Greenfields Mineral Exploration and Project Development in Victoria

Submission re thorium extraction and thorium power

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This submission relates to item (h) in the terms of reference:

> "opportunities to increase the net benefits from Victoria's minerals and energy earth resources, and to potentially provide for self- sufficiency in low cost energy and extractive minerals, consistent with the principle of economic efficiency."

Abstract

Victoria has a resource with potential for generation of safe, clean, reliable sustainable electrical energy. That resource is thorium, currently being mined in conjunction with mineral sands in the north-west of the state. Not only is this useful material unused, it is returned to the earth in dispersed and non-recoverable form.

A move to thorium power may not be economically or politically possible at this time. However, there would seem to be no barrier to the extraction and stockpiling of the thorium mineral pending investigation of the advisability of including thorium power in the energy mix for this state.

Now is the time for being 'bloody bold and resolute' by taking advantage of this rich natural resource.

Preamble

- The conventional wisdom in Australia at present regards reduction of carbon dioxide emissions as an imperative,
- Victoria has historically experienced economic superiority on the basis of electric power derived from burning cheap, accessible brown coal,
- Brown coal reserves remain extensive and cheap to exploit, but a vocal section of the community regards coal as dirty and evil,
- The call of the Greens for replacement of coal-fired generators by generation based on solar and wind energy does not stand up against reality checks in terms of efficiency, reliability, and cost – at least in the short to medium term,

- Reliable base-load non-CO_2 -emitting nuclear power based on uranium is technically and economically feasible in Australia; however the public fears associated with nuclear power are difficult to assuage,
- Objections to nuclear power in Australia can be largely overcome by use of the alternative fuel, thorium, in safer, cheaper reactors, having fewer waste storage problems, and low potential for military use.

Location of thorium in Victoria

In the north and west of Victoria mineral sands are currently being mined by Iluka Resources[1]. Mining occurs in the Murray Basin followed by processing at Hamilton. The main products are zircon and titanium minerals, but importantly the sands contain also a small proportion of thorium which, at present, is returned to the ground in a dispersed state, not easily recoverable thereafter.

To have thorium readily available for electricity generation in the future, a start could well be made on extracting the mineral and retaining it in a safe deposit. This has been done in USA, as illustrated and explained in an article from American Scientist published in July-August 2010[2]

Why was/is uranium used rather than thorium?

Historically, in the 1950s and '60s, both uranium and thorium were available and tested for power generation.

The technology was first successfully tested in the 1960s. At Oak Ridge National Laboratory an experimental molten-salt reactor was in operation from 1965 to 1969 when it was decommissioned. In 1977, a light-water reactor was used to establish a thorium232-uranium233 fuel cycle. This reactor was working at Shippingport Atomic Power Station from 1977 to 1982.[3]

The ultimate choice of uranium over thorium for commercial power generation was made on the basis that the uranium process provided material for military use – a pragmatic decision during the time of the cold war.

Without the requirement for nuclear weapon material, thorium would be a natural choice. However many countries have preferred to maintain their established industries rather than change to new processes and systems.

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[1] June 2011 Quarterly Production Report from Iluka Resources
http://www.iluka.com/Default.aspx?page=130&did=822
Iluka has had dealings with the Victorian Government related to infrastructure development and reduction of truck traffic.

[2] http://www.thoriumenergyalliance.com/downloads/American_Scientist_Hargraves.pdf

[3] http://en.wikipedia.org/wiki/Molten-salt_reactor_experiment

What are the advantages of thorium over uranium?

A paper on thorium in Australia commissioned by the Australian Government in 2007[4] lists some advantages of thorium:

- A thorium-based fuel cycle is more proliferation resistant than conventional uranium-based reactors though there is still a degree of risk
- Thorium-based fuel cycle waste products are not as long lived as those from conventional nuclear reactors
- Thorium is abundant in Australia.

Further advantages are discussed in a Cosmos article by Tim Dean[5], published in 2006-7. These include

- Thorium, unlike uranium, is not spontaneously fissile; it must be induced to split, and the process stops immediately upon removal of the inducing source; hence 'melt-down' cannot happen.
- There is an expectation of lower cost, since shielding of the reactor chamber need not be so extensive.
- Whereas a very small proportion of naturally-occurring uranium is fissile, thorium occurs in a form which is almost all 'fertile', i.e., capable of induced fission.
- Inclusion of some conventional nuclear waste products to induce fission of the thorium is potentially a way of using up some of these products such as plutonium.

