

Chapter 4: Strategic objectives

“Continuous effort – not strength or intelligence – is the key to unlocking our potential.”

~ Winston Churchill ~

Overview

Certain countries have made significant progress with the thorium-based fuel cycle (India and Norway) and nuclear technology in general (South Korea). Each country is introduced with a summary of their approach and policy. Each country has its own unique set of conditions that resulted in their original approaches. The current state of nuclear technology and the nuclear fuel cycle in SA is given. Identified lessons and policies are applied to the South African context, which results in different goals to achieve a thorium-based fuel cycle in future. These goals form an integral part of the roadmap to implement thorium-based fuels in SA.

4.1 Lessons learned from India, South Korea and Norway

The following countries have made significant progress with the thorium-based fuel cycle (India and Norway) and nuclear technology in general (South Korea). South Africa can relate to these countries and learn from their approaches. Each country is introduced with a summary of their approach and policy.

4.1.1 India

India is considered to be the leading country in terms of thorium research and development. India has a unique situation due to the large indigenous thorium reserves, modest uranium reserves and the fact that they were banned from accessing international nuclear technology

until recently. India has a fast growing population, demanding large energy production. These factors forced India to develop its own original flagship technology that utilizes their vast thorium reserves (Hesketh & Worrall, 2010). With the recommendations of Homi Bhabha, India committed to develop a thorium-based fuel cycle for future energy independence (Lung & Gremm 1998).

The aim of the Indian programme is to achieve a sustainable, closed, thorium-based nuclear fuel cycle. This plan consists of three stages.

First phase: Use natural uranium fuel in Pressurized Heavy Water Reactors (PHWR) to convert U^{238} into Pu^{239} (IAEA, 2002). PHWR are used, due to the higher conversion of Th^{232} to U^{233} (Schram & Klaasen, 2007).

Second Phase: Utilize the plutonium produced from the first phase and uranium and thorium used as the blanket in Fast Breeder Reactors (FBRs) to generate power and increase the (Pu^{239} and U^{233}) fissile material supply (IAEA, 2002).

Third phase: Based on thorium fuelled thermal (breeder) reactors, which burn the U^{233} and plutonium with thorium. Several theoretical studies have been carried out on thorium-based fuel cycles in Advanced Heavy Water Reactors (AHWR) (IAEA, 2002).

The achievement of the Indian thorium fuel cycle programme depends greatly on the recycling of both fissile and fertile components of the spent fuel. Reprocessing in India dates back to 1964 with the commissioning of a plant based on PUREX (Plutonium Uranium Extraction) technology (Dey & Bansal, 2006).

4.1.2 South Korea

The GDP of South Korea has shown an average annual development of 8,6% over the past 30 years. In parallel to the GDP, the consumption of electricity increased from 33 billion kWh to 371 billion kWh from 1980 to 2006. The first power reactor was a Westinghouse unit built on a turnkey contract that started operations in 1978. The next two reactors that followed were also purchased as turnkey projects. After the first three plants, South Korea involved local contractors and manufacturers for the six next-generation plants (WNA, 2012).

Experience and skills have been acquired from Westinghouse, Framatome (now Areva) and Combustion Engineering (now part of Westinghouse). Then South Korea designed their own recognised nuclear power plant, called the Korean Standard Nuclear Power Plant (WNA, 2012).

Matters of energy security and the need to reduce dependency on imports have driven the South Korean energy policy. Their plan, from the beginning, was to standardise the design of nuclear plants and to achieve much greater self-sufficiency in building them (WNA, 2012).

Nuclear energy is of tactical importance to South Korea, and the Prime Minister sanctioned a capacity increase in 2010 of 56% by 2030. Korea plans to be 100% self-reliant by 2012. The current capacity factor for South Korean power reactors is one of the highest in the world namely 96.5%. South Korea has an open fuel cycle, without reprocessing, due to the nuclear cooperation agreement with the USA, which will be renewed in 2014 (WNA, 2012).

4.1.3 Norway

In 2011 the Research Council of Norway (RCN) advised that “The thorium option be kept open in so far it represents an interesting complement to the uranium option to strengthen the sustainability of nuclear energy” (Duffey & Sur, 2011).

The significance of thorium in Norway is the indigenous reserves, and ThorEnergy has shown interest by means of investment. ThorEnergy is a daughter company in the Scatec group of renewable energy enterprises in Norway. They focus on the utilization of thorium-based fuels for use both in current- and future reactors applicable worldwide. Plutonium is used as the initial fissile material for LWRs, until U^{233} becomes sufficient to be used in the future (Hesketh & Worrall, 2010).

