Radioactive Material Management in South Africa

S. BVUMBI [1 4], P. NAIDOO [2 3], D. NICHOLLS [2 3], S. H. CONNELL [2 3], J. SLABBER [3 4]
National Radioactive Waste Disposal Institute [1]
University of Johannesburg [2], University of Pretoria [3]
SAIEE Nuclear Chapter [4]
South Africa

SUMMARY

The radioactive wastes produced in South Africa from medical, industrial and mining activities are mostly low level waste. The waste is controlled, managed and safely packed into sealed storage containers. The waste is long term stored at the National repository to full decay. The post application of nuclear fuel assemblies at the national nuclear power station produces high level spent fuel. For the last four decades, all the spent fuel assemblies are safely stored at the power station; in the spent fuel pools within the reactor. This storage is monitored by international policy and practices as driven by the United Nations. The paper describes South Africa's experiences with a deep dive into the management processes of radioactive materials. The study extracts the present-day practices that ensure the safe use of the uranium as a resource, with zero impact to the environment. Given the potential impact to future generations as the radioactivity decays into time and the material returns to natural ore, the study tables South Africa's engineered geological infrastructure solutions to accommodate the high level waste and absorb the long-time factor of decay back to natural ore.

KEYWORDS

Waste Classification, Waste Storage, Waste Density, Environmental Impact.

1 INTRODUCTION

The South African economy has different sectors and functions that give rise to the production of radioactive waste. This is described in figure 1. Radioactive waste is a term used for radioactive substances for which no further usage is envisaged. The radioactive substances contained in radioactive wastes contain radionuclides with activity concentration levels that calls for radiation control and protection. The type of radionuclides, the activity and the half-life are the main properties of radioactive wastes that are used when doing classification and waste categorization.

The International Atomic Energy Agency (IAEA) GSG-1 general safety guide document of 2009 is used to classify wastes in South Africa [1,2]. The commonly discussed radioactive wastes are Low-level wastes (LLW), intermediate level wastes (ILW), and High-level wastes (HLW). The main concerns when dealing with radioactive wastes is the safety of the public and the environment. Any activity involving radioactive wastes has to ensure that no hazards or exposures that could be harmful should occur. Radioactive wastes require safe handling, storage, transportation and disposal.

