. We could reasonably expect to have good data on the costs and methods of borehole storage well within this ten-year timeframe – as would any potential customers.[41]

Having spent $10 billion (not including the cost of shipping or a new port) and ten years, and with several thousand tonnes of spent fuel in storage,[42] there are, broadly speaking, two foreseeable outcomes:

1. If borehole and PRISM technologies, having been piloted commercially by Australia, are found to be as cheap and effective as hoped, other countries will have the opportunity to either use them themselves, or undercut our vast profits. It is not realistic to believe that Australia would continue to be paid five to ten times the cost of permanent storage alone.[43] Even if the hoped-for customers were nations that couldn't use borehole or PRISM technology, a number of other countries could.

2. If either technology is found to be too expensive for commercial deployment, or to have unforeseen safety problems, Australia will have locked itself into an expensive method of electricity generation with perhaps no long-term solution for the acquired waste.

---

[40] Kurzeme (1999). The Pangea Concept for an International Radioactive Waste Repository

[41] Kuhlman et al (2015). Deep Borehole Field Test: Characterization Borehole Science Objectives

[42] Assuming a linear increase reaching the maximum expected rate on the fifth year: approximately 7,500 tons after four years.

[43] That is, the mid-scenario price of $1,370 per kilo, compared with borehole storage of $138 per kilo (for PRISM-treated waste) or $214 per kilo (for existing spent fuel / other waste).

In short: either the technology works and we face stiff competition, both from other countries and the low costs of the technologies themselves – in which case the numbers in the plan are completely wrong; or the technology doesn't work as expected – in which case the numbers in the plan are completely wrong.

And in either case, the plan has still failed to cost a permanent solution for 56,000 tons of high-level waste – over 90 percent of the material taken in. The profits from the scheme would be spent in the early decades to subsidise the reactors and lower taxes, leaving future generations with a massive problem, and no plan or money left to deal with it.

There is no good outcome here.

Even if the technology succeeds, the business plan is fatally flawed. It is, in effect, a self-defeating plan. If it works, our customer base and commodity price dries up, killed by the very technologies we would have piloted at our own risk and at great expense.

Given the wildly optimistic price for waste modelled by the mid-scenario, not to mention the 56,000 tonnes of waste left over with no costed solution, and with all the uncertainties in developing the new technologies required, the simple conclusion is that this plan is simply all risk with no reward. No-one else will line up to take advantage of this "once in a lifetime opportunity", because the opportunity does not exist. The plan simply cannot succeed.

Conclusion

There are no magical solutions in the real world. When something sounds too good to be true, it usually is.

Even setting aside the technological and economic problems of the Edwards plan, its impossibility can be deduced by a simple observation: it only works if no-one else does it. It is a Catch-22. If the plan is a technological success it will open up competition, which would make it an economic failure.

There is also the question of popular will: perhaps Australia's edge would be in a unique willingness to implement such a plan? However, Australia has historically had a great deal of hostility toward the nuclear industry. If Australians could be convinced to embrace PRISMs and boreholes, surely some countries with an existing nuclear industry – countries which have, therefore, shown a much greater willingness to accept it – would also be willing to implement those solutions.

It makes far more economic sense to pay for your own boreholes, or PRISMs, or reprocessing, than it does to pay up to ten times the cost for Australia to do it for you – you would save on shipping and port costs, at least.

Not every country would or could implement this solution, but it would take just one other nation on earth to provide competition. If the deal really is as attractive as Senator Edwards claims, surely at least one other nation would be tempted to take a share of such a wildly profitable business. Assuming that Australia will somehow maintain a monopoly in technologies it does not own is naïve.

Deploying new technologies is inherently risky. PRISMs and boreholes may turn out to be massive white elephants financially, and leave us with thousands of tonnes of nuclear waste to deal with. But even if these technologies worked, some other countries would surely be in a position to implement them, and at a reduced risk, once Australia had piloted its development.

It is a plan which creates its own competition.

In reality, there is no reason to think any country would pay what the Edwards plan assumes they will. With no mature nuclear power or waste industry, holding no monopoly on the technologies needed, and far from potential markets, there is no reason to think that Australia would have a competitive advantage. There is no reason to think that Australians will accept 56,000 tonnes of waste with no costed long-term solution.

No other country will line up to take advantage of this amazing opportunity, because it does not exist. Sadly, Senator Edwards' dream is impossible.