The fuel would be (Th/Pu)O₂ (TOX) fuel, due to the central similarities to (U/Pu)O₂ (MOX). This choice of fuel would simplify the R&D, implementation (Hesketh & Worrall, 2010). The goals of ThorEnergy are to establish a thorium-based fuel cycle, and power reactor based on the utilization of Norwegian thorium and reactor-grade spent fuel. The first two thorium-based reactors of more than 2000MWe are planned for 2017 (ThorEnergy, 2009).

4.2 Current context in SA

Each country that is discussed in section 4.1 has its own unique set of conditions that resulted in their different approaches. The current context of nuclear technology and the fuel cycle in South Africa is given.

Koeberg is the only nuclear power plant in South Africa and it was built by Framatome and commissioned between 1984 and 1985. It is owned and operated by Eskom (the South African utility) and has two 900MWe PWRs. Necsa (previously AEC) has operated a 20MW research reactor Safari-1 at the Pelindaba Nuclear Research Centre since 1965. Necsa is the main supplier of medical radioisotopes in Africa and can produce up to 25% of the world's molybdenum/technetium requirements (WNA, 2010).

Eskom is planning to build a capacity of 9600MWe of new nuclear power stations (PWRs) before the end of 2030. Six reactors are planned, and the building rate is restricted to one unit every 18 months, starting in 2023 (SA, 2011). See Figure 4.1 for the building schedule on the timeline. Each blue line represents the time when each new reactor will be commissioned.

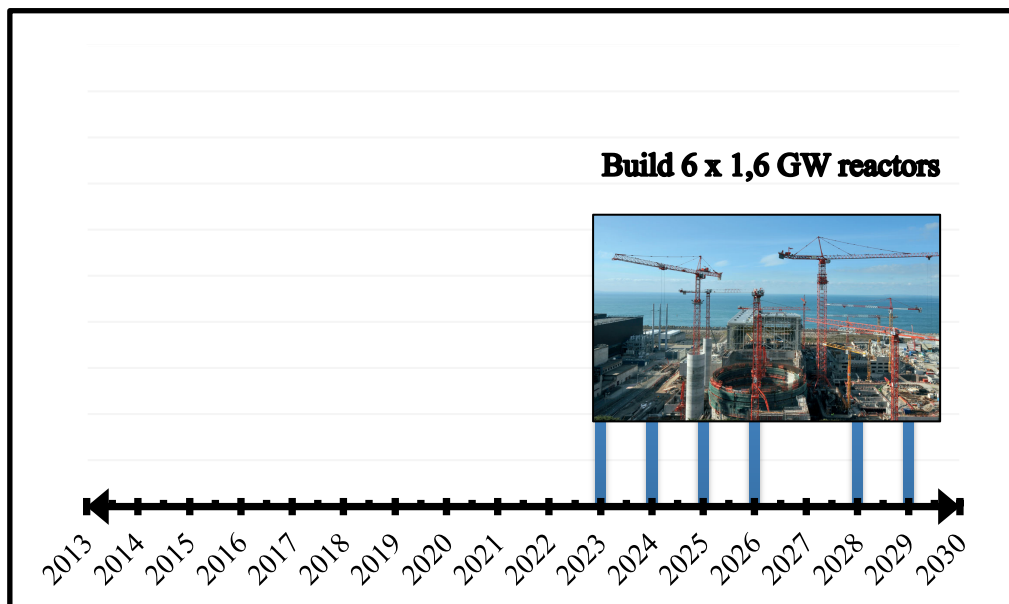


Figure 4.1 IRP building schedule for 6 reactors

Uranium mining in SA has normally been a by-product of gold and copper mining. Fuel for Koeberg was initially imported, but due to sanctions, conversion, enrichment and fuel manufacturing services were developed to produce fuel for Koeberg locally. Enrichment was done between the 1970s and 1980s using a unique aerodynamic separation process known as the Helikon vortex tube process. The technology was no longer economically competitive, and fuel was once again imported.

South Africa is a party to the Nuclear Non-Proliferation Treaty (NPT) as a non-nuclear weapons state. South Africa also agreed that they would not reprocess their spent fuel to use the Pu in MOX. The nuclear chief director of the Minerals and Energy department announced that Eskom would seek commercial arrangements to reprocess spent fuel overseas and utilize the MOX fuel (WNA, 2010).