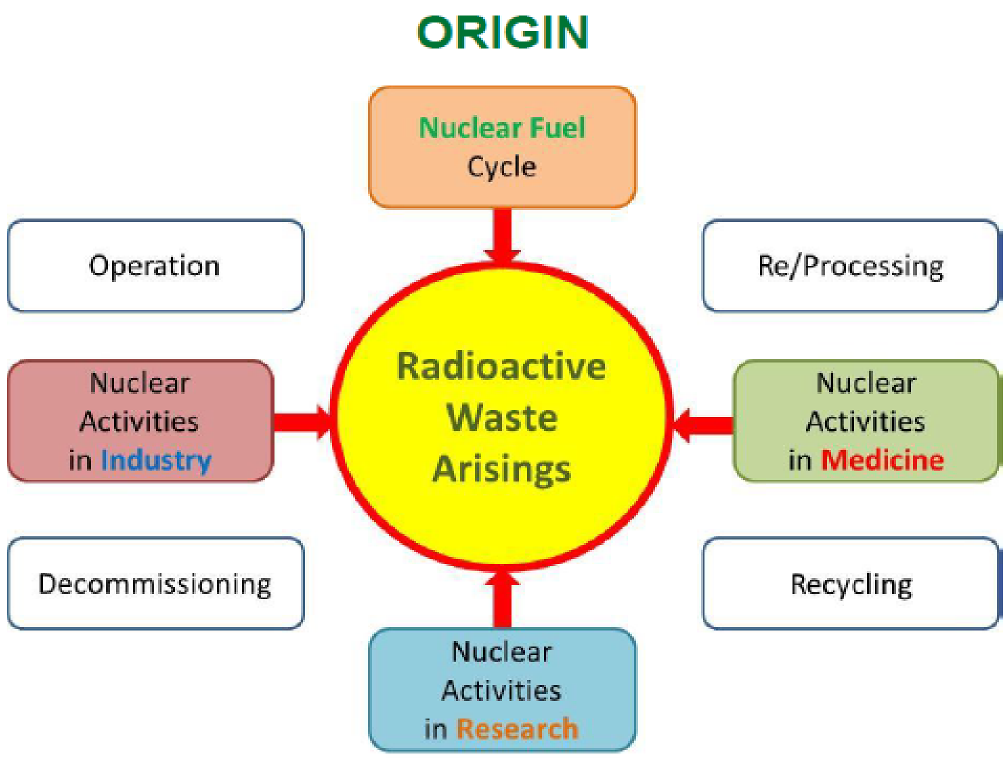

Figure 1 is a schematic diagram showing radioactive wastes arising from different nuclear activities.

1.1 Low Level (LLW) and Intermediate Level Wastes (ILW)

South Africa's waste depository site is located at Vaalputs, in the Northern Cape Province. Figure 2 shows the locality of the national facility relative to the two major national nuclear facilities; the nuclear power station in Western Cape and the national research facility that is located in the economic hub of the Gauteng province.

The source of low and intermediate level waste generally emanates from the medical, industrial and research activities of the national economy; plus that of general consumables at the national nuclear power station. The low and intermediate level waste is technically packaged and place in sealed containers. The containers are delivered and placed in near surface storage bunkers under virtual lock and key; effectively meaning that no member of the public or no part of the general environment of fauna or flora are exposed to the long term storage. With time, the residual energy content of the low and intermediate materials decays. Thereafter there is no threat or

harm. From ore and ore, the natural philosophy of “dust to dust” sustains. Figures 3 and 4 respectively shows the transportation and storage of the material at Vaalputs.

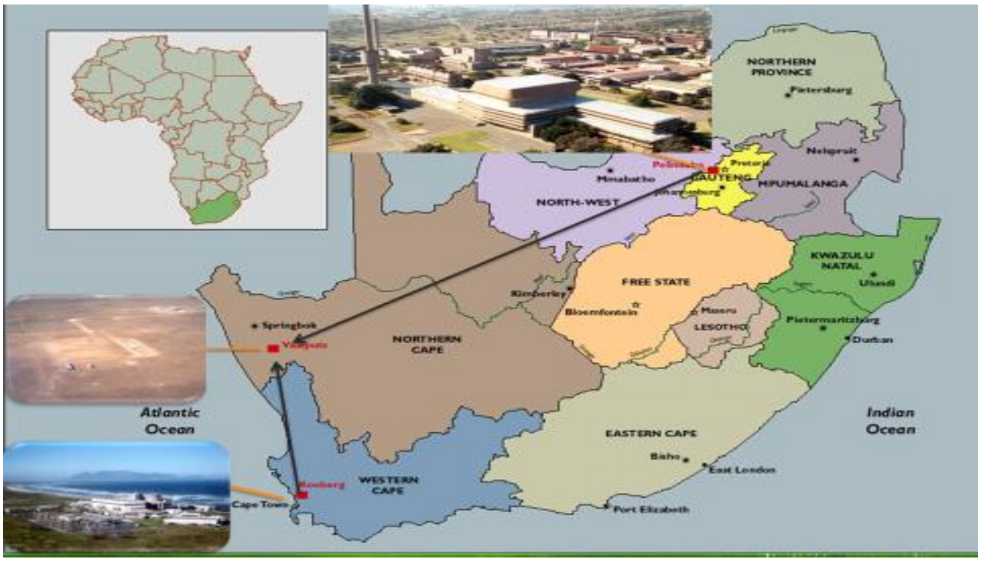

Figure 2 : The National Radioactive Storage Site at Vaalputs

Figure 3 : LLW and ILW Pack into Sealed Containers on Transport to Vaalputs

Figure 4 : The Sealed Containers are Packed into Near Surface Bunkers for Long Term Storage

1.2 High Level Waste (HLW)

South Africa's only source of high level waste is the spent fuel assemblies of the Koeberg nuclear power station. The power station was commissioned in 1985 and to date, all the spent fuel assemblies remain on site in the spent fuel pools within the reactor containment building. In 2014, Koeberg will celebrate four decades of continuous electricity generation to the South African national economy. To date, the power station has maintained an absolute zero emission into the air or the environment from its heat generating activity. Relative to its thermal coal or diesel powered counterparts, this is a remarkable achievement worthy of environmental celebration. Figure 5 shows the packing of the spent fuel assemblies in the spent fuel pool; each assembly is unique identified and globally monitored by the United Nations International Atomic Energy Association regulatory institute; all within a globally established regulatory policy and practices environment.

