INPUT FOR ESKOM NUCLEAR POWER EIA

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Date: 28 August 2007

This document is aimed at providing input to the Eskom Nuclear program EIA process. It aims to highlight the environmental benefit that can be attained from using an alternative nuclear fuel; Thorium.

1 BACKGROUND

One of the biggest problems in nuclear power generation is the treatment, storage and disposal of the waste produced by nuclear power stations. As such the aspects surrounding both the volume and toxicity of waste produced should take central stage in the EIA process.

The difference in wastes generated between the uranium and thorium cycles is so significant that it will be irresponsible of Eskom not to give serious consideration to the thorium fuel cycle.

2 HISTORY AND DEVELOPMENT OF THE THORIUM FUEL CYCLE

The first nuclear reactor that used thorium as fuel started operating in 1962 in the USA. This was after a specialist task force in the USA in 1959 found that a reactor design based on the thorium cycle "has *the highest probability of achieving technical feasibility*".

During the years a number of reactors have been operated on thorium, proving the technical feasibility of the concept. These include reactors in the USA as well as Europe. The HTGR, on which the current PBMR design is based, also operated on thorium fuel.

The thorium fuel cycle was abandoned during the cold war as is does not produce plutonium, which was a much sought after commodity in the nuclear arms race.

India commissioned a thorium based pilot reactor in 1995, the Kakrapar-1 reactor. This was followed up by a policy decision to use the thorium cycle as a cornerstone in the Indian energy strategy[1]. The first commercial thorium based power reactor in India is currently being commissioned.

Thorium programs are currently being investigated in a number of other countries. These include USA, Russia, Canada, Norway and the UK. The driving forces behind these developments are all similar and include the non-proliferatory nature of the thorium cycle, the diminished waste problem and the availability of fuel.

3 TECHNICAL ASPECT OF THE THORIUM FUEL CYCLE.

During 2005 the IAEA published a study on the use of thorium as nuclear fuel In this study they highlighted the following advantages of the thorium fuel:

a) *Thorium is 3 to 4 times more abundant than uranium, widely distributed in nature as an easily exploitable resource in many countries and has not been exploited commercially so far. Thorium fuels, therefore, complement uranium fuels and ensure long term sustainability of nuclear power.*

b) *Thorium fuel cycle is an attractive way to produce long term nuclear energy with <u>low radio toxicity waste</u>. In addition, the transition to thorium could be done through the incineration of weapons grade plutonium (WPu) or civilian plutonium.*

c) *Thorium dioxide is chemically more stable and has higher radiation resistance than uranium dioxide. <u>The fission product release rate for ThO_2–based fuels are one order of magnitude lower than that of UO_2.</u> ThO_2 has favourable thermo-physical properties because of the higher thermal conductivity and lower co-efficient of thermal expansion compared to UO_2.*

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[1] South Africa has an agreement with India to cooperate on nuclear power and has been instrumental in the closing of a nuclear power deal between India and the USA.

Thus, ThO_2–based fuels are expected to have better in–pile performance than that of UO_2 and UO_2–based mixed oxide.

