Research, Development, and Innovation on Peaceful Uses of Nuclear Technologies in South Africa

PROCEEDINGS REPORT

5 December 2023 | 09:00 – 13:00 | CSIR International Convention Centre, Pretoria

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

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South African National Energy Development Institute

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DOI http://dx.doi.org/10.17159/assaf.2024/97

Cite: *Research, Development, and Innovation on Peaceful Uses of Nuclear Technologies in South Africa launch*, 5 December 2023 DOI http://dx.doi.org/10.17159/assaf.2024/97

Published by: Academy of Science of South Africa (ASSAf)
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The Academy of Science of South Africa (ASSAf) was inaugurated in May 1996. It was formed in response to the need for an Academy of Science consonant with the dawn of democracy in South Africa: activist in its mission of using science and scholarship for the benefit of society, with a mandate encompassing all scholarly disciplines that use an open-minded and evidence-based approach to build knowledge. ASSAf thus, adopted in its name the term 'science' in the singular as reflecting a common way of enquiring rather than an aggregation of different disciplines. Its members are elected based on a combination of two principal criteria, academic excellence and significant contributions to society. The Parliament of South Africa passed the Academy of Science of South Africa Act (No 67 of 2001), which came into force on 15 May 2002. This made ASSAf the only academy of science in South Africa officially recognised by government and representing the country in the international community of science academies and elsewhere
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This report reflects the proceedings of
Research, Development, and Innovation on Peaceful Uses of Nuclear Technologies in South Africa launch, 5 December 2023.

Views expressed are those of the individuals and not necessarily those of the Academy nor a consensus view of the Academy based on an in-depth evidence-based study.

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Welcome and introduction (Prof Himla Soodyall, Executive Officer, Academy of Science of South Africa)

On behalf of the council of the Academy of Science of South Africa (ASSAf), Prof Soodyall welcomed the dignitaries and other attendees to the launch of the report, *A Review of Research, Development and Innovation of Peaceful Uses of Nuclear Technologies in South Africa*. The Department of Science and Innovation (DSI) commissioned ASSAf through the South African National Energy Development Institute (SANEDI) to evaluate the state of research, development and innovation (RDI) with regard to peaceful uses of nuclear technologies in South Africa. The report resulting from this study was presented at the launch.

Presentation on the report, *A Review of Research, Development and Innovation of Peaceful Uses of Nuclear Technologies in South Africa* (Prof Mike Sathekge, Chair of the ASSAf Panel)

Prof Sathekge acknowledged the members of the panel that had contributed to the report:

- Dr Faïçal Azaiez (iThemba LABS)
- Prof James Larkin (University of the Witwatersrand)
- Dr Moses Modiselle (Drs Van Niekerk Ramjee Modiselle and Lengana Inc.)
- Ms Tebogo Motlhabane (National Radioactive Waste Disposal Institute)
- Mr Gaopalelwe Santswere (South African Nuclear Energy Corporation)
- Prof Dawid Serfontein (North-West University).

Prof Sathekge also acknowledged the inputs from colleagues in other institutions, including ASSAf, the DSI and the Department of Mineral Resources and Energy (DMRE).

The release of the report is happening at a very opportune moment, because a commitment was made at the 28th Conference of the Parties (COP28) meeting in December 2023 to treble global nuclear capacity by 2050 as a means to cut global carbon emissions.

The aim of the study that led to the report is to support the high-level agreement between South Africa, via the DMRE, and the International Atomic Energy Agency (IAEA) by providing a solid foundation upon which a national strategic framework on peaceful uses of nuclear technologies in South Africa could be built. The objectives are to review relevant current and historical national policies, plans and strategies; to review the national landscape of existing and emerging nuclear-focused RDI role players and activities in the country; to develop baseline information around the nuclear technology landscape in order to assist with targets and indicators for monitoring and evaluation; to assess the relevant international agreements or collaborations, including the arrangements between South Africa and the IAEA; to review the Country Programme Framework between South Africa and the IAEA and make recommendations on how the IAEA Technical Cooperation Programme (TCP) can be leveraged to strengthen the nuclear technology sector in South Africa; and to make proposals on a South African nuclear technology RDI flagship programme and RDI sub-programmes to address emerging issues in South Africa.