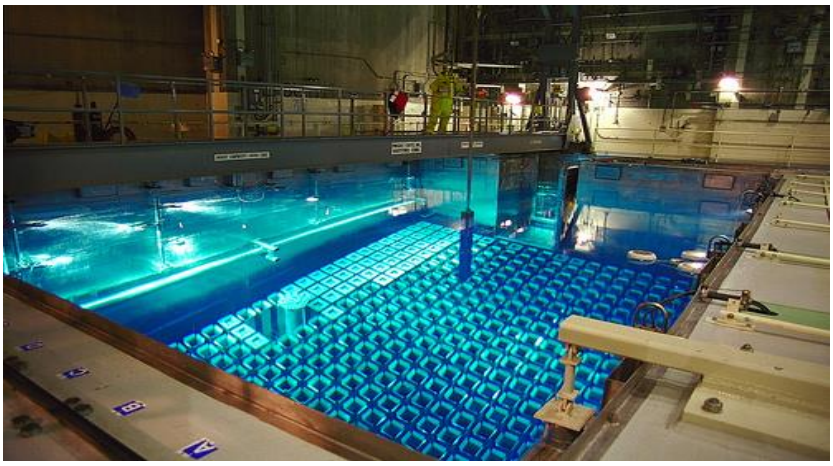

Figure 5 : The Spent Fuel Pool

A common operational challenge is the requirement for more space as new fuel assemblies are loaded into the reactor. A common practice is to re-rack existing pools. All of South Africa's four decades of spent fuel remains at Koeberg and each of the reactor pools are now full. For the next few years, the plan is to move storage from the "wet pools" to that of "dry casks". Figure 6 shows a dry storage vessel, a designed cask, to contain both radioactive emissions and residual heat.

Figure 6 : A Dry Storage Cask for Medium Term Fuel Assembly Storage

2 LITERATURE REVIEW

2.1 Radioactive wastes disposal methods or strategies

Radioactive wastes disposal strategies and methods require very careful and safe methods by design for zero impact to the environment of man, animals, fauna and flora. Given the extreme long term nature of radioactivity decay, design strategy chosen must not burden the future generations. By science led design, there must exist zero leakage of radionuclides. The risk is contamination of ground water. The international policy and best practices to deal with radioactive wastes includes near surface disposal of LLW and ILW, deep geological disposal in repositories of HLW; supported in transit by long term wet and dry storage. Transmutation and reprocessing are limited and constrained options. The method or strategy of disposal differ from country to country depending on factors such as, geology, climate, environment and many other factors.

2.2 Theory of Transmutation and Environmental Impact

Transmutation refers to the change in the nucleus of an atom. The process can be either natural or artificial. The intent is to transform the long term source of radioactivity, radiotoxity and heat into stable and short lived materials. Transmutation is research in progress and the challenge of long lived impact is described in figure 7 for the three scenarios of nuclear waste transmutation, spent fuel reprocessing and disposal and no reprocessing. [2]

