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REVISION HISTORY

This document has been revised in accordance with the following schedule:

Rev. No.	Date approved	Nature of Revision	Prepared
1.0	2022-12-14	First issue.	B Raphotle
2.0	See title page	- Amended the scope of the EAP to include Specialist Studies - Rectified the document number, and - Removed compliance requirements as these are clearly stipulated in the Tender Bid Document.	B Raphotle

1 INTRODUCTION

1.1 Necsa

The South African Nuclear Energy Corporation Limited (Necsa) is a state-owned public company (SOC), registered in terms of the Companies Act, (Act No. 61 of 1973), registration number 2000/003735/06.

The Necsa Group engages in commercial business mainly through its wholly-owned commercial subsidiaries: NTP Radioisotopes SOC Ltd (NTP), which is responsible for a range of radiation-based products and services for healthcare, life sciences and industry, and Pelchem SOC Ltd (Pelchem), which supplies fluorine and fluorine-based products. Both subsidiaries, together with their subsidiaries, supply local and global markets, earning valuable foreign exchange for South Africa and are among the best in their field in their respective world markets.

Necsa's safety, health, environment and quality policies provides for top management commitment to compliance with regulatory requirements of ISO 14001, OHSAS 18001 and RD 0034 (Quality and Safety Management Requirements for Nuclear Installations), ISO 9001 and ISO 17025.

Necsa promotes the science, technology and engineering expertise of South Africa and improves the public understanding of these through regular communications at various forums and outreach programmes to the community. We are a proudly South African company continuously striving, and succeeding in many respects, to be at the edge of science, technology and engineering related to the safe use of nuclear knowledge to improve our world.

1.2 Old SAFARI-1 Reactor

The South African Fundamental Atomic Research Installation 1 (SAFARI-1) Research Reactor is owned by Necsa and has played a pivotal role in the development of South Africa's nuclear infrastructure and research over the past 57 years. SAFARI-1, situated on the Pelindaba site of South African Nuclear Energy Corporation SOC Limited (Necsa), is a 20 MW (thermal) multi-purpose tank-in-pool reactor that achieved first criticality on 18 March 1965.

SAFARI-1 is approaching the end of its operational lifetime, and even if ageing programs are successfully licensed and implemented, or no unforeseen major plant failure occurs, the reactor is unlikely to operate at any appreciable level post 2030. South Africa will lose its ability to produce medical isotopes critical to the production of current and future radiopharmaceuticals and will lose its primary asset that ensures South Africa's current leadership in terms of nuclear-related research on the African Continent.

1.3 New Multi-Purpose Reactor (MPR)

The new Multi-Purpose Reactor (MPR) is intended to succeed SAFARI-1 and be in full operation before the end of life of the SAFARI-1 reactor. SAFARI-1 boasts a proud safety record having operated for over 57 years without any major incidents. The MPR to be constructed in South Africa is owned by the South African Nuclear Energy Corporation (Necsa) and supported by the Shareholder, the Department of Mineral Resources and Energy (DMRE), who plays an oversight role to ensure that the corporation mandate is fulfilled.

For the future of a new MPR, apart from nuclear medicine and isotopes production the reactor plays an important role within the South African framework for [2]:

(a) Ensuring technical expertise in nuclear science and technology remains at the cutting edge and internationally recognised, so that Government can be soundly advised and enabled to make informed decisions on nuclear policy and honour international obligations in this area.

(b) Provision of health care benefits to the South African community with respect to diagnostic and therapeutic radio-pharmaceuticals is maintained, enhanced and rendered secure for the foreseeable future through local production.

(c) The fields of mining and industry, power generation, agriculture, geosciences, forensics and education in South Africa, to mention just a few, have access to radioisotopes, neutron activation analysis, material modification and testing, neutron non-destructive testing facilities and a wide range of other applications that are only possible with a high flux nuclear reactor.

(d) Ensuring the cost to the state of operating the reactor is minimised by the generation of foreign revenue from the sale isotopes, irradiation products and services on all markets.

(e) Providing training in a wide spectrum of nuclear technologies for students at Southern African universities, industry and other institutions is well established and utilised.

(f) Maintain and substantially increase South Africa's global footprint in the Research and Development, as well as Application of Nuclear Science and Technology.

The key objective that this project is aimed to achieve is to ensure that the benefits derived from SAFARI-1 and more advance technologies are continued in the MPR in a sustainable and ever growing way going forward.

2 PURPOSE AND SCOPE

2.1 Purpose

The purpose of this document is to provide information to potential Environmental Assessment Practitioners (EAP) who will perform the Environmental Impact Assessment (EIA) and Specialist Studies for the Multi-Purpose Reactor (MPR).

2.2 Scope

This document will serve as a scope for all potential EAP's to work from in preparing the proposed tender documents.

3 REFERENCES AND ABBREVIATIONS

3.1 References

This document conforms to the requirements of:

[1]	ENVIRONMENTAL IMPACT ASSESSMENT REGULATIONS, 2014 Government Notice R982 in Government Gazette 38282 dated 4 December 2014. Gov. Gazette (NEMA).
[2]	MPR-EXT-PLN-0001, MPR Project Management Plan, Rev. 02.
[3]	Necsa, 2021/22, Large Strategic Infrastructure Proposal: Multi-Purpose Reactor – 2021/22 submission, BFI - 1703.
[4]	SP-DOE-REP-14004, Multipurpose Reactor Prefeasibility Report, Rev 02.
[5]	MPR-EXT-REP 0003, Multi-Purpose Research Reactor Request for Information Assessment Consolidated Report, 2022, Rev 1.0.
[6]	MPR-EXT-URS-0001, MPR User Requirement for use in the RFI, 2021, Rev 2.0.
[7]	LS-MPR-ASS-0001, Screening methodology and criteria for various Necsa site locations for the multi-purpose reactor (phase 1).
[8]	LS-MPR-ASS-0001, Phase 1 Site Screening Report.
[9]	MPR-INT-REP-0010, MPR footprint determination for siting & EIA RoD activities.
[10]	LSA-GEN2021-REP-0001, Site Description: Pelindaba site.
[11]	14080CH/Report/ML, Geohydrology on the proposed Necsa Nuclear Fuel Manufacturing Plant: A review – Levin, M. (2001).
[12]	GEA-1288, The Geohydrology of Pelindaba – Viviers JJP, Van Blerk JH, Pirow MPG and Heard RG (1997).
[13]	K8/157, A South African Aquifer System Management Classification. Water Research Commission Report – Parsons, R (1995).
[14]	GH 3749, Groundwater in the rocks of the Pretoria area. Directorate: Geohydrology, department of Water Affairs and Forestry, Report – Kok, TS (1993).
[15]	TT 74/95, Ground Resources of South Africa. Water Research Commission Report - Vegter, JR (1995).

[16]	Annual meteorology data reports sent to the NNR (based on measurements from weather stations at Pelindaba).
[17]	WB40, Climate of South Africa: Climate Statistics up to 1984, Weather Bureau Department of Environment Affairs, (1984).
[18]	MPR-EXT-DES-0001, Geotechnical and Geophysics Survey Description for MPR Siting.
[19]	MPR-EXT-DES-0002, Geological Comparison of MPR Candidate Sites.
[20]	MPR-EXT-DES-0003, Atmospheric Dispersion Modelling Description for MPR.

