Clean electricity, cheap electricity, safe electricity – pick any three

The federal government's Carbon Pollution Reduction Scheme signals its desire for Australian pcarbon emissions (currently 28.3 tonnes per capita, yearly) to drop to 60% of 2000 levels by 2020, after allowing for population growth.

If it's business as usual, I can see some difficulty meeting that goal.

However, we don't have time for business as usual – climate change slowly parboils us all. For those of you skeptical of global warming, there are still plenty of reasons to go full throttle nuclear – economic development, saving Australian lives from reduced air pollution, and energy/water security, to name three. Energy and water security vastly reduces the need for Australia to undertake foreign policy adventures to secure oil and clean water supplies, saving yet more lives.

It makes sense to go after the biggest source of carbon emissions first – which, in Australia's case, is the power generation industry. Power generation emits nearly 14 tonnes per head, and it's fairly concentrated, unlike agriculture (4.2 tonnes) and transport (3.8 tonnes).

Clean power generation up, and we can meet, and beat, the CPRS goal. We can't cut our own economic throats cleaning up our act, so we need reliable, emission-free power to avoid disrupting the Australian economy.

This can be done, for roughly the cost of Mr Rudd's stimulus package, inside ten years, benefiting Australian national security, the power generation industry, the coal industry, and the Australian consumer.

Enter the Liquid Fluoride Thorium Reactor (LFTR). As the name suggests, it is:

- A liquid-fuelled nuclear reactor;
- Running on thorium;
- Toothpaste and table-salt safe;

On top of that, it's cheap and quick to build, allowing us to have our cake and eat it too.

Table Salt and Toothpaste

What does high pressure in a pressure vessel want to do?
I put it to you, why do conventional reactors put their fuel there, at the highest pressure?

The LFTR doesn't do this- ***it puts its fuel at the lowest pressure in the reactor*** – and if we have a leak, **it leaks in**, not out. We simply don't need the massive, expensive, pressure vessel that is a conventional reactor!

I put it to you, how do you melt a liquid?
How do you melt the already-liquid water in your morning cup of tea or coffee?
Meltdown is simply not a problem in the LFTR.
Any leaking fuel drips out of the reactor and into dump tanks below, where it freezes solid. These tanks are so effective at putting the brakes on, that if the entire fuel load at full throttle dumped into those tanks at once, it would freeze solid inside 48 hours, as it sat there. These tanks only need to be 100 cubic metres in size for a 1 gigawatt reactor.

This combination of low pressure and inherent safety, results in an inherently safe reactor that is simple enough to be mass-produced in a factory, saving 75% of the cost of a conventional reactor.

Two real prototype reactors have shown these safety benefits: the original 1968 test reactor at Oak Ridge, Tennessee, and more recently in 2008 at the Nuclear Research Institute Rez at Prague, Czech Republic.

The Bit Left Over

Since we brush the ash out of the nuclear fission fire as we go, the thorium-uranium cycle can completely extract all the energy available – like a slow combustion stove, leaving only the ash, no half-burned fuel as happens now in conventional reactors. Thus, we use <u>a hundred times less fuel</u> than a conventional reactor, to generate the same amount of raw heat energy.

Out of every hundred heavy metal atoms we start with, the conventional uranium-plutonium cycle leaves 30 atoms unburned, but the thorium-uranium cycle leaves less than 3. *That's more than 10x less heavy metals left over per kilo of fuel used,* combined with using a hundred times fewer kilos, *for a thousand fold reduction in heavy metals left over per kilowatt-hour,* before we take advantage of the LFTR's full-burn nature.

Finally, the LFTR operates at much higher temperatures than conventional reactors – high enough that we get an extra third more power out of the same amount of heat. That's at least 130x less fuel used and 1300x less heavy metal left over per kilowatt-hour, meaning 130x less so-called "waste". Since the processing cycle can keep all but 0.3% of the heavy metals in the salt, we have 400,000x less heavy metal going to so-called "waste" per kilowatt-hour.

1300x less heavy metal per kilowatt-hour;
330x overall reduction in heavy metal to "waste" from recycling;
429,000x less heavy metal to "waste" per kilowatt-hour.

Too much? Simply process the leftover ash again. Then, there will be more heavy metal in the ground you sit above as you read this, than in the ash.

You can think of LFTR as a heavy metal "roach motel" - heavy metal checks in, but it doesn't check out.

If we take Australia's total electricity generating capacity (48 gigawatts), double it (allowing for growth), and convert the lot to LFTR running flat out all the time, *it would take 620 years for the combined ash from all those plants to fill an Olympic-sized swimming pool.* As natural processes compost the ash, it becomes less radioactive than the ground you're sitting above in 300 years. Europe has many buildings that have been continuously used longer than that, so the compost heap can be kept secure.