Bibliography

Argonne National Laboratory. Integral Fast Reactor
http://www.ne.anl.gov/About/reactors/integral-fast-reactor.shtml

Arius Association (2015). Arius Association (2015). Comments of the Arius Association
http://nuclearrc.sa.gov.au/app/uploads/2015/11/Arius-Association-13-07-2015.pdf

Arnold et al (2014). Deep Borehole Disposal Research: Geological Data Evaluation, Alternative Waste Forms, and Borehole Seals
http://prod.sandia.gov/techlib/access-control.cgi/2014/1417430r.pdf

Bunn et al (2001). Interim Storage of Spent Nuclear Fuel
http://whrc.org/wp-content/uploads/2015/09/BunnetalHarvardTokyo.01.pdf

Cornwall, W. Deep Sleep. *Science* (10 July 2015), Vol. 349, Issue 6244, pp. 132-135
http://science.sciencemag.org/content/349/6244/132

Edwards, Sean (2015) [1] (3 August 2015). Transforming our Economy. Cleaning our energy. Sustaining our future.
http://nuclearrc.sa.gov.au/app/uploads/2015/10/Senator-Sean-Edwards-03-08-2015.pdf

Sean Edwards (2015) [2] The Nuclear Opportunity, presentation to The Sydney Institute, 7 April 2015
http://www.senatoredwards.com.au/speeches/nuclear-opportunity-sydney-institute-7-april-2015

Electric Power Research Institute (EPRI) 2009, Cost Estimate for an Away-From-Reactor Generic Interim Storage Facility (GISF) for Spent Nuclear Fuel
http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001018722

Generation IV International Forum (accessed 25 November 2015).
https://www.gen-4.org/gif/jcms/c_9260/Public

Government of South Australia (2015). Budget Statement: 2015-16 Budget Paper 3
http://servicesa.cdn.on.net/releases2015/2015-16%20BP3%20-%20Budget%20Statement.pdf

International Atomic Energy Agency (2012). Waste Technology Section: Overview of Disposal Options
https://www.iaea.org/OurWork/ST/NE/NEFW/Technical-Areas/WTS/geologicaldisposal-options.html

International Panel on Fissile Materials (2015). Taiwan tenders spent fuel reprocessing contract
http://fissilematerials.org/blog/2015/03/taiwan_tenders_spent_fuel.html

Kasza, K (2007). Argonne Liquid-Metal Advanced Burner Reactor: Components and In-Vessel System Thermal-Hydraulic Research and Testing Experience Pathway Forward
http://www.ipd.anl.gov/anlpubs/2007/05/59352.pdf

Kuhlman et al (2015). Deep Borehole Field Test: Characterization Borehole Science Objectives
http://prod.sandia.gov/techlib/access-control.cgi/2015/154424r.pdf

Kurzeme, M (1999). The Pangea Concept for an International Radioactive Waste Repository
http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/31/033/31033869.pdf

PNTL Fact Sheet: Pacific Grebe.
http://www.pntl.co.uk/wp-content/uploads/2012/09/PNTL_Grebe_01.pdf

Reuters (2012). As nuclear waste piles up, South Korea faces storage crisis
http://www.reuters.com/article/2014/10/12/us-southkorea-nuclear-storage-idUSKCN0I10WR20141012#9JWLajmZYcj7sGSa.97

US Government (2015). Department of Energy. Final Report of the Plutonium Disposition Red Team
http://www.ucsusa.org/sites/default/files/attach/2015/08/final-pu-disposition-red-team-report.pdf

US Government (2015). Energy Information Administration. Annual Energy Outlook 2015
http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

US Government. Nuclear Waste Policy Act (1982)
http://www.gpo.gov/fdsys/pkg/STATUTE-94/pdf/STATUTE-94-Pg3347.pdf

World Nuclear Association (2015) [1]. Radioactive Waste Management
http://www.world-nuclear.org/info/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management/

World Nuclear Association (2015) [2] Transport of Radioactive Materials
http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Transport/Transport-of-Radioactive-Materials/

World Nuclear Association (2015) [3]. Taipower launches overseas reprocessing tender
http://www.world-nuclear-news.org/WR-Taipower-launches-overseas-reprocessing-tender-1902155.html

World Nuclear Association (2015) [4]. Taiwan reprocessing tender suspended
http://www.world-nuclear-news.org/WR-Taiwan-reprocessing-tender-suspended-2003151.html