3.2 Abbreviations

Abbreviation	Description
BBBEE	Broad Based Black Economic Empowerment
CA	Competent Authority
CAGR	Compound Annual Growth Rate
CARA	Conservation of Agricultural Resources Act
CNCC	China National Nuclear Corporation
CT	Computed Tomography
DST	Department of Science and Technology
DSI	Department of Science and Innovation
EAP	Environmental Assessment Practitioners
EIA	Environmental Impact Assessment
EMG	Environmental Management Group
EMPR	Environmental Management Programme
FMT	Fuel and Material Testing
HEU	High Enriched Uranium
HTR	High Temperature Reactor
IAEA	International Atomic Energy Agency
INVAP	Investigación Aplicada (Spanish words for Applied Research) – Argentine's Technological Company
IMNT	Intensity Modulated Neutron Therapy
IRP2019	Integrated Resource Plan for 2019
KAERI	Korean Atomic Energy Research Institute
LEU	Low Enriched Uranium (<20% U-235)
L&SA	Licensing and Safety Analysis
MPRDA	Mineral and Petroleum Resources Development Act
MPR	Multi-Purpose Reactor
MTR	Material Test Reactor
Mo-99 (99Mo)	Molybdenum 99
Necsa	South African Nuclear Energy Corporation
NEMA	National Environmental Management Act
NEM:AQA	National Environmental Management: Air Quality Act
NEM:BA	National Environmental Management: Biodiversity Act
NEM:WA	National Environmental Management: Waste Act,
NBH	Neutron Beam Hall
NBLC	Neutron Beam Line Centre
NEPS	Nuclear Energy Policy Strategy

Abbreviation	Description
NFC	Nuclear Fuel Cycle
NGH	Neutron Guide Hall
NHRA	The National Heritage Resources Act
NIPP	National Industrial Participation Plan
NNR	National Nuclear Regulator
NTD	Neutron Transmutation Doping
NTP	NTP Radioisotopes (Pty) Ltd
NTeMBI	Nuclear Technologies in Medicine and the Biosciences
NuMERI	Nuclear Medicine Research Infrastructure
NWA	National Water Act
OPAL	Open Pool Australian
PET	Positron Emission Tomography
PICC	Presidential Infrastructure Coordinating Commission
PIE	Post Irradiation Examination
PWR	Pressurised Water Reactor
RBH	Reactor Beam Hall
RERTR	Reduced Enrichment for Research & Test Reactor (program)
R&D	Research and Development
RoD	Record of Decision
SAFARI	South African Fundamental Atomic Research Installation
SPLUMA	Spatial Planning and Land Use Management Act
SOC	State Owned Company
SPECT	Single Photon Emission Computed Tomography
SQEP	Suitably Qualified and Experienced Person
TB	Tuberculosis
TBC	To Be Confirmed

4 SCOPE OF WORK

4.1 Environmental Authorisation Processes

The scope of work is to undertake the necessary environmental authorisation processes as required in terms of the National Environmental Management Act (No. 107 of 1998) (NEMA) (as amended) [1],

(a) Environmental Impact Assessment (EIA) Regulations, 2014 (as amended)

(b) National Water Act (Act 36 of 1998) (NWA),

(c) National Environmental Management: Waste Act, 2008 (Act No 59 of 2008) (NEM:WA),

(d) National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004) (NEM:AQA),

(e) National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004) (NEM:BA),

(f) Conservation of Agricultural Resources Act 43 of 1983 (CARA),

(g) The National Heritage Resources Act, (Act No. 25 of 1999) (NHRA),

(h) Spatial Planning and Land Use Management Act, 2013 (Act No. 16 of 2013) (SPLUMA),

(i) Mineral and Petroleum Resources Development Act (Act 28 of 2002) (MPRDA) and

(j) Relevant Provisions of the Nuclear Energy Act (Act 46 of 1999) and the National Nuclear Regulators Act (Act 47 of 1999) and any other acts and/or guidelines that may apply to the proposed activities.

4.2 Environmental Assessment Practitioner (EAP)

The consultant to fulfil the role of Independent Environmental Assessment Practitioner (EAP) and as such to apply for Environmental Authorisation (EA) to the competent authorities needs to scope the work required to obtain all the required authorisations for the proposed MPR as described below.

It is anticipated that the proposed project will trigger listing activities of the NEMA EIA Regulations and would therefore require a Scoping and EIA process. The process for application for EA must follow the requirements of the NEMA EIA Regulations and should include as a minimum the following:

(a) Authority Consultation throughout the process, including a pre-application meeting with the Competent Authority (CA).

(b) Compilation and submission of an Application Form.

(c) Compilation and submission of a Scoping Report prepared in accordance with Appendix 2 of GNR982 (NEMA EIA Regulations).

(d) Plan, and execute a public participation process which aligns with the requirements of Chapter 6 of GNR982. Consideration should be given to the nature of the proposed development as well as the sensitivity of the affected communities and public. The proposal must provide details on the proposed approach and strategy for the public consultation.

(e) Provision must be made for:

   1 Initial notification and call to register
   2 Public review of the Scoping, EIA, and EMPR documents
   3 Notification of the CA decision

(f) Compilation and submission of an Environmental Impact Assessment Report prepared in accordance with Appendix 3 of GNR982 (NEMA EIA Regulations).

(g) Compilation and submission of an Environmental Management Programme prepared in accordance with Appendix 4 of GNR982 (NEMA EIA Regulations).

(h) Specialist studies: The exact specialist studies and the scope of these studies can only be accurately defined once complete information is available, including an initial site assessment and conceptual designs. Further the results of the scoping phase may identify the need for further specialist investigations.

Furthermore, the following shall be taken into account:

(a) The EAP shall comply with all relevant Necsa quality system requirements such as to access and security requirements.

(b) The EAP is also required to manage and execute Siting Specialist Studies on Geotechnical and Geophysical survey (including seismic study), Geological Characterisation and Atmospheric Dispersion Modelling. These studies form part of Phase 2 MPR Site Selection process as listed in Section 7. The project descriptions, tasks required and the outcomes these studies are provided in [18] [19] [20], respectively.

(c) Any studies requested by the EAP not included in the original proposal from the EAP, shall be motivated by the EAP and presented for approval to the MPR Project Manager.

5 BACKGROUND ON THE MPR PROJECT

5.1 MPR Facility Purpose

The goal of this project is to provide South Africa with a new 20 to 30 MW (thermal), Multi-Purpose nuclear research Reactor (MPR) to replace the ageing SAFARI-1, build national capability to design and manufacture nuclear components, locally manufacture both fuel, control rods and targets, establish on-site accommodation, perform fuel and material testing and establish a beamlines centre through the provisions of various neutrons sources (cold and thermal) [2].

The facility will be equipped to provide the necessary flexibility to operate for 60 years considering potential changes in: current and potential medical isotope markets, current and anticipated future research requirements, and the necessity to provide South Africa with a critical nuclear fuel and material testing facility in support of the Nuclear New Build program.

The MPR project is expected to provide South Africa with:

(a) A critically needed modern nuclear and material testing research facility enabling South Africa to maintain and consolidate its position as the Centre for Nuclear Science and Technology within the Southern African region.