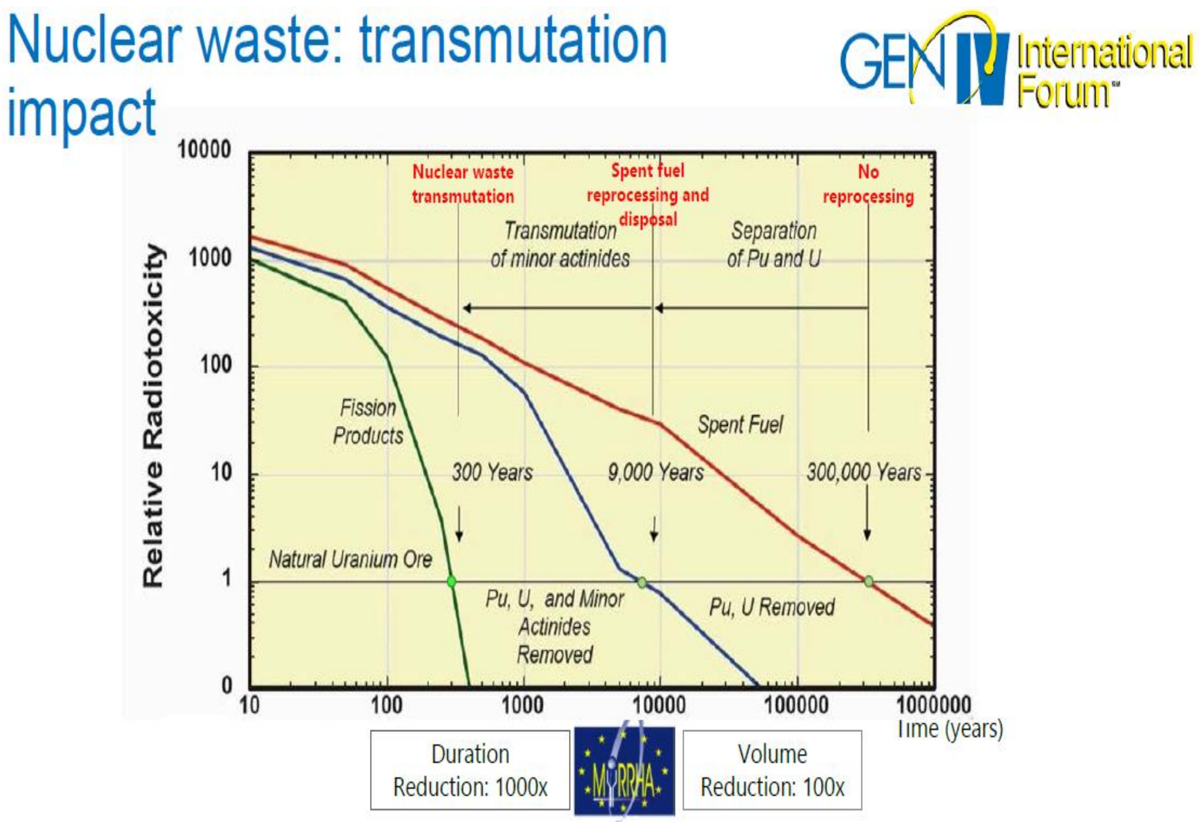

Figure 7 : Nuclear Waste Transmutation Impact

2.3 Internationally Accepted Practices for Waste Management and Disposal

Over the years science, technology and research development have progressed and the storage and disposal of nuclear waste has improved approaches and technologies. There are different scenarios that a country can consider depending on their regulations, policies, economics and many other factors. The scenarios showed in figure 8 were generated using the two electronic, excel-based, decision support tools which were developed by the IAEA to assist Member States in developing their RRSNF (Research Reactor Spent Nuclear Fuel) management strategies [3]. This is namely the Back-end Research reactor Integrated Decision-making Evaluation (BRIDE), which includes the cost estimation comparative input module Back end Analytical Scenario Cost Estimation Tool (BASCET); Fuel Cycle Cost Estimation for Research Reactors in Excel (FERREX) - a cost analysis tool. BRIDE allows quantitative comparison of available technologies and thereby determine the best strategy. The FERREX tool is used to determine detailed cost estimates for the chosen strategy.

Currently South Africa has chosen scenario 5 for the management of our spent nuclear fuel from SAFARI1 research reactor and the Koeberg nuclear power station.