And in that ash, the so-called "waste", are valuable minerals, such as platinum (catalysts), neodymium (permanent magnets), caesium (food sterilisation), xenon (light bulbs), strontium (space probes) and gold. Is it really "waste" if people will buy it off you?

Get Ready To Launch

Like all engines, the LFTR needs a spark plug to get going. Merely 500 kilograms of uranium enriched to just under 20% (keeping it in the low-enriched range) gets each hundred-megawatt core going. That's 100 litres of uranium, not even one and a half car fuel tanks, in the exact chemical form that the LFTR uses.

After that, no uranium needs to be loaded – that hundred megawatt reactor will tootle away on the smell of an oily rag, munching one hundred kilograms of thorium per year, year in, year out. That's 20 litres of thorium – about half of one of those car fuel tanks.

Australia is right for the thorium – 450 thousand tonnes of the stuff, and we haven't looked too hard. We are similarly right for the raw uranium – 700 thousand tonnes cheaply minable.

Yes, to power that 100 gigawatt LFTR build (double Australia's current power generation), we would need 100 tonnes of thorium each year. Assuming *absolutely no further exploration,* Australia has over 4,000 years of fuel available to power itself.

To get that spark plug, we send 25.4 tonnes of raw uranium to someone like Urenco, USEC or AREVA and pay them to enrich it to 20%. The ideal would be for Australia to develop its own enrichment capabilities, under a program like the Global Nuclear Energy Partnership, allowing it to not only enrich its own spark plugs for its LFTR fleet, but add value to the uranium it currently exports. However, Urenco, USEC and AREVA all have enrichment plants operating now.

To decarbonise Australian power generation (48 gigawatts) would take 12,1100 tonnes of raw uranium – less than 2% of our uranium reserves.

Money for short

It costs 2000 dollars per kilowatt, and takes four years, to build a conventional reactor, on-site. This has already been done repeatedly in both Korea and Japan.

For 500 dollars per kilowatt, taking two years to build, we can mass produce the much-simpler LFTR in factories. A good size for Australia, with a big export market, is 100 megawatt reactor units, instead of the gigawatt behemoths common in the USA, Europe and Asia. This has the following benefits:

- develops Australian heavy manufacturing capacity, as 480 units would be needed to convert all current Australian power generation plants
- smaller LFTR unit size mean more units are produced, speeding progress down the learning curve (getting cheaper, better, safer faster than bigger units)
- plenty of places are big enough to need a hundred megawatts but not big enough for a gigawatt
- right size to convert existing plants, using multiple units per plant site
- smaller units can be built quicker and trucked on-site, ready to install
- reduces risk for both buyer and seller
- builds capability to rapidly adapt and produce a variant for naval or spacegoing use etc

Converting existing powerplants can be done at low cost to any other alternative – we're only changing the heat source, and using the rest of the old plant. This includes the turbines, the switch yard, the power supply contracts – everything but the hot bit. The conversion would then work out to three hundred dollars a kilowatt.

For a concrete example, consider Hazelwood, in Victoria's Latrobe Valley. A world leader in carbon emission per megawatt, Hazelwood is rated at 1600 megawatts of electrical output. It would take 16 one hundred megawatt LFTR core units to convert Hazelwood. Total cost 572 million dollars, 30 million dollars per core, with startup fuel costs of 6 million dollars per core. This would remove 17.6 million tonnes of annual emissions permanently, at just over $4.90 per tonne of avoided carbon.

What is LFTR worth to the coal industry?

About 40 dollars per tonne dug out of the ground.

The LFTR operates hot enough to supply what is called ‘process heat’, which can be used to upgrade coal to higher, more profitable grades. This cheap, abundant process heat can be used to push coal upgrading to new heights, while reducing the upgraded coal’s ultimate emissions by 20-25%.

Victorian brown coal, currently considered barely worth the cost of taking it out the front gate (which is why the Latrobe Valley plants each have a dedicated mine), can be upgraded to high-rank bituminous coal for powerplant or steelmaking use. High quality thermal coal sells for around $130/tonne – as brown coal is 50-60% water, the upgraded coal gets 52 dollars per tonne dug up.

Low-rank, sub bituminous, black coals are somewhat drier (20-30% water) but still benefit from aggressive, LFTR-powered, coal upgrading. White Energy claims, on the basis of their pre-production results, a 42 dollar per tonne increase in the upgraded coal’s value.