(b) A production facility producing medical radioisotopes ensuring the long term maintenance and growth of the NTP Radioisotopes SOC business, enabling South Africa to retain its global leadership position in producing currently used and new innovative radiopharmaceuticals.

(c) A facility to test nuclear fuel and materials in support of a Nuclear New Build Pressure Water Reactors (PWR) or High Temperature Reactors (HTR).

(d) A project of sufficient size and complexity providing learning and localization opportunities prior to the Nuclear New Build program.

(e) Nuclear fuel, control rods and target manufacturing facility.

(f) On-site accommodation to support the research community.

(g) Design, manufacturing and supply capability for nuclear grade components.

5.2 High-level Scope of the MPR Facility

The scope of the facility comprise of the reactor complex, including its siting, construction, commissioning, operation, utilization (i.e., production rigs/jigs, experimental rigs and fuel/material test rigs) and decommissioning.

5.3 MPR Project Objectives

A key objective of the MPR project is to achieve the vision of the South African Government through facilitating economic diversification beyond our current reliance on traditional commodities and non-tradable services. It recognizes that there is still a tremendous gap between South Africa and those countries with true knowledge-driven economies.

The MPR thus needs to facilitate the promotion of increased value-adding products and services that compete in export markets and replace imports, obtained through the intensification of our industrialization processes. Within this framework, the MPR will contribute to the following [2]:

(a) 30%-50% of the total estimated 2020 base cost of ZAR 12 648 Million (excluding any escalation or contingency) will be spent locally.

(b) It is estimated that ±R300m of direct off-sets will result from the foreign procurement component of the MPR plant over a ten year period as a result of the Government's National Industrial Participation Programme (NIPP) requirements on foreign supplied products and sub-systems to be used in the design and construction of the plant. This would offer additional long-term employment opportunities and experience with on-going developmental projects and initiatives.

(c) It will ensure a supply of affordable medical isotopes to the people of South Africa, which will have to be imported at excessive costs if the MPR is not built. The African market for Nuclear Imaging is expected to grow at a healthy Compound Annual Growth (CAGR) from 2016 to 2021. Till now, a

Single Photon Emission Computed Tomography (SPECT) imaging was the mainstream modality for nuclear medicine applications like nuclear cardiology procedures. However, the trend is soon going to flip upside down because of shortage of molybdenum-99 isotope which is in turn will lead to shortage of Technetium-99, which is the daughter product of molybdenum. Hence, PET imaging products which includes hybrid Positron Emission Tomography Computed Tomography (PET-CT) scanners holds a potential market size in coming years. The cost associated with PET-CT service contract is usually 105 of the system purchase price annually and can be as high as $275,000 per year. The Africa Nuclear Imaging Market is segregated on the basis of Diagnostic Technologies (SPECT Radioisotopes [Technetium-99m (TC-99m), Thallium-201 (TL-201), Iodine (I-123) and Others] and PET Radioisotopes [Fluorine-18, Rubidium-82 (RB-82) and Others]), Applications (SPECT [Cardiology, Lymphoma, Thyroid, Neurology and Others] and PET [Oncology, Cardiology, Neurology and Others]) and Geography (South Africa, Egypt and Others).

(d) It will grow, maintain and develop SA's pool of nuclear skills.

(e) It will support the country's endeavour to beneficiate resources – supporting the establishment of a nuclear fuel cycle (the local manufacturing of the fuel, control rods and target, fuel testing, R&D, material testing and skills development).

(f) It will allow South African researchers to continue and advance the high level of South African scientific research output as well as keeping abreast with scientific developments. Staff training and human capacity building remain at the core of the R&TD division, specifically for the Radiation Sciences department.

(g) It will support the expansion of nuclear power in SA, through the testing of nuclear fuel for the fuel qualification process, provision of specialised services to the nuclear power industry and fabrication of nuclear components for the nuclear new build reducing our carbon footprint.

(h) The project will offer unique and valuable opportunities for the skills development of young professionals.

(i) The project will provide opportunities for Broad Based Black Economic Empowerment (BBBEE) at all levels of the corporate and business environment – from strategic international partnerships to local industrial enterprises to small and medium enterprises.

5.4 MPR Justification [3]

5.4.1 Global Application of Research Reactors

The following diagram taken from the IAEA Technical Report "Strategic Planning for Research Reactors" indicates possible stakeholders, supporters and users of a research reactor. It indicates the diversity of applications for a research reactor, and also indicates the opportunities a MPR could offer South Africa in addition to those already identified. These applications support the Strategic Integrated Projects for Infrastructure as identified by the Presidential Infrastructure Coordinating Commission (PICC).

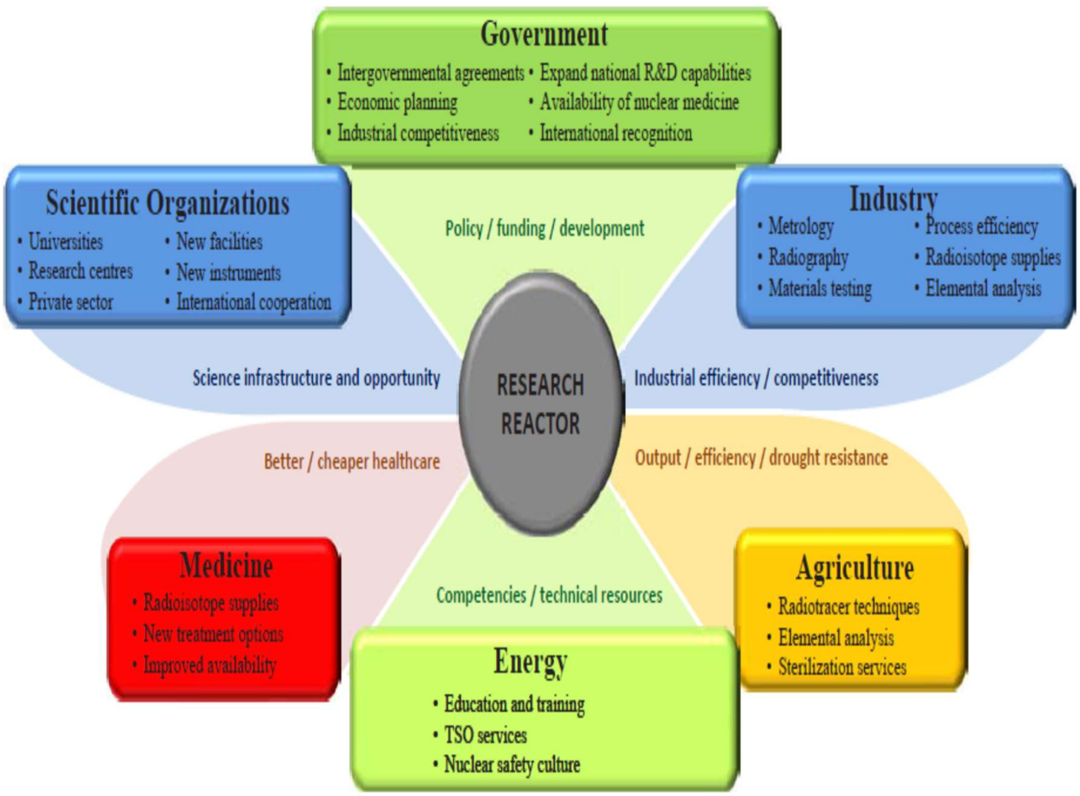

Figure 1: Strategic Planning for Research Reactors

5.4.2 Reasons for Replacement of SAFARI-1 Research Reactor

Currently SAFARI-1 is virtually fully utilised for the production of Molybdenum-99 and other isotopes. Molybdenum-99 is the raw material used to produce Technecium-99m, a key medical isotope used in excess of 40 million nuclear medical procedures globally per annum.