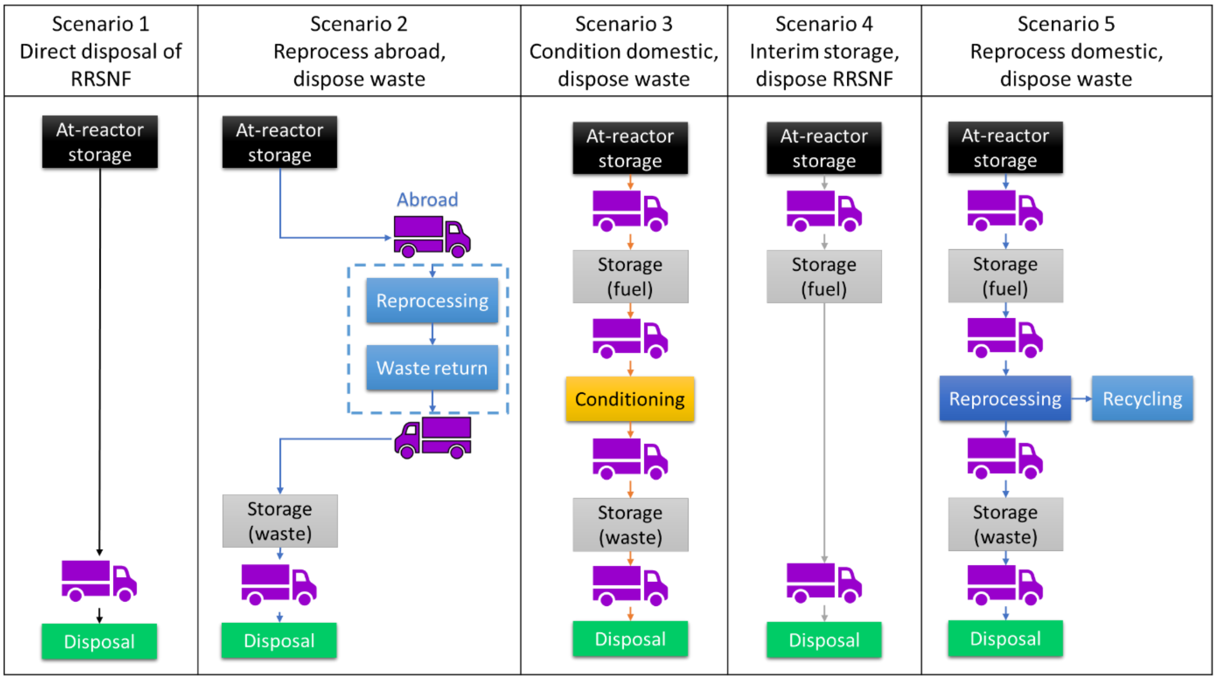

Figure 8: International accepted practices for waste management and disposal.

3. THE SOUTH AFRICAN SCENARIO FOR WASTE MANAGEMENT AND DISPOSAL

Based on scenario 5 of Figure 8, the spent nuclear fuel from our two nuclear reactors at Koeberg will be moved from the respective facilities to a dry storage facility for long-term dry storage, offsite. Dry spent fuel storage facilities can be used for periods of more than 50 years with an appropriate level of monitoring, surveillance, and ageing management planning. Over the past 20–30 years the role played by dry storage in filling the gap between available wet storage and other back-end services has increased. The main attractions of dry storage are its passive cooling capability, reduced possibility of fuel cladding corrosion (over wet storage) and reduced life cycle costs through the ability to add incremental capacity, and lower maintenance costs than a spent fuel pool.

The National Radioactive Waste Disposal Institute (NRWDI) was given a mandate by the Ministry of Mineral Resources and Energy to establish a CISF, and the ideal site would be Vaalputs, which is the low-level waste near surface disposal facility [4]. However, that is just a preferred site, not overlooking site selection and public acceptance processes that go with other regulatory requirements. The CISF is envisaged to be ready for use by 2030 as shown on the CISF timelines in figure 9 [5]. However, given that the spent fuel pools at the nuclear power station is approaching the full capacity, the temporary plans are for a Temporary Interim Storage Facility (TISF) to be located onsite. This internal plan is still not the ultimate long-term plan for South Africa. Koeberg is near the sea, and there are wet sands that will give rise to corrosion challenges. The CISF establishment is still not the ultimate solution.