Where are thorium reactors currently in use or planned?

A Wikipedia[6] summary includes the following:

- The U.S Energy Department has supported research into thorium fuel (1997), and the International Atomic Energy Agency has also begun to study the use of thorium in reactors (1996).
- An Israeli nuclear scientist has led an international consortium including Brookhaven National Laboratory and the Kurchatov Institute in Moscow to develop thorium reactors.
- Some countries including India are now investing in research to build thorium-based nuclear reactors; development of thorium power is a priority in India.
- In 2007, Norway, having large deposits of thorium, was debating whether or not to focus on thorium reactors. A government-sponsored report received a cool reception from some scientists in 2008. However, research was forging ahead in 2010.[7]

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[4] http://www.aph.gov.au/Library/pubs/RP/2007-08/08RP11.pdf

[5] http://www.cosmosmagazine.com/features/print/348/new-age-nuclear?page=5%2C0

[6] http://en.wikipedia.org/wiki/Thorium#Thorium_as_a_nuclear_fuel

[7] http://newenergyandfuel.com/http:/newenergyandfuel/com/2010/05/03/one-step-closer-to-a-thorium-fueled-power-plant/

- Notably, at the 2011 annual conference of the Chinese Academy of Sciences[8], it was announced that China has initiated a research and development project in thorium molten-salt reactor technology.

How far developed is the necessary technology?

India is considered to be a global leader in thorium-based reactors. India purchased two CANDU (Canadian deuterium-uranium) nuclear reactors from Canada, and has since built thirteen more, based on the CANDU design, with an additional three now under construction. The CANDU reactor is capable of using thorium as a fuel. This perhaps explains why India has been able to develop expertise in using thorium.

The progress of nuclear (with emphasis on thorium) technology development in India is detailed in a paper entitled "Shaping the Third State of Indian Nuclear Power Program"[9]. Like China, India is looking for a clean, reliable, sustainable and politically palatable source of energy for urban areas and industry.

Research continues on reactors of different designs. In countries where uranium nuclear power is well established, there is debate over the cost-effectiveness of continuing with tried technologies versus converting to new, albeit cleaner and safer, technologies. A country entering this field with thorium fuel in mind would have a wide range of design choices to consider. This consideration requires expert consultation.

Could Victoria lead Australia in implementation of thorium power?

Victoria has available fuel.

Victoria has coal-fired power plants at or near their use-by dates.

A precedent of collaboration with the Chinese in the coal-based industry has been established.[10] It remains to be seen whether negotiations will eventually result in action. However, this precedent would assist in establishment of similar collaboration in the development of thorium-fuelled reactors, should the government decide that this is the way to go for Victoria.

In this context, Ted Baillieu's speech as reported in The Age of Aug 11 2011 (Victoria set to lead the way in China links)[11] is of particular relevance.

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[8] http://english.cas.cn/Ne/CASE/201102/t20110209_64985.shtml
[9] http://www.dae.gov.in/publ/3rdstage.pdf
[10] http://www.theage.com.au/victoria/green-for-go-with-browncoal-station-20100413-s7n6.html
[11] http://www.theage.com.au/opinion/politics/victoria-set-to-lead-the-way-in-china-links-20110810-1imnj.html

Added reasons can be found for adding a new technology to the energy mix for Victoria. Other value-adding innovations can be more easily incorporated when developing an entirely new system. The design can include methods for using collateral heat energy (as well as electrical), such as for heating and/or cooling local towns, fish farming, growing algae for producing biodiesel…

Jack Lifton[12], an international technology metals consultant, says thorium fuelled civilian- use- only nuclear electric generating industry is *looming on the economic and political horizon.*[13]

Recommendations

A vital and forward-thinking government should give consideration to establishing Australia's first nuclear power industry.

Consultation with appropriately qualified academics would be a necessary first step.

Pending this action, at the very least, immediate consideration should be given to the extraction and stockpiling of thorium.