SAFARI-1 is now over 57 years old and needs to be replaced. Its replacement could take up to 10 years from start of feasibility to completion. When the new MPR can potentially take over, SAFARI-1 will be over 60 years old, and will be globally one of the oldest operating research reactors. The underlying technology of SAFARI-1, in particular its R&D and material testing capability have become outdated. In addition, the original research and development capabilities of the reactor have been superseded by operational requirements necessitated by the revenue it receives from isotope production, a primary source of income for Necsa. The new MPR is needed to support South Africa's nuclear industry as a vital nuclear research and test facility as well as a commercial reactor for the production of Molybdenum-99 and other isotopes.

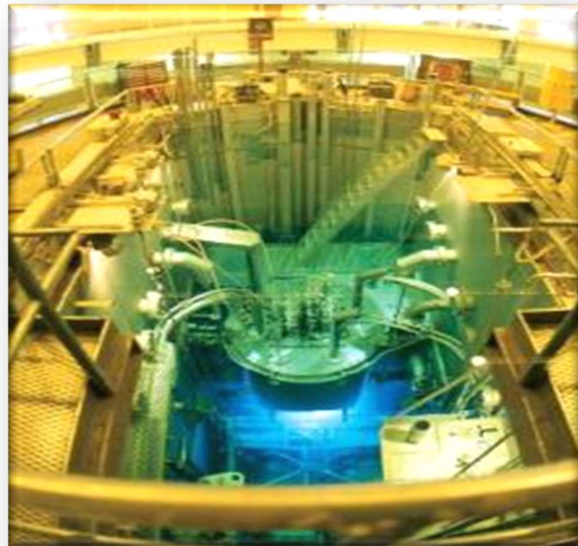

Figure 2: A view of SAFARI-1 Reactor's Operating Floor

As the SAFARI-1 nuclear research reactor was originally commissioned in 1965, Necsa is currently implementing an ageing management program extending the life of SAFARI-1, for up to ten years. It is important to ensure that the ageing SAFARI-1 nuclear research reactor is replaced timeously and to ensure that there is additional capacity for production and research purposes into the future. The SAFARI-1 research reactor was the first research reactor globally to convert both its nuclear fuel and target plates (for medical isotope production) from High Enriched Uranium (HEU) to Low Enriched Uranium (LEU) as part of the global Reduced Enrichment for Research and Test Reactors (RERTR) program. SAFARI-1 is currently regarded as one of the best operated and utilized research reactors globally. Without a replacement research reactor the global credibility South Africa has achieved will be lost.

The current SAFARI-1 reactor at Pelindaba is a facility vital for Necsa and South Africa due to:

(a) It provides a critically needed tool for training of nuclear scientists and engineers who lead South Africa's development into becoming a significant player in the international nuclear field as well as scientific developments. The local availability of and easy access to neutron scattering instruments, neutron activation analysis facilities, and general purpose irradiation positions provided for by the MPR, will facilitate and promote the training of quality professionals, preparing them to face highly complex technological problems.

(b) It provides the anchor technology around which Necsa's subsidiary, NTP Radioisotopes, has established the enabling technology which led NTP into being a world-leading supplier of medical and industrial isotopes. The current research constraints associated with SAFARI-1 severely curtails Necsa's ability to develop potentially highly lucrative alternative medical isotopes to grow NTPs' radiopharmaceutical product portfolio.

Radioisotopes are varieties of the same chemical element that have an unstable nucleus, which decays emitting alpha, beta and gamma rays.

5.4.3 National Interest

The proposed MPR is in the national interest because of the following aspects:

(c) It will support economic growth through the increased localization of nuclear research and nuclear infrastructure.

(d) It will maximize the benefit to the country within the context of South Africa's Integrated Resource Plan of 2019 (IRP2019), as a precursor to the building of PWR nuclear reactors and associated nuclear fuel cycle (NFC) facilities.

(e) The MPR, as the first major nuclear plant to be built since South Africa last built the Koeberg Nuclear Power Plant and Nuclear Fuel Cycle facilities at Necsa in the 1980's, will provide the stimulus and platform for an increased participation of South Africa's suppliers (localisation) in the global nuclear supply chain of sustained products and services.

(f) The technological base for the nuclear industry of South Africa needs to be grown through the creation of a stable local demand for products and services. During the construction of the MPR, a coordinated effort will be made to ensure that the component purchase for and construction of the MPR is not done in isolation, but rather as a precursor to the envisaged nuclear new build programme.

(g) Building the MPR as a precursor to a much bigger new build programme, will give local suppliers an early start with respect to transfer of technology, and training and local capacity-building to establish a nuclear supply capability. This will accelerate the establishment of a local nuclear industry, which has the potential to increase the local content during new build significantly.

(h) The MPR will provide a material testing facility for PWR fuel assemblies required by the South African Nuclear new Build program.

(i) In the longer term, the South African nuclear industry needs to be sustainable, mature, globally competitive and on par with international competitors.

5.4.4 Necsa as a Centre of Nuclear Science and Technology

Necsa is a centre of South African nuclear science and technology as mandated by the Nuclear Energy Policy and Strategy (NEPS). As such, advancement of nuclear technology through R&D in South Africa can only be conducted at Necsa. Through R&D conducted at these facilities, nuclear skills are developed and trained. This contributes towards building a knowledge economy as high end skilled (masters and doctorate) individuals are trained.

There is a viable and steadily growing community of South African researchers from Necsa and various universities that regularly use neutron scattering instruments, either at limited SAFARI-1 nuclear research reactor facility or facilities abroad. Access to international facilities is vastly oversubscribed due to their value adding and extensively used in materials research under User Access Programs with the emphasis on scientific excellence.

The Multi-Purpose Research Reactor will be employed for the following purposes:

In-core:	- Irradiation of target materials to produce medical radioisotopes; - Irradiation of silicon ingots to produce the basic material for the manufacturing of semiconductor devices; - Irradiation of material samples for neutron activation analyses; - Irradiation of material samples for material damage studies; - Irradiation of target materials for research
Ex-core:	Material science research using neutron beams and a suite of associated experimental equipment.

5.4.5 Production of Radioisotopes

Using a research reactor is currently the only proven way to reliably produce bulk quantities of medical-grade radioisotopes. Radioisotopes are created by placing target materials inside the core. After irradiation the targets are stored in the reactor pool for a cool-down period, and are then transferred in specially designated casks to existing Necsa facilities for chemical processing. Of the 40 million medical procedures with medical and industrial radioisotopes being carried out in the world each year, approximately 10 million of these radioisotopes are produced by South Africa's SAFARI-1 reactor. The demand for nuclear medicine is growing due to its ability to diagnose and treat cancer, heart disease and other illnesses. Notwithstanding its excellent safety record and being proven as one of the world's most reliable reactors for the production of medical isotopes, this facility is ageing and need to be replaced.