South Africa is considering reinstating its uranium enrichment and conversion facilities, to ensure security of fuel supply for the new fleet of nuclear power stations. The new nuclear fleet is expected to use 465 tonnes of enriched uranium a year by 2030. Preliminary feasibility studies showed that a fleet of around 10000MW would make uranium enrichment a viable choice (Roelf, 2012).

Eskom suggested that the enrichment facility develop together as part of the nuclear programme to ensure that fuel production plants can be economically sustainable. Necsa supplied nuclear fuel between 1988 and 1994 to Koeberg. Areva and Toshiba's Westinghouse Electric Corp at present supply Koeberg with 30 metric tonnes of enriched uranium per year for its two units (Roelf, 2012). The current fuel cycle in SA is shown in Figure 4.2.

Steenkampskraal thorium limited (STL) is a mine in the Western Cape Province containing monazite. STL has the ability to store thorium (mixed with concrete) in casements underground in a recoverable form. The historic in-situ thorium grade is about 2.5% and Rareco will be extracting the thorium during the production step of the final mixed rare earth chloride concentrate. The current amount of thorium at STL is estimated at 6250 tonnes and the total thorium resources in South Africa are estimated at around 55000 tonnes (Van Rooyen *et al.*, 2012)

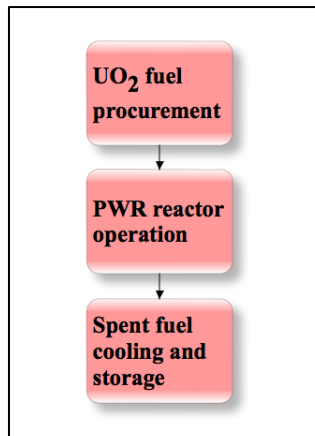


Figure 4.2 Current fuel cycle in SA

4.3 Objectives

The significant lessons and approaches from India, South Korea and Norway have been identified. These lessons and policies can now be applied to the South African context. The resultant South African energy policy should include the following goals.

South Africa is rich in uranium and thorium reserves unlike India, which has modest uranium and large thorium reserves. Thorium in South Africa should supplement uranium and ensure future energy security. Thorium implementation and development should commence before there is a shortage of uranium. It should also be noted that South Africa does not have an established fuel reprocessing facility like India. For South Africa to achieve a closed fuel cycle, South Africa needs to start with rigorous and focused development of a reprocessing facility.

Like South Korea, it is possible for South Africa (and any other country) to learn from US and French vendors to become independent. Governmental commitment and thorough project management could ensure the success of obtaining experience from world-leading vendors.

Like Norway, South Africa can develop fuel, for not only “South African reactors” (like India). South Africa can produce thorium-based fuel internationally, especially since South Africa has sufficient amounts of thorium and uranium. This would significantly boost the South African economy.

South Africa should:

- Recognise and acknowledge its rich thorium resources.
- Commit to develop a thorium-based fuel cycle. To achieve a sustainable, secure, independent, nuclear fuel cycle complimented by thorium-based fuels.
- Obtain as much as possible experience and skills from the vendor/vendors building the first reactors.
- Involve local contractors and manufacturers in the nuclear expansion program.
- Standardise the design of its nuclear plants to achieve higher self-sufficiency.
- Develop its own original reactor technology based on experience (in the far future).
- Reduce fuel dependency on imports and become self-reliant.
- Develop thorium-based fuels not only for South Africa but also in the future for the whole world.
- Consider reprocessing in the future to close the fuel cycle.
- Apply for major research and development investments and funding.

4.4 Conclusion

Different approaches of countries that have made significant progress with thorium-based fuel cycles and nuclear technology in general, have been derived and applied to the South African context. The different goals to achieve a thorium-based fuel cycle in the future are given. These goals will form an integral part of the roadmap to implement thorium-based fuels in SA.

South Africa can commit to develop a thorium-based fuel cycle to become energy independent and achieve a sustainable, secure, nuclear fuel cycle. South Africa is rich in uranium and thorium reserves and South Africa can learn from US and French vendors to become independent. Local contractors and manufacturers could be involved in the nuclear expansion program (like South Korea).

South Africa can standardise the design of their nuclear plants to achieve higher self-sufficiency and develop its own original reactor technology based on experience (like India and South Korea). South Africa should consider reprocessing in the future to close the fuel cycle (like India). South Africa can reduce its fuel dependency on imports and become self-

reliant (like South Korea and India) as well as to develop a fuel implementation strategy in different phases (like India).