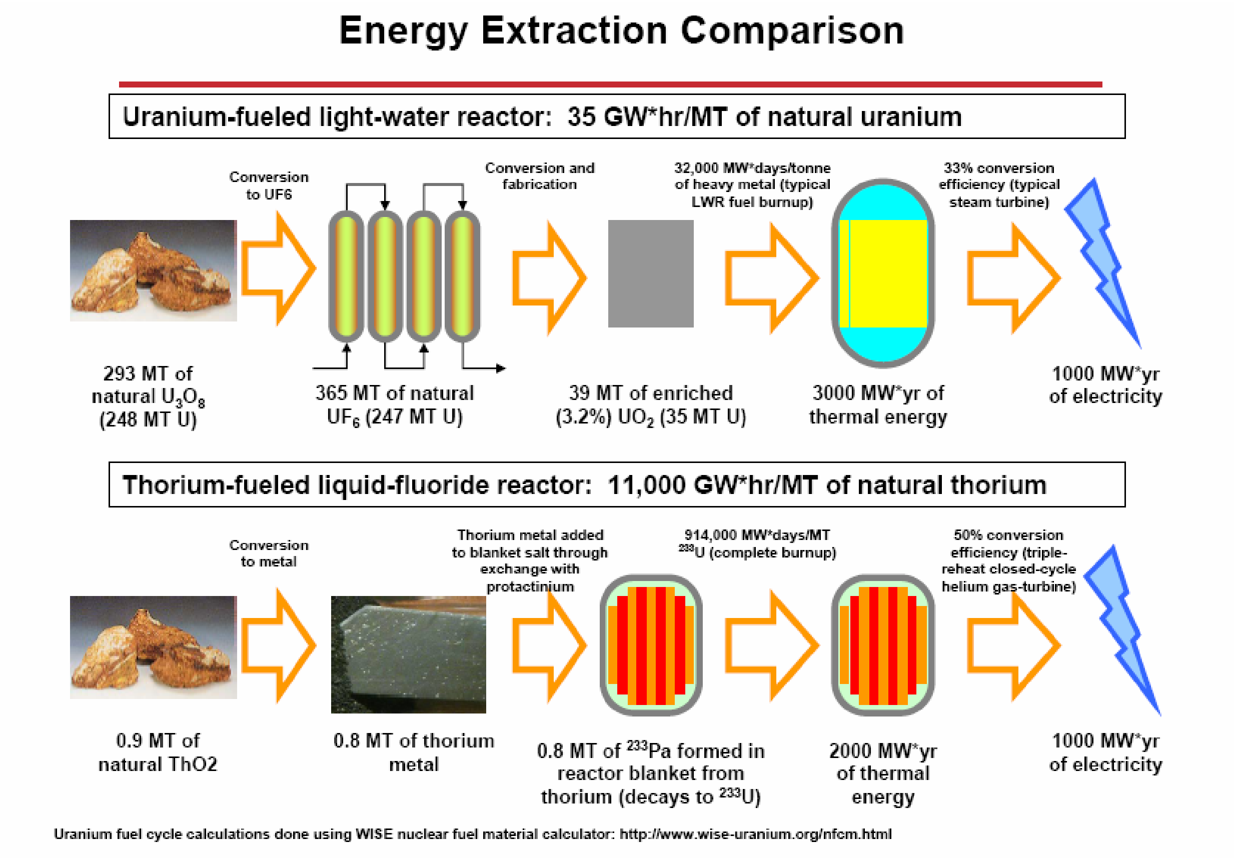
d) *ThO_2 is relatively inert and does not oxidize unlike UO_2, which oxidizes easily to U_3O_8 and UO_3. Hence, long term interim storage and permanent disposal in repository of spent ThO_2–based fuel are simpler without the problem of oxidation.*

e) *Th–based fuels and fuel cycles have intrinsic proliferation-resistance due to the formation of ^{232}U via (n,2n) reactions with ^{232}Th, ^{233}Pa and ^{233}U. The half-life of ^{232}U is only 73.6 years and the daughter products have very short half-life and some like ^{212}Bi and ^{208}Tl emit strong gamma radiations. From the same consideration, ^{232}U could be utilized as an attractive carrier of highly enriched uranium (HEU) and weapons grade plutonium (WPu) to avoid their proliferation for non-peaceful purpose.*

f) *For incineration of WPu or civilian Pu in 'once-through' cycle, $(Th, Pu)O_2$ fuel is more attractive, as compared to $(U, Pu)O_2$, since plutonium is not bred in the former and the ^{232}U formed after the 'once-through' cycle in the spent fuel ensures proliferation resistance.*