Medical and industrial isotopes now being produced at SAFARI-1 will in the future be produced in the proposed new Multi-Purpose Research Reactor.

5.4.6 Material Testing

A number of the in-core irradiation positions at the Multi-Purpose Research Reactor will be reserved for material testing. This type of material testing is typically performed to determine the impact that a radiation environment has on the materials used in a nuclear power reactor. A small material sample is inserted in the research reactor core and exposed to very high intensity radiation over a short period. This enables scientists and engineers to predict the behaviour of power reactor internal structures over the lifetime of the reactor. Another application of radiation damage involves the study of the impact of cosmic radiation on sensitive instrumentation used in the aeronautical and space (satellite) industry.

Depending on the nature of the test, the samples may be placed inside the core in a location where high flux of fast neutrons is present to study the neutron damage to material and fuel testing. Where the tests require irradiation by thermal neutrons, the in-core Molybdenum-99 target positions may be used interchangeably. Test samples are inserted into the designated core positions with special rigs. The volume of a container within which test samples are placed is typically in the order of 400 mm tall with a diameter of approximately 60 mm. After irradiation the samples are removed and transported in dedicated under-water channels to post-irradiation examination facilities within the Multi-Purpose Research Reactor facility.

Neutrons are categorised by their energy, expressed in units of electron volts (eV). For example, fast neutrons: more than 1 million eV, thermal neutrons: around 2.2 eV and cold neutrons: less than 0.02 eV.

5.4.7 Irradiation of Silicon Ingots

Semiconductors are key components in modern electronics. When pure silicon is irradiated, some silicon atoms change to phosphorus atoms; thus creating a semiconductor for use in high quality electronic devices, including cell-phones and computers. This irradiation process, referred to as Neutron Transmutation Doping or NTD, involves the placement of silicon ingots inside an aluminium canister, near the core of the nuclear reactor where doping occurs. The irradiated product is decontaminated and shipped to the client. NTD is superior to other available technologies to produce the highest quality semi-conductors with a very homogeneous distribution of phosphorous atoms in the silicon crystal. This controlled process achieves superior conductivity performance in electronic devices and is widely used by the semiconductor manufacturing industry.

Figure 3: The ingot diameter varies from 128 mm to 152 mm, with a length of 600 mm.

Neutron activation analysis is a process used to determine the concentrations of elements in materials. In this analysis sample sizes as small as 50 mg can be used. At the SAFARI-1 reactor small samples of elephant tusk and rhino horn were irradiated for the South African Police to determine, from their relative mineral content, which part of the country they were poached from. This technique is also used for analysing works of art and historical artefacts and for research.

The sample specimen is placed inside a canister and irradiated in the reactor core, where it is bombarded with thermal neutrons, creating radioisotopes of the elements present in the sample. After a short irradiation in the core, the samples are sent to existing facilities at the Pelindaba site for analysis. The radioisotopes created in the irradiation process decay via the emission of gamma rays. These gamma rays are characteristic of the element from which they were emitted, thereby enabling scientists to very accurately characterize the material being studied.

5.4.8 Neutron Beams and Associated Instruments

Neutrons produced in the reactor core are channelled into neutron guides attached to the portals in the reflector vessel, forming beams which are directed to the neutron beam instruments. Material samples at the instruments scatter the neutrons onto a detector, and the resulting patterns are then interpreted by researchers. The majority of the material samples are laboratory size samples, ranging from 1 cubic millimetre (the size of a pin head) to 1 cubic centimetre. The material samples analysed in the strain scanning instruments are larger, such as a section of a railway track or part of a power station turbine blade.

The Multi-Purpose Research Reactor is to be equipped with thermal and cold neutron guides. Thermal neutrons are used to look inside metallic objects such as aircraft and engine components, and to investigate the magnetic and atomic structure of materials such as pharmaceuticals, minerals and superconductors.

Cold neutrons are generated by slowing down thermal neutrons with a device referred to as a cold neutron source. The cold neutron source operates at temperatures in the region of -250 °C near the reactor core, from where the low energy neutrons are transported through neutron beam guides to the beam hall. The beam hall, to be located adjacent to the reactor building, houses instruments and detection equipment. Neutron guides begin within 1 meter from the reactor core and continue through beam shutters until the outer perimeter of the reactor, and from there as far as 40 meters (or more) to the various neutron beam instruments. These neutron guides are 5 cm wide and between 5 cm and 30 cm high (the length of a ruler), and operate under vacuum. Beam lines are equipped with super mirrors which bend and focus neutron beams onto the materials being sampled. Cold neutrons allow researchers to study the structure and properties of plastics, ceramics, magnetic materials, pores in rocks and biological materials.

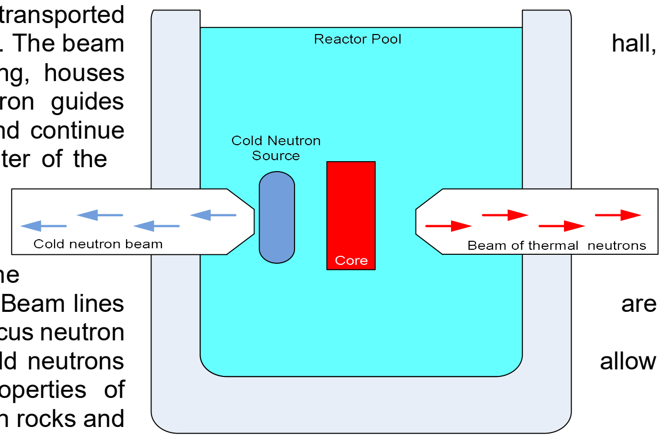

Figure 4: Cold Neutron Source Position Illustration

Besides providing these highly sophisticated services to industry, this facility will also support South African universities to produce world class doctoral and post-doctoral scientists and engineers in related fields of study using South African based technology instead of applying for the use of international research reactor instruments.

5.4.9 Hot Cells

Material irradiated in the reactor is transported to post-irradiation handling facilities located at the reactor service pool. Hot cells are constructed to provide radiation shielding to the operator when handling the irradiated material. The operator is positioned outside the hot cell and uses tele-manipulators to remotely handle equipment inside the hot cell. Work in the pool-side hot cells includes unpacking irradiated material from the containers that housed it during irradiation, and to re-pack the material into transport containers.

Additional Hot Cell Handling and Post Irradiation Examination Facilities are planned as dedicated post-irradiation examination for material testing purposes. In the post-irradiation examination hot cells the samples are visually inspected and subject to various tests and analysis. The tests include impact testing, tensile tests, fatigue tests, fracture toughness tests, metallographic studies, hardness tests and irradiation damage evaluation. These hot cells will be equipped with lathes, drilling machines and other machine tools for cutting and shaping samples for use in the various testing equipment mentioned.

Figure 5: Example of hot cells at a research reactor facility

5.4.10 South African Pharmaceutical Industry and Nuclear Medicine

The South African demand for pharmaceutical products in South Africa is increasing. The country has an established supply chain, with local production meeting almost 70% of the pharmaceutical sector's demand. The bulk of local pharmaceutical output comprises generic medicines, representing 50% of the overall market. The South African pharmaceutical market is forecast to grow around 7% a year and reach R54 billion in value by 2021. Pharmaceutical companies will increasingly benefit from a centralised procurement database. South Africa is the only country in Africa that meets World Health Organization standards to manufacture pharmaceutical products. State support for localisation will underpin domestic manufacture.