[12] http://www.techmetalsresearch.com/about-us/jack-lifton/
[13] http://www.australianuranium.com.au/thorium-analysis.html

APPENDIX: A SELECTION of THORIUM REFERENCES

About the element thorium

http://www.lycos.com/info/thorium--uranium-thorium.html
What is thorium? (Basic chemical information)
http://www.australianuranium.com.au/thorium-analysis.html
Jack Lifton's case for thorium mining and reactors, 2009
http://www.techmetalsresearch.com/about-us/jack-lifton/
Who is Jack Lifton?

http://minerals.usgs.gov/minerals/pubs/commodity/thorium/690398.pdf
Between 1993-1996, 80% of thorium imported by USA was in the form of monazite from Australia. Imports ceased as demand decreased and non-radioactive substitutes became available.

Cosmos articles

http://www.cosmosmagazine.com/features/print/348/new-age-nuclear?page=5%2C0
Tim Dean's article is a comprehensive and readable introduction to energy forms, nuclear energy in general and thorium-based nuclear energy in particular, presenting thorium as the basis for 'new-age nuclear power'.
http://www.cosmosmagazine.com/news/1341/green-nuclear-power-coming-norway
Liz Williams in 2007 speaks of Norway's investigation into the possibility of thorium power for Norway.
http://www.reuters.com/article/2008/02/15/us-norway-nuclear-thorium-idUSL1538756620080215http://www.reuters.com/article/2008/02/15/us-norway-nuclear-thorium-idUSL1538756620080215
This article describes negative reaction of scientists reporting to Norway's government in 2008.
http://newenergyandfuel.com/http:/newenergyandfuel/com/2010/05/03/one-step-closer-to-a-thorium-fueled-power-plant/
Nevertheless research and plans continue in Norway in 2010

A Norwegian response to Australian Tim Dean's article

This is an email from a Canadian friend who has been of great assistance in browsing the internet for information of thorium power and on CANDU reactors:

Vemund Kaarstad is the Chief Engineer at Siemens Oil & Gas Offshore. He's also an inventor, and the holder of a number of patents, both domestic and international. Siemens is part of a 'consortium of companies' working with the Norwegian Ministry of Petroleum & Energy. According to the websites I viewed, a number of scientists from companies in the consortium, including Vemund Kaarstad, have been seconded from their private corporate positions to assist

the Norwegian government in the coordination of research and development efforts with private industry re nuclear energy as a 'renewable energy source'.

When Kaarstad said (in his comment) that he congratulated Tim Dean for the content of the April 2006 Cosmos article, this clearly indicates that he believed that Dean's article got it right about thorium being used as a fuel in nuclear reactors. Given Kaarstad's role in both private industry and in the ongoing coordinated effort between private industry and the Norwegian government, Dean's article becomes that much more important (dare I say, [almost] 'authoritative') as a source of relevant information for both politicians and bureaucrats to read and make serious note of in their deliberations and report writing.

Research in China

http://www.climateactionprogramme.org/news/china_research_surge_to_dominate_thorium_nuclear_technology/

The full article is reproduced here

Scientists and private firms in China have embarked on a major new surge to develop liquid-fluoride thorium reactor (LFTR) technology. First developed by the US military in the 1950s and 1960s, research was abandoned, perhaps because the technology offered no potential for producing nuclear weapons.

Research has re-commenced in the US, and India, Japan, and Russia, are now also working on thorium reactors. Last month, China showed evidence of joining the race towards a credible LFTR design.

Thorium is three to four times more abundant throughout the world than uranium, and could be used to create nuclear energy in various ways; however the Manchester Report in 2009 found LFTR technology use most notable.

Benefits of thorium nuclear include waste remaining toxic for hundreds, rather than thousands, of years, and power stations that are smaller and considered safer than uranium reactors.

Alexander Cannara, an electrical engineer and green activist, told Spectrum (August, 2010): "there are millennia of thorium atoms within easy reach, requiring no energy-intensive, proliferation-endangering 'enrichment', and no wasteful removal of delicate fuel pellets and rods before even 10 percent of their fuel is consumed."

A thorium reactor cleans up after itself, and proponents indicate that as part of its regular energy generation process, it could function as a kind of waste disposal mechanism for plutonium and other weapons grade material, said Cannara.

China's development of thorium nuclear was announced in the Chinese Academy of Sciences (CAS) annual conference on Tuesday, 25 January.