Since coal-fired power generation currently makes up 80% of Australia’s generating capacity, that’s 11 tonnes per head of annual emissions avoided by converting existing coal plants to LFTR. The coal previously burned to emit that 11 tonnes per head (226.8 million tonnes annual emissions) can then be upgraded and exported, displacing a further 2.2 tonnes per head of Australian population (45.4 million tonnes annual emissions avoided by coal upgrading).

Natural gas-fired power plants also need to be converted – natural gas is far more valuable turned into petrol than burned.

That is at least 140 million tonnes of upgraded, high-grade, coal product exported instead of burned – how does an extra 5.5 billion dollars, yearly, sound?

What is LFTR worth to the power industry?

About 10 dollars per megawatt-hour of electricity generated.

High-temperature operation means more efficient power generation. For example, Callide C power station, in Biloela, Queensland, operates at a thermal efficiency of 39%. That means, for every megawatt-hour of electricity generated, it has to get rid of 1.6 megawatt-hours of waste heat. Callide C gets rid of that waste heat through cooling towers that use lots of water – 1500 litres of fresh water turned into a white, cloudy plume for each megawatt-hour sent to the grid.

On the lower end, Hazelwood power station, in the Latrobe Valley, Victoria, operates at a thermal efficiency of 24%. For every megawatt-hour of electricity, it has to get rid of 3.1 megawatt-hours of waste heat, through water-hungry cooling tours. 3000 litres of water turned into that cloudy plume.

By contrast, the LFTR runs at a thermal efficiency of 44%, using dry cooling – much like your car’s radiator, on a slightly bigger scale. Dry cooling means a LFTR unit doesn’t have to be sited near a water source, and can go where the power is needed. An existing water-using power station, after being converted, can then sell the water it used to draw for its own use

An intriguing possibility for coastal and barge LFTR sites is cooling them by desalinating seawater, resulting in overall production of fresh water. Using a simple membrane distillation process, an all-coastal LFTR fleet could produce enough fresh, drinkable water to fill Sydney Harbour every 5 months, as *an afterthought* of generating Australia's 2007 power consumption, 240 million megawatt-hours. That's half of Australia's total drinking water consumption made independent of drought, putting a dent in the Murray-Darling's problems.

How does an extra 2.4 billion dollars, yearly, sound?

What about the jobs?

That's part of the beauty of converting existing powerplants – **no one needs to lose their job**. In fact, **more people are needed, at coal mines,** to tend the LFTR cores dedicated to coal upgrading and run the coal upgrading equipment. These added jobs are at the high end of skilled and professional labour – $100k and up per year.

Yes, we need factories to build the 500 units needed to convert Australian power generation and provide process heat. Three such factories, building 40-50 units per year each, would each employ roughly 2000 people to build the reactors, 500 to 600 supporting the factory, and that again for mobile crews to install the reactors. Again, this is skilled and professional work (pipefitters, electricians, engineers), with the obvious effects on the local area's economy (250 million dollars yearly from salaries alone per factory, before counting any indirect effects).

The jobs at each onshore unit simply cannot be exported, and will be around for the next two to three plant lifetimes – 250 to 300 years of highly skilled, highly paid Australian labour really kicking the economy along. Similarly for the factories – high tech, high value centres of excellence and heavy manufacturing, employing thousands of people and bringing in billions of export earnings – keeping that all onshore, benefiting Australian wallets.

This effort then places Australia in an excellent position for tens of billions of dollars in export earnings each year. Supplying and installing preassembled LFTR units, taking advantage of the Australian fleet build to form centres of excellence, and operating exported LFTR units under contract, keeping the Australian Safeguards Office happy.

Just as an afterthought, we could repeat that performance (48 gigawatts of LFTR, 480 more reactor units, on Australian-flagged and crewed barges, at twice the cost of land-based versions) to clean up the world's top 12 bad boys of carbon.

Plant	City	Country	CO2 output (tonnes/yr)
Taichung	Lung-Ching Township	Taiwan	41.3 million
Poryong	Poryong-gun	South Korea	37.8 million
Castle Peak	Tuen Mun	China	35.8 million
Reftinskaya	Reftinsky	Russia	33.0 million
Tuoketuo-1	Tuoketuo	China	32.4 million
Mailaio	Mailaio	Taiwan	32.4 million
Vindhychayal	Sidhi District	India	29.0 million
Hekinan	Hekinan	Japan	28.9 million
Kendal	Witbank	South Africa	28.6 million
Janschwalde	Peitz	Germany	27.4 million
Suralaya	Serang-Merak	Indonesia	27.2 million
Tangjin	Tangjin-kun	South Korea	26.9 million

Thanks to coal2nuclear.com for the compilation and CARMA for the raw data.