The Nuclear Medicine Research Infrastructure (NuMeRI), an initiative partly funded by the Department of Science and Technology (DST) and led by Necsa, is a medical imaging facility dedicated to drug development and clinical research. It provides a framework to consolidate expertise and implement new strategic initiatives relating to Research and Development in nuclear technologies in medicine and the biosciences (NTeMBI). The completed infrastructure will be a distributed network comprising of the Intensity Modulated Neutron Therapy (IMNT) centre at iThemba LABS in Cape Town, the PET Centre for Infection Imaging at Tygerberg Hospital in Cape Town, and the main NuMeRI facility to be established at Steve Biko hospital. Necsa, through its subsidiary NTP, supplies a variety of radioisotopes and tracers, the key ingredient for the studies performed at a facility of this nature. These are currently produced using SAFARI-1.

NuMeRI will be a sought after destination for pre-clinical and clinical screening of new drug entities that can be performed under one roof giving drug developers (local and international) a one-stop shop service. It will create a viable pipeline of radiopharmaceutical compounds that will be exploited on the world market. Drug development will not be limited to radiopharmaceuticals (diagnostic and therapeutic) but of equal importance will be the evaluation of conventional drug candidates such as new antibiotics, TB or oncology drug formulations.

The replacement of SAFARI-1 with a Multi-Purpose Reactor will ensure the following key value indicators:

(a) The anchor role the SAFARI-1 MTR reactor has played in the development and sustainability of South Africa's radioisotope production programme,

(b) The important political, social, educational, research and commercial value the new reactor will have for South Africa,

(c) the pivotal role the South African radioisotope production programme, run by NTP Radioisotopes and Necsa, is playing in the national and global nuclear medicine industries,

(d) The imperative, in national and global context, to consolidate and expand the South African radioisotope production programme, and

(e) The need to expand nuclear research in South Africa through material testing, fuel development and beam line capabilities.

5.4.11 Alternative Neutron Production Technologies

The alternative neutron production technologies considered included the following:

(f) Smaller reactors.

(g) Neutron activation (using natural U-238).

(h) Solution reactors.

(i) Accelerator driven systems, using a subcritical nuclear reactor.

(j) New generator technologies.

Each option was evaluated extensively looking at their primary purpose as part of the Prefeasibility study report [4], and none of the above technologies was found to meet the project objectives as set out in section 7.2. In fact the evaluation confirmed the Multi-Purpose Reactor as the preferred option to meet all the stakeholders' needs.

5.4.12 Reactor Track Record

A number of research reactors in the world are renowned for their scope of applications and track record. These are:

(a) The OSIRIS reactor in France

(b) The Petten reactor in the Netherlands

(c) BR-2 in Belgium

(d) NRU in Canada

(e) OPAL in Australia

(f) SAFARI-1 in South Africa

Collectively, the abovementioned reactors have had several hundreds of thousands of operating hours. Some of these reactors do not run at the availability levels of SAFARI-1. Some of these reactors have been shut down in the past due to leaks or other operational reasons, but no incidents of a serious nature have been reported in the several hundreds of thousands of operating hours.

In South Africa, SAFARI-1 has rightly been accorded as the said that it is the best performing production reactor in the world, utilising the reactor between 305 and 308 power days per year, with no serious incidents. SAFARI-1 is also the one operating with the highest level of commercial funding at 80% of its operational costs. This indicates a high level of expertise in South Africa pertaining to the operation of an Isotope production reactor.

The MPR will be an expansion of SAFARi-1's capabilities to include neutron beam lines, fuel and material testing facility and others. The request for information send out to the market in the first quarter of 2022 confirmed that there are suppliers available globally with recent international experience in the supply of MPRs, namely Technicatome (France) and INVAP (Argentina), Rosatom (Russia), KAERI (Korea), and CNNC (China) [5].

The international technology and know-how are therefore available to supply a state-of-the-art MPR that operates on LEU fuel and targets and it is the intention to procure the new MPR as a turnkey project from an experienced supplier. This, together with the excellent track record of isotope producing reactors in general, in conjunction with high level of expertise in South Africa in the operation of an Isotope production reactor, and research and development signifies a low risk to the public and environment in operating the MPR.

5.5 Reactor Technical Information

5.5.1 Technical Specification Framework

The design of the MPR Facility is to be such that it is able to safely operate for >300 days per annum at full power for the operational life of the Facility, which is more than 60 years and the current capabilities and production capacities achieved by SAFARI-1 are at a minimum maintained. The safety of the reactor to be compliant with the NNR requirements and current applicable international best practices for research reactors.

The design of this facility shall be based on proven technology. The reactor core shall utilize LEU fuel and LEU dispersion targets, manufactured with proven and qualified technology and taking into account existing Necsa fuel manufacturing plant. Besides the reactor being designed to meet all the operational and safety requirements, it must be simple to operate and comply with the established Integrated Management System at Necsa.

The enveloping technical scope, included in [2] for MPR are as follows:

(a) The reactor nominal power level shall be an absolute maximum of 30 MW, including the power from the Mo-99 targets and any other fissile sources (those cooled by the Primary System). Note that this power level is not necessary a design target for operation, but an engineering provision for possible future power upgrades.

(b) The reactor power shall be minimised to ensure that all performance requirements are met.

(c) The reactor design shall be aimed towards achieving the lowest operating cost, whilst complying with other related requirements.

(d) The MPR project envelope includes isotope production, beam-lines for research, material and fuel testing and in-core irradiation facilities for research (neutron activation analysis, heat transfer experiments, etc.).

(e) Existing utility services available at the Pelindaba site will be used. Should the reactor facility require additional services, such services shall be provided by expansion of the scope of existing services or be included in the design of the MPR, as appropriate.

(f) The facility will be constructed on a suitable, authorised location within Necsa's Pelindaba site.

5.5.2 Reactor Characteristics

The reactor will be designed for a life of 60 years. It will is proposed to be a pool design with easy access to all core positions. It will use a light water coolant and moderator, flowing downward. The reactor thermal power rating will not exceed 30MW, with variable power operation depending on user requirements and irradiation requirements.

The table below contains the main reactor characteristics for the MPR as defined in [6].