The research is led by Dr. Jiang Mianheng, a graduate of Drexel University in electrical engineering. He said that the aim is to secure intellectual property rights for thorium's implementation.

Technology journalist Andrew Orlowski reported that a private company in China is aiming to build a prototype within five years, which can produce electricity for as little as 6.8p per kilowatt hour.

Although the thorium reactor could be a safer and less environmentally destructive alternative to uranium fuelled nuclear, with China as the forerunner in the global renewable energy industry, the investment in further nuclear remains controversial.

Given China's domination in other technological fields, with new developments including a proposed hydropower project at the Nu River, the nation's exploitation of thorium as an energy source, and its emergence as a leader in the field, could soon become a reality.

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http://www.wired.com/wiredscience/2011/02/china-thorium-power/
Here is another article directed at the general reader
The official announcement comes as the Obama administration has committed itself to funding R&D for next-generation nuclear technology. The president specifically mentioned Oak Ridge National Laboratory in his State of the Union address Jan. 25, but no government-funded program currently exists to develop thorium as an alternative nuclear fuel.

A Chinese thorium-based nuclear power supply is seen by many nuclear advocates and analysts as a threat to U.S. economic competitiveness. During a presentation at Oak Ridge on Jan. 31, Jim Kennedy, CEO of St. Louis–based Wings Enterprises (which is trying to win approval to start a mine for rare earths and thorium at Pea Ridge, Missouri) portrayed the Chinese thorium development as potentially crippling.

"If we miss the boat on this, how can we possibly compete in the world economy?" Kennedy asked. "What else do we have left to export?"

According to thorium advocates, the United States could find itself 20 years from now importing technology originally developed nearly four decades ago at one of America's premier national R&D facilities. The alarmist version of China's next-gen nuclear strategy come down to this: If you like foreign-oil dependency, you're going to love foreign-nuclear dependency.

"When I heard this, I thought, 'Oboy, now it's happened,'" said Kirk Sorensen, chief nuclear technologist at Teledyne Brown Engineering and creator of the Energy From Thorium blog. "Maybe this will get some people's attention in Washington."

While the international "Generation IV" nuclear R&D initiative includes a working group on thorium MSRs, China has made clear its intention to go it alone. The Chinese Academy of Sciences announcement explicitly states that the PRC plans to develop and control intellectual property around thorium for its own benefit.

Safe nuclear does exist, and China is leading the way with thorium
http://www.defence.pk/forums/china-defence/99304-safe-nuclear-does-exist-china-leading-way-thorium.html

A timely article, written post-Fukushima

A few weeks before the tsunami struck Fukushima's uranium reactors and shattered public faith in nuclear power, China revealed that it was launching a rival technology to build a safer, cleaner, and ultimately cheaper network of reactors based on thorium.
This passed unnoticed –except by a small of band of thorium enthusiasts – but it may mark the passage of strategic leadership in energy policy from an inert and status-quo West to a rising technological power willing to break the mould.
If China's dash for thorium power succeeds, it will vastly alter the global energy landscape and may avert a calamitous conflict over resources as Asia's industrial revolutions clash head-on with the West's entrenched consumption.
China's Academy of Sciences said it had chosen a "thorium-based molten salt reactor system". The liquid fuel idea was pioneered by US physicists at Oak Ridge National Lab in the 1960s, but the US has long since dropped the ball. Further evidence of Barack `Obama's "Sputnik moment", you could say.
Chinese scientists claim that hazardous waste will be a thousand times less than with uranium. The system is inherently less prone to disaster.
"The reactor has an amazing safety feature," said Kirk Sorensen, a former NASA engineer at Teledyne Brown and a thorium expert.

"If it begins to overheat, a little plug melts and the salts drain into a pan. There is no need for computers, or the sort of electrical pumps that were crippled by the tsunami. The reactor saves itself," he said.
"They operate at atmospheric pressure so you don't have the sort of hydrogen explosions we've seen in Japan. One of these reactors would have come through the tsunami just fine. There would have been no radiation release."
Thorium is a silvery metal named after the Norse god of thunder. The metal has its own "issues" but no thorium reactor could easily spin out of control in the manner of Three Mile Island, Chernobyl, or now Fukushima.
Professor Robert Cywinksi from Huddersfield University said thorium must be bombarded with neutrons to drive the fission process. "There is no chain reaction. Fission dies the moment you switch off the photon beam. There are not enough neutrons for it continue of its own accord," he said.
Dr Cywinski, who anchors a UK-wide thorium team, said the residual heat left behind in a crisis would be "orders of magnitude less" than in a uranium reactor.
The earth's crust holds 80 years of uranium at expected usage rates, he said. Thorium is as common as lead. America has buried tons as a by-product of rare earth metals mining. Norway has so much that Oslo is planning a post-oil era where thorium might drive the country's next great phase of wealth. Even Britain has seams in Wales and in the granite

