

Chapter 1: Introduction

“Research is formalized curiosity. It is poking and prying with a purpose.”

~ Zora Neale Hurston ~

Overview

The problem statement and research objectives are discussed, followed by the structure of the dissertation. The chapter ends with an explanation of the validation of this project.

1.1 Problem statement

Nuclear technology for electricity production has received increased attention in South Africa (SA), especially after the IRP2010 (Integrated Resource Plan 2010) was published. The nuclear power industry can expect growth due to amplified focus on depleting coal resources and the overall drive to utilize carbon-free power sources.

The nuclear industry security of fuel supply is imperative to be considered a sustainable energy resource. Other fuel resources than uranium need to be considered in view of the vast nuclear expansion plans of a single country, such as China. The price of uranium is uncertain and uranium fuel cycles still contribute to the unacceptable build-up of worldwide plutonium stockpile growth. An evolutionary strategy of introducing thorium-based fuels into existing and future reactor technologies is required.

Eskom is planning to build a capacity of 9600MWe of new nuclear power stations (most likely PWRs) before the end of 2030 (SA, 2011). The current policy direction of governments has forced researchers to investigate technologies that incinerate plutonium, reduce the production of long-lived radioactive isotopes, enhance burnup and extend refuelling cycles.

1.2 Research aims and objectives

The main objectives of this study are to:

- Identify the most important thorium-based fuel options.
- Evaluate the impact of thorium-based fuel cycles in terms of modifications and strategies required in PWR's.
- Make suggestions on the choice of modifications and strategies for thorium-based fuels on PWR's.
- Economic comparison of the thorium-based fuel options to uranium in the PWR, focusing on extended refueling cycles.
- Develop a thorium introduction strategy/roadmap for South Africa.

1.3 Structure of the dissertation

The dissertation consists of the following chapters:

Chapter 2: The literature survey consists of an overview of past experience with different research and power reactors. The material properties, fertile and fissile isotope properties as well as the decay chain of thorium are discussed in order to evaluate thorium as a fuel.

Chapter 3: The different thorium-based fuel designs for PWR cores are discussed and resulting difficulties and solutions are given. These suggestions are compared and critically evaluated (in terms of advantages and disadvantages). A process of elimination selects the best option for each strategy, which results in a combination of mitigation and optimisation strategies.

Chapter 4: Certain countries have made significant progress with the thorium-based fuel cycle (e.g. India and Norway) and nuclear technology in general (South Korea). Each country is introduced with a summary of their approach and policy. The current context of nuclear technology and the nuclear fuel cycle in SA is presented. Identified lessons and policies are applied to the South African context, which result in different goals to achieve a thorium-based fuel cycle in the future. These goals form an integral part of the roadmap aimed at implementing thorium-based fuels in SA.

Chapter 5: The prices of uranium and thorium are discussed. This chapter focuses on the economic advantages of thorium-based fuel cycles, especially the fuel cycle cost and the

refuelling outage costs. Thorium-based fuels can extend refuelling cycles, which in turn reduce the fuel requirements and the spent fuel for disposal, as well as the reactor downtime for refuelling.

The results indicate that (Th/U)O₂ shows economic benefits over traditional uranium fuel cycles. Unfortunately, (Th/Pu)O₂ did not show any economic benefit over UOX. The total savings were calculated by adding the fuel cycle savings and the refuelling outage saving. (Th/U)O₂-fuel proved to be the most economical and Eskom could save up to 49 billion rand in 60 years.

Chapter 6: Based on research and results obtained from previous chapters, a systematic strategic thorium-based fuel implementation roadmap is developed. Economic, strategic and historical aspects direct the roadmap. The advantages of thorium-based fuels are summarised from knowledge gained from Chapter 1 to Chapter 5. All these advantages form the initiative to implement thorium-based fuels in SA.

A timeline (which forms the basis of the roadmap) is constructed. The roadmap consists of three different phases. Phase 1 starts in 2013 and extends to 2030. Phase 2 starts in 2031 up to 2044 and Phase 3 from 2045 to 2060. Each phase is discussed with regard to construction, implementation and research activities. This roadmap will progress and advance to future technologies, corresponding to the evolutionary approach.

Chapter 7: The research is concluded and comments and recommendations are given to suggest future research and development work. Thorium-based fuel cycles are at present not mature and need further investigation and refinement before implementation in 2028. The identified areas that need further investigation are given in this chapter.

1.4 Validation

This project is validated based on the principle of “Do nothing approach vs. alternative approach vs. proposed approach”. The economic evaluation compares the (Th/U)O₂ (proposed approach) with the (Th/Pu)O₂-fuel (alternative approach) with the current UO₂-fuel (do nothing approach). This dissertation is also validated by a thorough and wide-ranging literature survey continued in Chapter 3 and Chapter 4. The strategic roadmap is based on

historical (Chapter 2), technical (Chapter 3), strategic (Chapter 4) and economic (Chapter 5) aspects.