The research is based on a consensus study methodology, led by a multidisciplinary panel of experts from a variety of sectors. The experts conducted desktop studies in their respective fields, and panel meetings were held to discuss the findings. An independent part-time researcher was appointed to assist with collating and documenting the information. Finally, a workshop was held to verify the information collected and to test the high-level preliminary findings with experts in the field. The report was peer-reviewed by external experts and endorsed for publication by the ASSAf council, SANEDI and the DSI.

Prof Sathekge presented a brief outline of the content of the report. The report starts with the background and rationale for the study and describes the legislative environment of the nuclear sector. To place the report in context, the South African nuclear technology research landscape is discussed. The document then presents the findings in six broad thematic areas, namely:

1. Agriculture and food security
2. Human health
3. Radiation protection
4. Water and the environment
5. Energy and industry
6. Nuclear safety, security and safeguards.

For each thematic area the background is outlined, followed by an examination of the applications of nuclear technology in the specific field, related infrastructure, and production and human capacity. In order to address the objectives, the panel carried out an analysis of strengths, weaknesses, opportunities and threats (SWOT), allowing the needs and gaps in each theme to be identified. Lastly, the report includes recommendations and indicators for monitoring and evaluation.

Nuclear technology research in South Africa commenced with the establishment of the Atomic Energy Board through the Atomic Energy Act of 1948, and became firmly entrenched in 1961 with the establishment of a nuclear research centre at Pelindaba near Pretoria. South Africa is a founding member of the IAEA and holds a permanent position on its board.

In South Africa, nuclear technology is regulated by the following legislative instruments:

- Nuclear Energy Act (No. 46 of 1999), which led to the establishment of the South African Nuclear Energy Corporation (Necsa)
- National Nuclear Regulator Act (No. 47 of 1999), which established the National Nuclear Regulator (NNR)
- National Radioactive Waste Disposal Institute Act (No. 53 of 2008), on which the National Radioactive Waste Disposal Institute (NRWDI) is based
- Non-Proliferation of Weapons of Mass Destruction Act (No. 87 of 1993), which regulates the import, end use and export of controlled goods
- Hazardous Substances Act (No. 15 of 1973), which led to the formation of the Directorate of Radiation Control in the Department of Health (DoH)
- Nuclear Energy Policy (DMRE, 2008), which addresses energy-related applications of nuclear technology.

An overview of the milestones of the seventy-year history of nuclear energy research in South Africa was presented, covering the period from the creation of the Atomic Energy Board in 1948 until the approval of a new multipurpose reactor by the South African Cabinet in 2021.

South Africa's strength in nuclear technology has largely been underutilised. However, climate change posed serious challenges, creating global disasters such as food and water shortages and increased frequencies of heatwaves and cyclones. The increasing adoption of nuclear technologies would be a way to address these threats by reducing the need for fossil fuels.

The common challenges in all thematic areas are:

- An innovation gap between research and practice
- Limited collaborations and partnerships between government and the private sector, and also between institutions

- A shortage of skilled labour, skills transfer and innovation capacity
- A shortage of funding for infrastructure and equipment
- Limited financial capacity to acquire new technologies
- Deficiencies of government policies regulating the nuclear sector
- A lack of public trust in nuclear technologies.

To address the challenges, general recommendations are proposed:

- Integration, collaboration and interdepartmental approaches in RDI must be prioritised and improved. This could be achieved by creating a central coordinating desk.
- The number of institutions and RDI projects collaborating in the IAEA Technical Cooperation Programmes and contributing to the African Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology (AFRA) should be increased through multicentre projects that focus on national priorities.
- A human capital development strategy for sustainable nuclear application should be developed, and the creation of interdisciplinary centres of excellence at South African universities must be realised.