cliffs of Cornwall. Almost all the mineral is usable as fuel, compared to 0.7pc of uranium. There is enough to power civilization for thousands of years.

I write before knowing the outcome of the Fukushima drama, but as yet none of 15,000 deaths are linked to nuclear failure. Indeed, there has never been a verified death from nuclear power in the West in half a century. Perspective is in order.

We cannot avoid the fact that two to three billion extra people now expect – and will obtain – a western lifestyle. China alone plans to produce 100m cars and buses every year by 2020.

The International Atomic Energy Agency said the world currently has 442 nuclear reactors. They generate 372 gigawatts of power, providing 14pc of global electricity. Nuclear output must double over twenty years just to keep pace with the rise of the China and India.

If a string of countries cancel or cut back future reactors, let alone follow Germany's Angela Merkel in shutting some down, they shift the strain onto gas, oil, and coal. Since the West is also cutting solar subsidies, they can hardly expect the solar industry to plug the gap.

BP's disaster at Macondo should teach us not to expect too much from oil reserves deep below the oceans, beneath layers of blinding salt. Meanwhile, we rely uneasily on Wahabi repression to crush dissent in the Gulf and keep Arabian crude flowing our way.

So where can we turn, unless we revert to coal and give up on the ice caps altogether? That would be courting fate.

US physicists in the late 1940s explored thorium fuel for power. It has a higher neutron yield than uranium, a better fission rating, longer fuel cycles, and does not require the extra cost of isotope separation.

The plans were shelved because thorium does not produce plutonium for bombs. As a happy bonus, it can burn up plutonium and toxic waste from old reactors, reducing radio-toxicity and acting as an eco-cleaner.

Dr Cywinski is developing an accelerator driven sub-critical reactor for thorium, a cutting-edge project worldwide. It needs to £300m of public money for the next phase, and £1.5bn of commercial investment to produce the first working plant. Thereafter, economies of scale kick in fast. The idea is to make pint-size 600MW reactors.

Yet any hope of state support seems to have died with the Coalition budget cuts, and with it hopes that Britain could take a lead in the energy revolution. It is understandable, of course. Funds are scarce. The UK has already put its efforts into the next generation of uranium reactors. Yet critics say vested interests with sunk costs in uranium technology succeeded in chilling enthusiasm.

The same happened a decade ago to a parallel project by Nobel laureate Carlo Rubbia at CERN (European Organization for Nuclear Research). France's nuclear industry killed proposals for funding from Brussels, though a French group is now working on thorium in Grenoble.

Norway's Aker Solution has bought Professor Rubbia's patent. It had hoped to build the first sub-critical reactor in the UK, but seems to be giving up on Britain and locking up a deal to build it in China instead, where minds and wallets are more open.

So the Chinese will soon lead on this thorium technology as well as molten-salts. Good luck to them. They are doing Mankind a favour. We may get through the century without tearing each other apart over scarce energy and wrecking the planet.

Existing thorium energy projects
http://en.wikipedia.org/wiki/Thorium#Thorium_as_a_nuclear_fuel

Some additional articles of interest
http://www.aph.gov.au/Library/pubs/RP/2007-08/08RP11.pdf
Paper on thorium in Australia commissioned by Aust Gov 2007

http://www.popsci.com/technology/article/2011-06/next-gen-nuke-designs-promise-safe-efficient-emissions-free-energy?page=1
Popular Science article

http://www.thoriumenergyalliance.com/
Thorium Energy Alliance website with an immense amount of information presented at scientifically-literate general level

http://www.thoriumenergyalliance.com/downloads/American_Scientist_Hargraves.pdf
An excellent article from American Scientist - lots of technical info, historical perspective, prospects for USA and for other parts of the world, problems of moving to a new technology as distinct from modifying old technologies