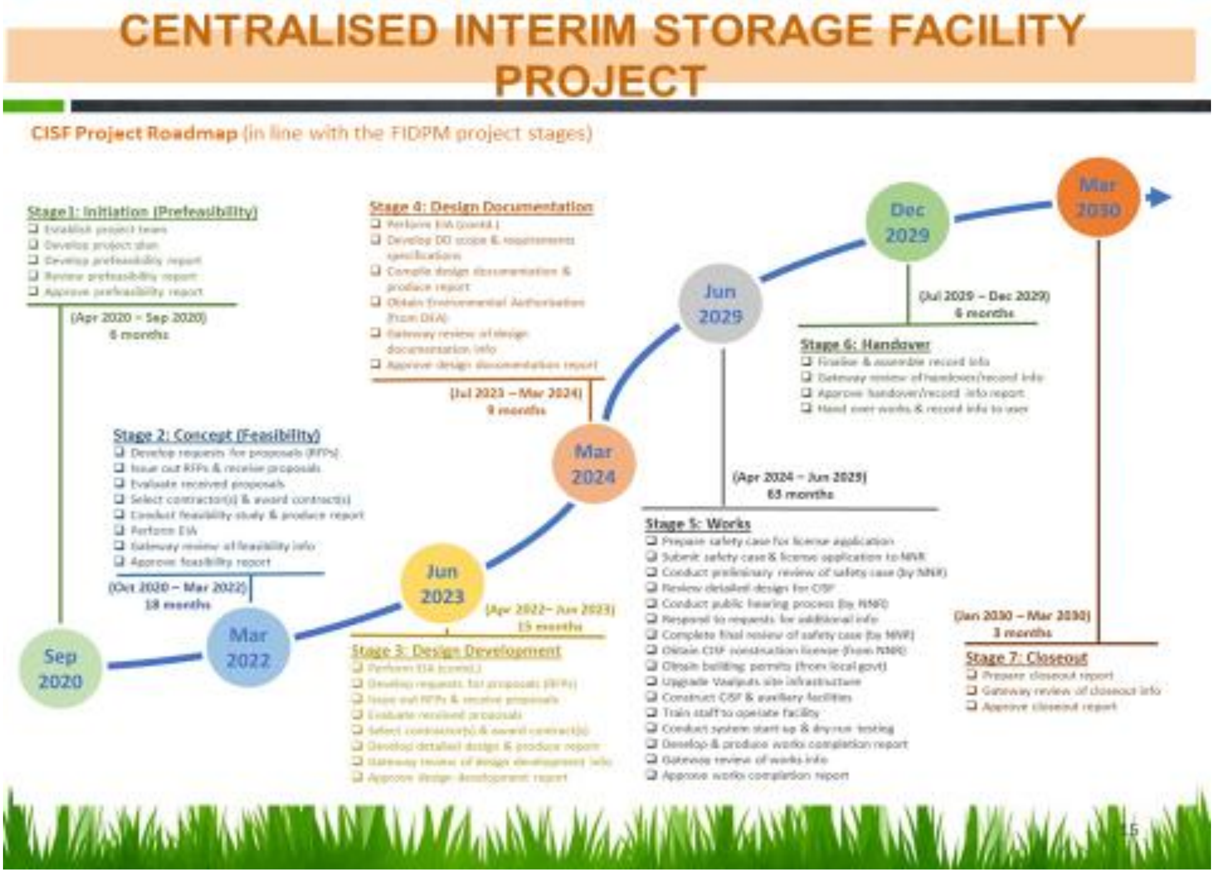

Figure 9 : The 2020 to 2030 Decade of Temporary Storage

In the absence of transmutation of the spent fuel material, a final solution will be the deep geological repository, envisaged to be operational by 2065. The planning timelines are described in figure 10 [5].