The first thematic area, agriculture and food security, is important for South Africa to reach its target to produce 30% of local nutritional needs by 2030. Nuclear techniques have been integrated into agriculture for purposes such as insect pest control, plant breeding and genetics, food and environmental protection, soil and water management, as well as animal production and health. The strengths of nuclear technologies in agriculture include effective food-monitoring and surveillance services, successful pest control mechanisms, and good control of livestock diseases. Weaknesses are created by the reluctance of consumers to accept irradiated foods, and inadequate inclusion of nuclear agriculture in strategic planning. Climate change and the emergence of new or endemic diseases pose the greatest threats, but opportunities exist in the use of modern electron accelerators and high-flux bremsstrahlung devices, and through climate diversity.

The recommendations with respect to agriculture and food security include:

- To improve routine practices for soil and water management through the inclusion of nuclear techniques
- To increase the application of isotope ratio mass spectrometry (IRMS) to enable the monitoring of food fraud
- To improve the levels of preparation for and responses to zoonotic infections
- To increase the applications of radiation for food preservation through improved isotope methods.

With regard to the second thematic area, human health, the rise in the burden of disease in South Africa, especially non-communicable diseases, is of great concern. Nuclear technologies could play an important role in relation to oncological, non-oncological and preventative medicine.

South Africa has significant strength in infrastructure, education and training, and theragnostics[1] in nuclear medicine. However, there are very few opportunities to employ nuclear specialists in the health sector. There is confusion in the regulation of radiation research and development (R&D), as well as funding limitations. A serious threat is posed by the loss of potential for R&D, leading to the loss of revenue, market share, and human skills from the country. Opportunities include the introduction of nuclear medicine to secondary

[1] Theragnostics is a treatment strategy that combines therapeutics with diagnostics.

level hospitals, investment in nuclear medical research infrastructure, and improved public–private partnerships.

For the human health thematic area, the recommendations are:

- To introduce nuclear medicine departments in level 2 (regional) hospitals
- To develop a comprehensive national cancer control programme to address optimal usage of radiation medicine (radiotherapy, nuclear medicine, radiology, medical physics and radiobiology)
- To reduce the cancer burden and enable support for the IAEA Rays of Hope initiative, which strives for cancer care for all
- To commission a full and separate study regarding radiation oncology.

The third thematic area, radiation protection, is closely aligned to radiation health in terms of the applications of radiation, dosage criteria, situational limitations, and the practical application of radiation. Training in radiation protection in South Africa is of a high standard, incorporating highly developed technologies. Radiation protection officers (RPOs) are employed at all levels, and South Africa is collaborating with the IAEA to develop new radiation control methods and regulations. However, harmonisation between the NNR and the South African Health Products Regulatory Authority (SAHPRA) in the application of regulations is a weakness. More facilities need to be accredited, and more RPOs placed at national radioactive waste disposal facilities. The expansion of nuclear programmes in other countries and the potential loss of human skills, as well as the lack of knowledge amongst the public, are threats. Opportunities that could be optimised include the implementation of a common software database among institutes, and maintaining good cooperation with the IAEA.

In terms of radiation protection, it is recommended that a public–private partnership model for education, training and research on radiation protection is implemented, and that an accreditation system for the private sector is developed. Moreover, the functioning of the NNR and the SAHPRA Directorate of Radiation Control needs to be harmonised using the Regulatory Authority Information System (RAIS).

The fourth thematic area, water and the environment, entails the protection of water resources as an essential prerequisite for inclusive economic growth, poverty reduction and addressing the high degree of inequality in South Africa. Nuclear technologies need to be integrated with the implementation of the water protection and waste RDI roadmaps. Examples of such integration include the use of isotopic hydrology in the management of groundwater resources and desalination plants using nuclear energy.