Table 1: MPR Main Reactor Characteristics

Application/ User requirement	Reactor design requirement
Isotope production	- Thermal neutron peak flux ≅ 1015cm−2. s−1 - Sufficient thermal flux irradiation space - Some epithermal/fast neutron irradiation sites
Neutron Transmutation Doping of Silicon	- Horizontal translation stage flux region ≅ 1013cm−2. s−1
Materials testing	- Fast neutron flux greater than or equal to thermal flux - Fast flux irradiation positions that can accommodate irradiation rigs or loops
Neutron science and applications to render a service to the NSI	- Epithermal and thermal positions for pneumatic rabbits to introduce materials for activation - Thermal and Cold Neutron beam tubes for neutron scattering applications - Beam Port space inside the reactor hall for neutron scattering instruments - Beam Guides that transport neutrons from reactor to instruments in Neutron Guide Hall.
Economy of operation	- Optimisation of income/running expense e.g. minimisation of operational cost

Application/ User requirement	Reactor design requirement
	- Minimum reactor power to attain required Multi-Purpose scope
Flexibility and adaptability	- Easy and flexible access to refuelling and irradiation positions - Adaptable to include new applications in a phased manner
Ease of operation	- Simple, low maintenance
Safety	- Inherently safe under loss of coolant
Minimal extra licensing requirements (above that of SAFARI-1)	- Reactor power limited to: 20 MW < P < 30 MW
Neutron energy spectrum	- The neutron energy spectrum is also important for Neutron transmutation doping - For isotope production, a thermal neutron peak flux of 1E15 would be desirable

5.6 Site Layout

5.6.1 Brief Site Description

The Multi-Purpose Reactor (MPR) will be sited on the Pelindaba site of Necsa near Pretoria. A high level screening of the Pelindaba site was done and subsequently potential sites were identified as shown in Figure 6. A total of 39 sites were identified in this step. Details on the various screening assessments employed to eliminate unsuitable areas and sites, as well as the justification thereof are available [7]. These include screening assessments based on acceptance / rejection criteria and sites that are screened due to being unfavourable when compared to other sites. Implementation of these methodologies and results obtained are documented in the Phase 1 Site Screening Report [8]. Through this process site locations 1, 15. 27 and 29 were recommended for further investigations as candidate sites. Furthermore, Site locations 1 and 29 were combined into a single site (site location 1) due to their proximity to each other. Therefore site locations 1, 15 and 27 advanced to Phase 2 Site Selection. The status and details of what Phase 2 entails are contained in section 11 of this document.

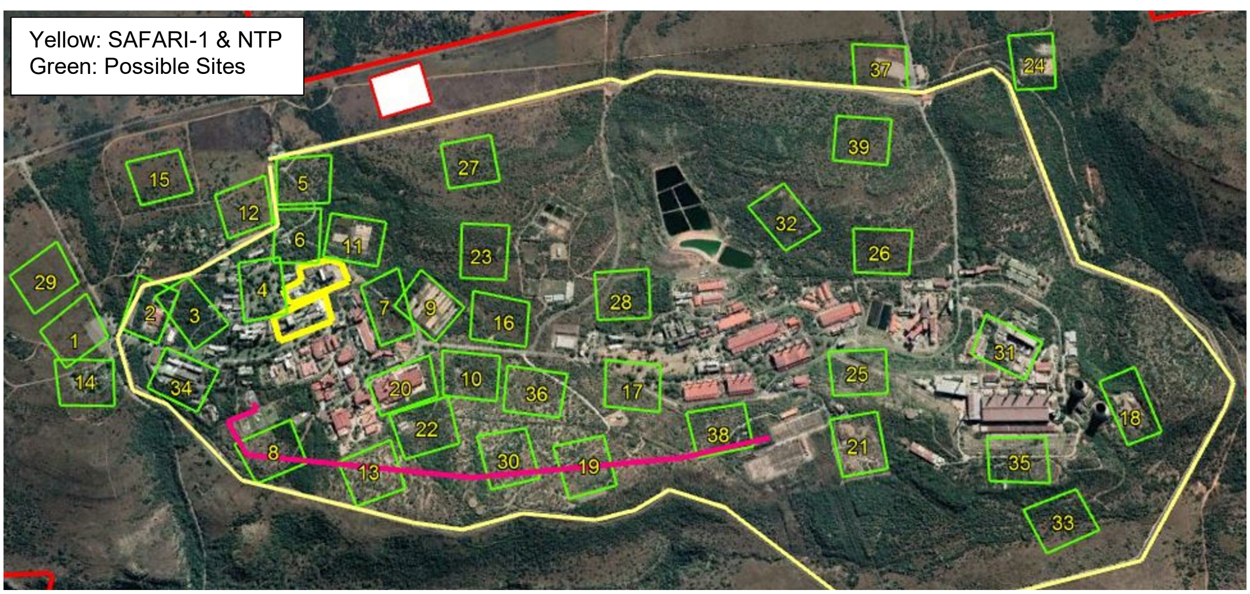

Figure 6: Location of potential MPR sites within Necsa Pelindaba site

To provide an early indication of the footprint required to accommodate the MPR facility and commence with the siting and EIA RoD activities, a reference reactor facility was adopted by the project team [9]. This is premised on best international practice and the fact that no conceptual design exists for the MPR facility at this stage. The OPAL reactor in Australia was adopted as the best representation of the possible footprint required for the MPR facility, with some additional facilities as denoted in Figure 7.

The Open Pool Australian Light-water (OPAL) reactor is described as a state-of-the-art 20MW multi-purpose reactor that uses low enriched uranium (LEU) fuel to achieve a range of activities to benefit human health, enable research to support a more sustainable environment and provide innovative solutions for industry. The reactor features facilities such as those desired for the MPR, except for the Fuel and Material Testing facility and the second Neutron Beam Hall (NBH). From the facility layout, the area earmarked for the expansion to their second NGH is clearly seen as indicated in Figure 7. To ensure that the MPR caters for all future requirements, a footprint of 215 x 176 m2 was recommended to be considered for the siting process. This included a 10% contingency margin to enable access of construction vehicles and transport to the site.

The User Requirement Specification for use in the Request for Information process defines the MPR project to contain [6]:

(a) MPR Facility that comprises the Reactor Building incorporating a Reactor Beam Hall (RBH) experimental area, Neutron Guide Hall (NGH) (with provision for the latter expansion to a second NGH) and with NGH viewing gallery. The NGH includes instrument cubicles, meeting rooms, laboratories, workshops and restrooms.

(b) Neutron Beam Line Centre (NBLC).

(c) Fuel and Material Testing (FMT) facility.

The MPR facility will be sited at any of the preferred site from the site locations advanced to Phase 2 for further investigations.