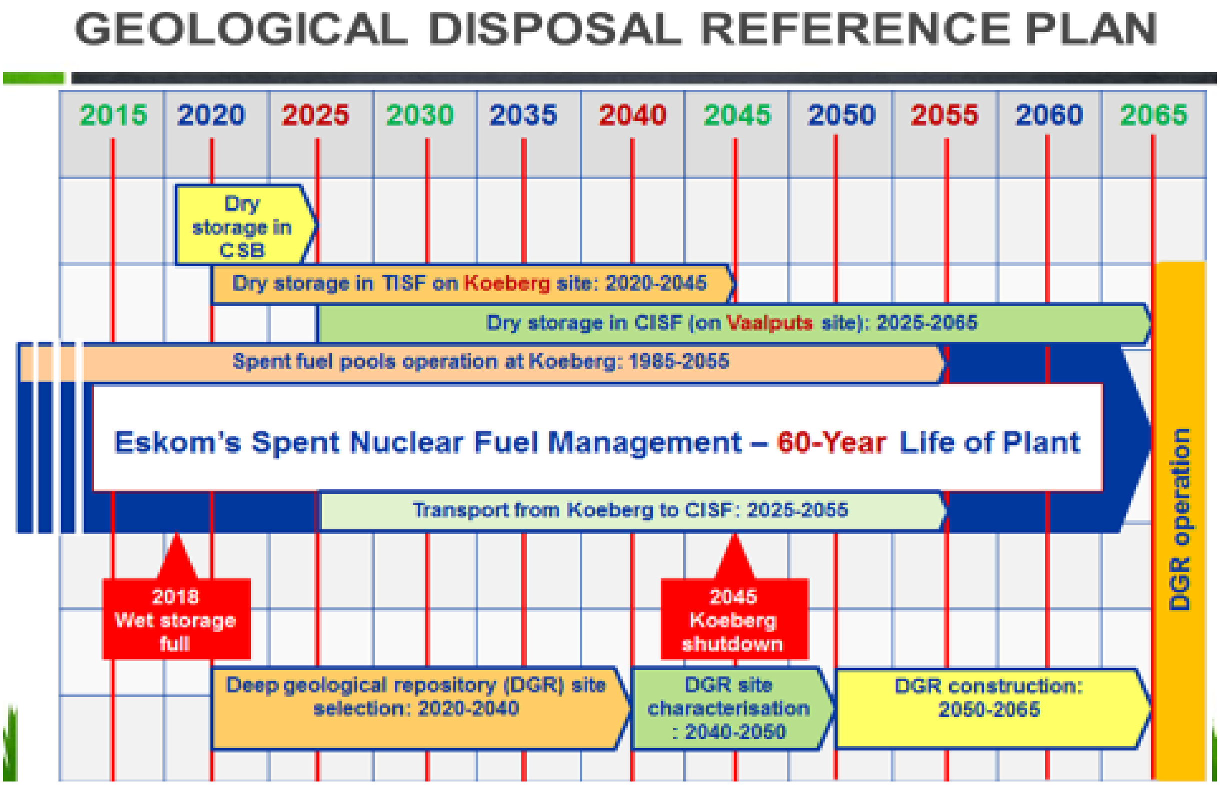

Figure 10 : The Final Deep Geological Long Term Storage

4. CONCLUSION

The paper has provided a general overview of the safety and environmental practices of South Africa is managing the waste from an industrialised economy. The paper emanates from the study committee workings of the Nuclear Chapter of the South African Institute of Electrical Engineers, as part contribution to the gathering and sharing of knowledge and information on the professional management of the nuclear residues post the gains delivered to society. The general fears of the greater public pertains to accidents and the longevity of the high level waste. These fears are well founded. It remains the duty of the professionals to continuously communicate the assurances of the science and technology that is deployed to manage the application of the resource.

The nuclear resource is one of high energy density. Given the increasing demands for clean energy resources from an increasing human population and their associated activities, nuclear energy has a key role in society. Compared to the vast quantities of waste produced by equivalent energy resources of fossil fuels, nuclear has the edge. Koeberg's two-reactors generates approximately 32 tons of spent fuel each year ; for a 40-year lifetime 1 280 tons will be accumulated ; negligible as compared to the waste ash and air emissions generated by fossil resources.

For the future, the drive is for green energy resources from intermittent wind and solar sources, with production and storage of energy of green hydrogen as ammonia. The plan is to direct combust ammonia for electricity and heat. The scale and volume of toxic ammonia that will be made available to the greater environment will certainly have its impact. Nuclear will hold its edge when compared to toxic ammonia.

Nuclear is completely fenced off the general environment as an energy resource, from front end (natural ore) to back end (spent fuel as HLW). Given its high density characteristic, it has very low volumes on both front and back ends. In the first year of storage in the reactor spent fuel pool, the radioactive nuclides in the material decays very quickly. After ten years, the fuel assembly has greatly reduced heat and radioactive content. The assemblies then move from wet to dry storage outside the reactor building. The dry casks are then available for long term storage in deep underground mines. In time, the low residual radioactivity decays and consumes its own toxic content such that a net zero point is ultimately reached ; the net environmental impact sustains at zero. This all occurs with very low volumes of material that require long term storage.

A recommendation is that a comprehensive environmental impact study be done for all the clean energy resources.

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