South Africa has advanced nuclear techniques for groundwater management and research on environmental hazards, denoting strength in this sector. A weakness, however, is that few personnel are trained in the application of nuclear techniques for water and environmental management, and there is limited interaction between these specialists. The challenge of energy supply to power new desalinisation plants, and the negative social perceptions of the use of nuclear technologies to ensure the supply of potable water, are serious threats in South Africa. At the same time, the use of isotope hydrology and desalination plants using nuclear energy are opportunities that need to be fully pursued. As an arid continent, Africa needs to take advantage of desalination technologies, and South Africa could play a leading role in this regard.

The recommendations include improving the integration of isotope hydrology in the management of water resources as a cost-effective way to assess the vulnerability of groundwater sources to pollution. Furthermore, new and more sustainable methods of water

production through desalination should be pursued by using nuclear power for water desalination.

Energy is an important thematic area. Optimisation and diversification of South Africa's energy generation mix are fundamental to meeting the energy capacity requirement of 40 000 MW by 2030, and nuclear energy could significantly contribute to this. The challenges of climate change will not be addressed comprehensively without the inclusion of nuclear energy, which could assist in reaching the target of zero carbon emissions. Nuclear energy could also drive hydrogen production and desalination.

Nuclear energy has a number of disadvantages, such as the high initial investment and the time required to construct new power plants, but these are offset by the long-term advantages of lower operating costs and reliable and more affordable energy generation.

The strengths of South Africa's nuclear energy sector are the internationally respected levels of R&D in nuclear technology, the expertise in the Koeberg generation unit, and the development of the Pebble Bed Modular Reactor (PBMR). South Africa has the largest particle accelerator in the Southern Hemisphere and the only one on the African continent. With South Africa's rich uranium resources and the requisite skills of extraction and refining of uranium, the country has distinct advantages in this field. A serious weakness, however, is inadequate public education in nuclear energy, which gives rise to confusion and negative perceptions. The need for large capital investment amid financial constraints is also problematic, resulting in uncertainties in the industry and the lack of opportunities for skilled professionals. The main threats to the nuclear energy sector are the competition created by the promotion and development of alternative forms of electricity generation, the high cost of building new nuclear power plants, and the loss of experts in the field to other countries. IAEA's support for 'green' power sources and the establishment of small modular reactors represents opportunities to boost local RDI in nuclear energy technologies.

Recommendations are therefore made to strengthen the analytical capacity for developing energy supply and demand models for the medium and long term, as well as better understanding and planning for small modular reactors. Furthermore, uranium exploration and extraction need to be included in national strategic planning. Communication and education on nuclear energy should be improved through the dissemination of clear and readily understandable information on the benefits and risks of nuclear energy.

The use of nuclear technology in industry is an important thematic area. This includes uranium mining, non-destructive testing and radiation technology, and radioisotope production. The existence of efficient and effective technologies is a strength, but is undermined by the weakness of limited information on the usage of the technologies, contributing to poor acceptance of nuclear technology and competition from alternative technologies. Yet, the nuclear industry offers opportunities for South Africa to adopt sustainable methods to combat climate change and environmental degradation. Recommendations include improving the competitiveness and quality of industrial processes and products through the use of radiation technologies, which could reduce factors contributing to climate change and inefficient energy consumption. It is also essential to sustain and optimise training and R&D in non-destructive testing and related areas in the industry.

The last thematic area is nuclear safety, security and safeguards. South Africa, as a founding member of the IAEA, and through the NNR and collaborations with the IAEA, upholds nuclear law and its four pillars: safety, security, safeguards, and civil liability for nuclear