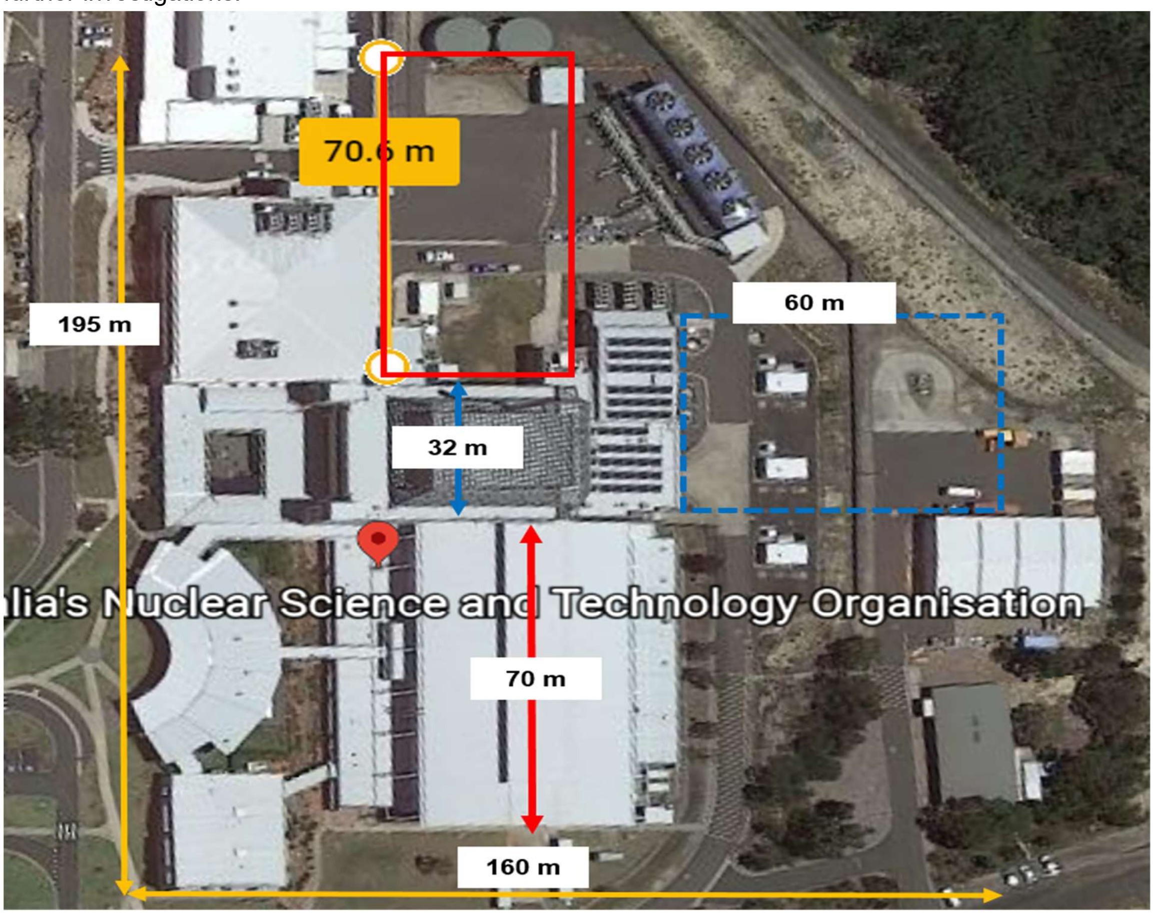

Figure 7: Possible layout of the MPR facility.

Figure 7 illustrates the footprint of the possible MPR reactor facility layout using OPAL as a reference facility. Estimated dimensions of key facilities are indicated. This includes a second NGH and Fuel and Material Test facility mapped onto the site. The red rectangle indicates the area reserved for the future expansion to a second Neutron Beam Hall. The blue rectangle represents the typical size of a Fuel and Material Test facility (not included in the OPAL design).The width of the FMT is assumed (due to unavailable data) to be between 40 – 60 m. The length of the facility is not impacted due to the facility design layout running parallel to the site length.

5.6.2 Criteria for Relative Placement of Major Buildings on MPR Site

The MPR buildings and structures and related services and infrastructure shall cater for the diverse needs of:

(a) Safety, security and the environment.

(b) The users, operators, maintainers and managers of the facility.

(c) Visitors to the facility.

(d) Access for disabled persons to all general areas and elsewhere when practicable.

The design of the MPR buildings and structures and related services and infrastructure shall facilitate extensions during the operating life of the facility.

Due consideration shall be given to the interfaces of the MPR with all necessary services and infrastructure in their current locations.

The MPR, with the possible exception of the interfaces with existing services and infrastructure, is to be fully located within the area of land designated as the Site.

5.6.3 Construction of the Lay Down Area and Access Route

The construction lay down area is dependent on the preferred site, which will emanate from any of site locations recommended for further investigations in Phase 1 Site Screening. A possible construction lay down area can be assumed as any of the sites adjacent or opposite to the selected sites from Figure 1. The proposed access route to the construction site will be determined with the preferred site.

6 SPECIALIST STUDIES PHASE 2 SITE SELECTION

6.1 Site Related Safety Parameters

Along with the outcomes of Phase 1 Site Screening assessment was the determination of site related safety parameters to assess the candidate sites in Phase 2 siting process. A list of these parameters and their drivers is contained below in Table 2.

Table 2: Phase 2 Site Safety Parameters for Assessment of Candidate Sites

Parameter	Driver
Seismicity	SHE/cost
Geology	SHE
Geotechnical and Geophysical	SHE/Cost
Atmospheric Dispersion	SHE
Preliminary Environmental sensitivity	SHE
Security	SHE
Utilities	Cost

The Phase 2 investigative studies entails the following:

(a) Comparative studies; a full site characterization will be done in phase 3. Detailed studies fall outside the scope of Phase 2 and will be carried out in Phase 3.

(b) Using information currently available on the Pelindaba site and SQEPs.

(c) Review of the complete list of site safety related parameters to identify those not considered in Phase 1 that are to be assessed in Phase 2.

(d) Specifying the Phase 1 site related safety parameters that require additional investigation in Phase 2.

(e) Identifying and contract internal and external specialists (as applicable) to perform specialist investigations to compare preferred candidate site locations.

(f) Assigning importance factors and associated scoring system to Phase 2 parameters.

(g) Incorporating Phase 2 parameters into the comparison and ranking model of Phase 1

(h) Comparison and ranking of preferred candidate site locations to identify the preferred site location based on the complete set of site safety related parameters.

The Phase 2 site investigation studies are currently in the implementation phase and the results thereof will form suite of package of reports for the EAP in fulfilling their mandate.

6.2 Geohydrology

The Pelindaba site is situated on the ridges of the Skurweberg with its western boundary being the Crocodile River. The site is drained to the south and west by a small non-perennial tributary of the Crocodile River. To the north the Moganwe Spruit and its tributaries drain the site. The Moganwe Spruit is near-perennial drainage with its source on the western outskirts of Pretoria [10]. A few documents on the Geohydrology for the Pelindaba site are available [11], [12], [13], [14] and [15]. Annual Ground -; Surface - and Water Reports are also available.

6.3 Meteorology

The Pelindaba site is situated in the central interior of South Africa, a region that receives much of its rainfall during the warm to hot summer season. Much of this rainfall is produced by local scale convection which typically results in thunderstorm activity that is usually accompanied by strong winds while other synoptic scale systems also contribute some rainfall.

The winter season in this region is characterized by relatively low temperatures which lead to moderate-to-cold days and cold nights. However, temperatures drop drastically after the passage of a cold front. Winds are generally light during this period except during the passage of cold fronts which can result in strong and predominantly southerly winds which from time to time are accompanied by rainfall. The strongest winds tend to occur during August and September [10].

No severe weather phenomena like hurricanes, tornadoes, freezing rain, snow, ice or sandstorms normally occur in the Pelindaba area [16]. Thunder, lightning and hail storms are dominant during the summer season.

Meteorological data, as measured by weathers stations at the Necsa site, are available [17].

6.4 MPR Interfaces with Other Necsa Facilities and Utilities

It is expected that the MPR facility will interface with existing facilities, utilities and services at their current location, as Pelindaba site is well established. A separate engineering infrastructure assessment study is to be conducted to determine the capabilities of the existing infrastructure and recommend upgrades where necessary according to the needs of the project.

7 RECORDS

DESCRIPTION	RETENTION PERIOD	BY WHOM
Documentation generated by EAP	Duration of the MPR Project	QA Records