After we've cleaned our own backyard up, cleaning up the 12 bad boys would stop a further 380 million tonnes of carbon dioxide each year. Australian know-how, sweat and ingenuity would then be responsible for stopping nearly **three quarters of a billion tonnes of carbon dioxide each year**, at a cost of $9.85 per tonne of avoided carbon.

What's in it for me?

I thought you'd never ask.

Cleaner air is a slam dunk – fossil fired power plants are well known as large sources of air pollution. Convert them to LFTR, and that air pollution goes away. And your health care costs also go down since you're now breathing that cleaner air.

Lower energy prices follow from conversion, in two parts. Firstly, decarbonising power generation means no carbon is emitted to produce electricity, thus **no carbon tax needs to be paid** or **emission permits need to be bought.** As a result, the standing ETS costs that would be passed onto the customer aren't there. Secondly, you aren't paying for over-hyped, under-delivering "renewable" power, such as solar or wind – they have their place, but it isn't delivering reliable power for millions of ordinary Australians. (Germany, despite its much hyped renewable build-out, has some of the highest power prices in Europe, well above current Australian levels. France, getting 80% of its power from conventional nuclear, has Europe's cheapest power).

And finally, job creation. Those factories mentioned earlier will create more than 6,000 jobs – only counting their direct effects. An entire industry will need staffing, and the education system will need to be vastly expanded to meet the demand for qualified people, such as nuclear-qualified plumbers, pipe-fitters, engineers, chemists and electricians. By accepting LFTR technology, you solve the ETS dilemma while benefiting from the economic side effects of high paying, permanent, job creation.

Why haven't I heard of this?

The LFTR was originally prototyped in 1968; the US Government ultimately pulled the plug on it because *there were so many ways to more cheaply produce less contaminated material usable in a nuclear device!* The very reason that damned it in the USA, saves it this time around for Australia. The Americans got it off the ground, and did a lot of the basic research, while other groups, such as Professor Hideki Furukawa at the International Thorium Molten-Salt Forum in Kanagawa, Doctor Jan Uhlir at the Nuclear Research Institute Rez in Prague, and Kirk Sorenson at the University of Tennessee, have filled in the gaps since. It's up to Australia to take the LFTR beyond the speed of sound.

There have been seventy thousand operational nuclear devices constructed since 1945, and not one from thorium. Yes, it is so difficult that out of the ten countries with nuclear arsenals (USA, USSR/Russia, UK, France, China, Israel, India, Pakistan, South Africa and North Korea), none have bothered.

In Summary

Using LFTR, we can:

- solve the current ETS "problem"
- convert all our coal and natural gas powered plants, cutting their carbon emissions by 99%
- eliminate 275 million tonnes of annual emissions, forever

- upgrade coal for export (made possible by the LFTR) and eliminate another 55 million tonnes – the coal industry pocketing 5.5 billion dollars of export earnings yearly for its trouble
- revitalise power generation, freeing it from worries about carbon emissions
- quit worrying about safety – no meltdowns, boiler explosions, etc
- power Australia while producing merely 48 tonnes of by-product per year (12 bathtubs of valuable, reusable and recyclable by-product, for such uses as lightbulbs, catalytic converters and jewellery)

Thanks are due to Professor Barry Brook (University of Adelaide) and three anonymous commentors, whose combined feedback has improved this article immensely.

Appendix A: Benefits of converting Hazelwood Power Station to LFTR

15% more electrical generation

17.6 million tonnes less carbon dioxide emitted (allowing for associated emissions) for 15% more power

Remaining plant life extended from 25 years to at least 80 years

Makes 25 million tonnes of low grade brown coal available to upgrade to 10 million tonnes yearly of high grade upgraded coal product available for export

Item ($ per megawatt-hour)	Now	Converted	Difference
Capital costs	11.81	22.73	10.92
Decommissioning	0.00	0.011	0.01
Fuel	11.14	0.015	-11.125
Carbon permit cost	10.86	-4.840	-15.710
Operations & maintenance	4.28	6.2	1.92
Total	38.09	24.12	-13.98

Appendix B: Benefits of converting Callide C Power Plant to LFTR

20.5% more electrical generation

4.8 million tonnes less carbon dioxide emitted annually for 20.5% more power

Remaining plant life extended from 35 years to at least 80 years

Makes 2.6 million tonnes of mid-grade black coal available to upgrade to 2 million tonnes yearly of high grade upgraded coal product available for export.

Item ($ per megawatt-hour)	Now	Converted	Difference
Capital costs	14.76	24.81	10.05
Decommissioning	0	0.008	0.01
Fuel	18.14	0.02	-18.12
Carbon permit cost	3.85	-4.93	-8.78
Operations & maintenance	4.08	6.20	2.12
Total	40.83	26.11	-14.72