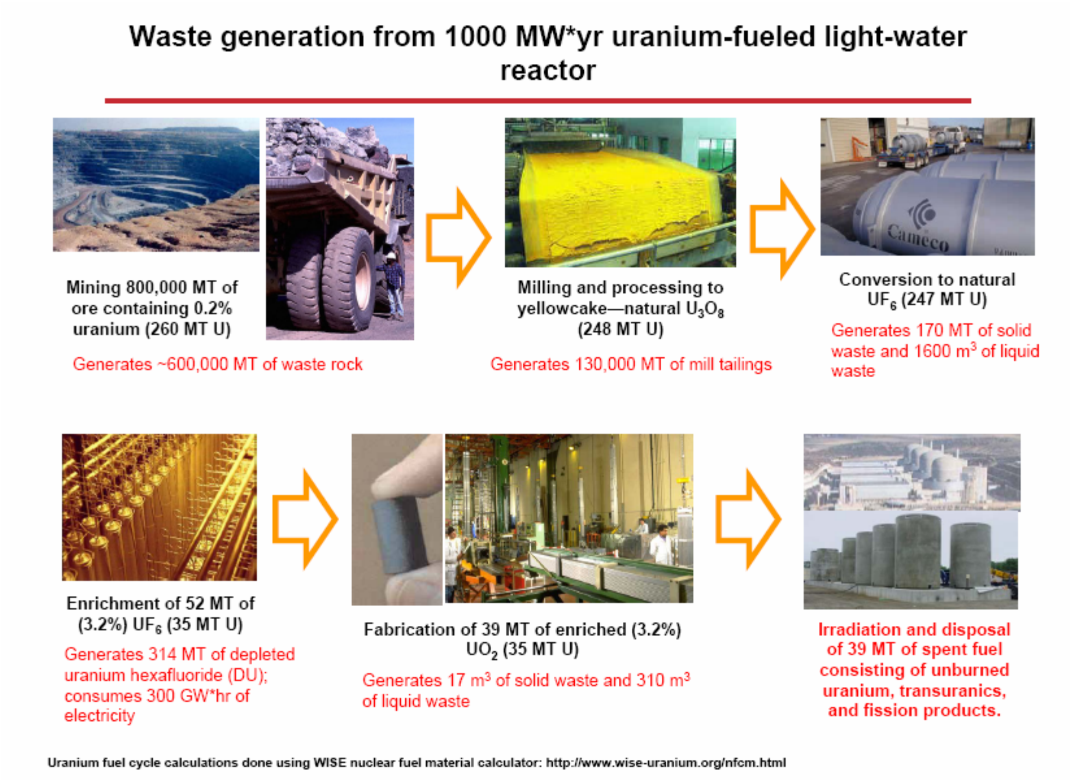
g) *In ^{232}Th–^{233}U fuel cycle, much lesser quantity of plutonium and long-lived Minor Actinides (MA: Np, Am and Cm) are formed as compared to the ^{238}U–^{239}Pu fuel cycle, thereby minimizing the radio toxicity associated in spent fuel. However, in the back end of ^{232}Th–^{233}U fuel cycle, there are other radio-nuclides such as ^{231}Pa, ^{229}Th and ^{230}U, which may have long term radiological impact.*

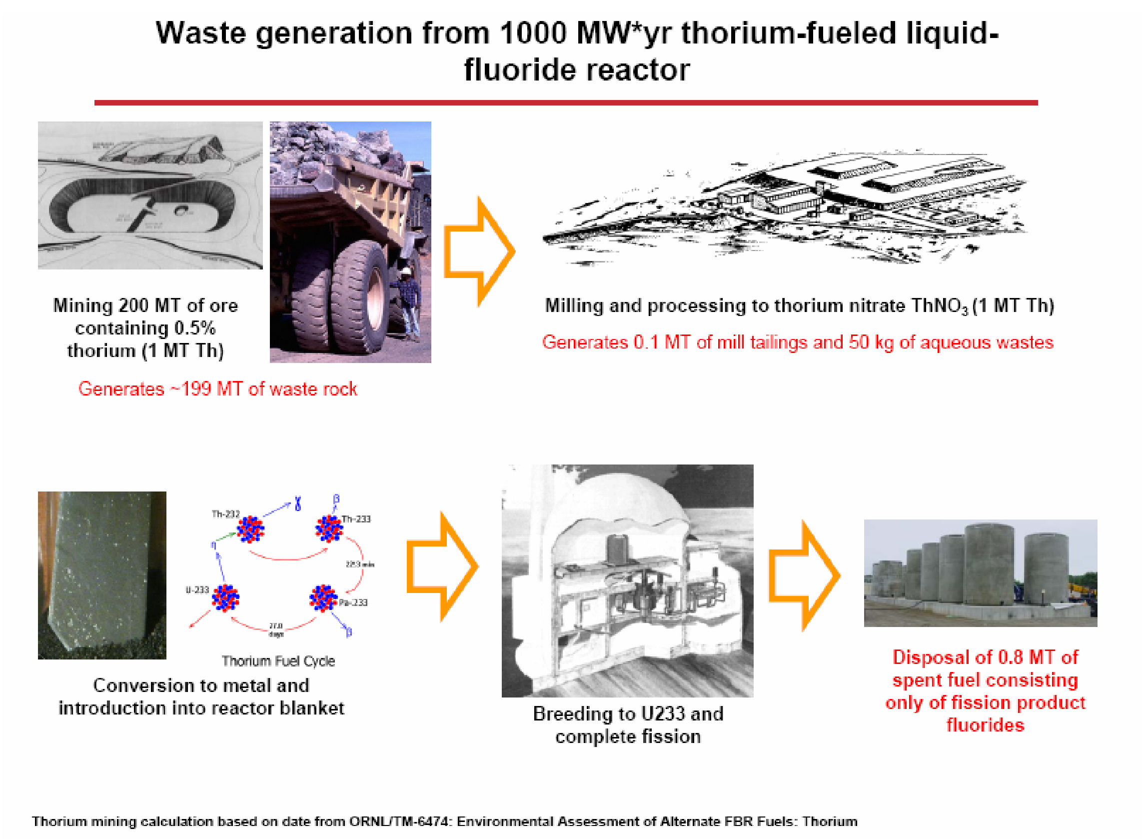
In addition to these benefits to the environmental impact of the thorium fuel cycle is significantly less than that of the uranium cycle, as can be seen in the following figures:



Here it can be seen that the uranium fuel cycle requires 325 times more ore than the thorium fuel cycle to produce the same amount of electricity. The environmental impact of this is tremendous.

Eskom should, as part of the life cycle assessment of the power they generate give serious consideration to the mining impacts of the fuel they use.





These figures indicate that the amount of waste generated from the uranium cycle is almost 50 times higher than that produced in the thorium cycle.

4 CONCLUSION

Ensuring that the correct technological choices are made is a central theme of the EIA process. As such it is important for this project that the differences in environmental impact between the uranium and thorium fuel cycles be highlighted and investigated.

It will be irresponsible of Eskom not to give serious concideration to the thorium fuel cycle in their investigation to build more nuclear power stations.

Appendix: Thorium based reactors

Name and Country	Type	Power	Fuel	Operation period
AVR, Germany	HTGR Experimental (Pebble bed reactor)	15 MW(e)	Th+^{235}U Driver Coated fuel particles Fuel, Oxide & dicarbides	1967 – 1988
THTR, Germany	HTGR Power (Pebble Type)	300 MW(e)	Th+^{235}U, Driver Fuel, Coated fuel particles Oxide & dicarbides	1985 - 1989
Lingen, Germany	BWR Irradiation-testing	60 MW(e)	Test Fuel (Th,Pu)O_2 pellets	Terminated in 1973
Dragon, UK	HTGR	20 MWt	Th+^{235}U Driver Fuel,	1966 - 1973
OECD-Euratom also Sweden, Norway & Switzerland	Experimental (Pin-in-Block Design)		Coated fuel particles Dicarbides	
Peach Bottom, USA	HTGR Experimental(Prismatic Block)	40 MW(e)	Th+^{235}U Driver Fuel, Coated fuel particles Oxide & Dicarbides	1966 – 1972
Fort St Vrain, USA	HTGR Power (Prismatic Block)	330 MW(e)	Th+^{235}U Driver Fuel, Coated fuel particles Dicarbide	1976 - 1989
MSRE ORNL, USA	MSBR	7.5 MWt	^{233}U Molten Fluorides	1964 - 1969
Borax IV & Elk River Reactors, USA	BWRs, (Pin Assemblies)	2.4 MW(e) 24 MW(e)	Th+^{235}U Driver Fuel Oxide Pellets	1963 - 1968
Shippingport & Indian Point, USA	LWBR PWR(Pin Assemblies)	100 MW(e) 285 MW(e)	Th+^{233}U Driver Fuel, Oxide Pellets	1977 – 1982 1962 - 1980
SUSPOP/KSTR KEMA, Netherlands	Aqueous Homogenous Suspension (Pin Assemblies)	1 MWt	Th+ HEU Oxide Pellets	1974 - 1977
NRU & NRX, Canada	MTR (Pin Assemblies)		Th+^{235}U Test Fuel	Irradiation–testing of few fuel elements
KAMINI, CIRUS, & DHRUVA, India	MTR Thermal	30 kWt 40 MWt 100 MWt	Al-^{233}U Driver Fuel ‘J’ rod of Th & ThO_2‘J’ rod of ThO_2	All three research reactors in operation
KAPS 1&2, KGS 1&2, RAPS 2,3&4, India	PHWR (Pin Assemblies)	220 MW(e)	ThO_2Pellets For neutron flux flattening of initial core after start-up	Continuing in all new PHWRs
FBTR, India	LMFBR (Pin Assemblies)	40 MWt	ThO_2blanket	In operation