damage. South Africa's major nuclear organisations (the NNR, Necsa, iThemba LABS, Eskom, Koeberg Nuclear Power Station and NRWDI) have adopted the global nuclear safety regime and are operating in accordance with these regulations. The high level of competence in this area is a strength that contributes to South Africa's international leading role. Another strength is the dismantling of atomic weapons in South Africa and the termination of weapon manufacturing. However, uncoordinated structuring of the various regulatory bodies in South Africa, the lack of adequately qualified staff in key positions within the various regulatory bodies, as well as the lack of succession planning, pose weaknesses and challenges. A serious threat to the industry is the uncertain and tenuous position of the South African government towards nuclear policy in the energy future, which could lead to potential loss of investment in the industry and threaten South Africa's leadership in the field if universities cease to support nuclear teaching and research programmes. South Africa is currently the leading African country in providing nuclear and radiological expertise, training and education, with advantages for the sustainability of the industry. It is recommended that the promotion of high standards in safety, security and safeguards should enjoy priority. The impending government approval of the multipurpose reactor could be exploited. Global harmonisation of safety requirements via the IAEA-wide small modular reactor platform is also recommended.

In closing, recommendations are made on the role of the DSI and DMRE for setting indicators to enable monitoring and evaluation of the following aspects:

- Number of RDI projects, collaborating centres and publications to indicate policy influence
- Number of IAEA technical cooperation programmes and AFRA projects
- Usage, integration and inclusion of nuclear technologies in the strategic plans and annual plans of relevant departments
- Number of local citizens who have obtained skills, and upskilling in the nuclear sector
- Achievement of implementation dates.

The recommendations in the report support the development of a national strategy and the inclusion of nuclear technologies, articulating the priorities of the country in line with existing policy documents. The recommendations require a South African nuclear technology RDI flagship programme, which would inform the Country Programme Framework.

Handover of the report to the Department of Science and Innovation (Prof Mike Sathekge)

Prof Soodyall thanked the members of the working group for their contribution, and acknowledged the support of Dr Melusi Thwala and Mr Aluwani Ramulifho of ASSAf for the project. Consensus studies are not easy to achieve, and similar to academic outputs, they are peer-reviewed by independent scholars. This has been a long and thorough process, and ASSAf is proud to finally launch the report of this study.

Prof Stephanie Burton (ASSAf acting president) presented a hard copy of the report to Dr Rakeshnie Ramoutar-Prieschl (Acting DDG: Technology and Innovation).[2]

Keynote remarks by the Department of Science and Innovation (Dr Rakeshnie Ramoutar-Prieschl, Acting DDG: Technology and Innovation, DSI)

The DSI is a strong advocator for research in nuclear technology, actively supporting projects and initiatives with a focus on building knowledge and skills, particularly for the peaceful use of nuclear technologies. The value of nuclear technology is multisectoral and multifaceted,

[2] The digital report is available at https://www.dst.gov.za/index.php/documents/strategies-and-reports/82-nuclear-technologies-in-south-africa-for-peaceful-uses/file.

with the potential to play a significant role in enhancing the socioeconomic wellbeing of South Africans by improving access to energy and water, healthcare, agriculture, food security, and maintaining environmental integrity.

The DSI commissioned the report in July 2019, and ASSAf was tasked to lead the development of a strategic framework to help identify priorities that would inform the Country Programme Framework with the IAEA. The objectives are to review historical and current national policies, consider the national landscape in terms of existing capacities and emerging trends, and make recommendations on the South Africa's Country Programme Framework with the IAEA. A secondary focus is to develop baseline information on the pockets of excellence in the South African nuclear sector, define smart indicators and set targets for a monitoring and evaluation framework, and make recommendations on building a more robust framework.

South Africa has advanced research infrastructure, which, together with flagship initiatives such as the Nuclear Medicine Research Infrastructure (NuMeRI), is reason for celebration. Private partners, academia and industry, together with practitioners from around the globe and different disciplines, are developing new diagnostic tools for cancer treatment and new drugs. Furthermore, the election of NuMeRI as an anchor centre for establishing radiotherapy services to provide cancer care for all in the IAEA Rays of Hope initiative[3] will have far-reaching impacts and consequences for South Africa.

The report also highlights a number of gaps and challenges in realising sustainable and equitable access to nuclear technology in South Africa, including lack of integration, uncoordinated planning, disparate mobilisation of resources, and failure to capitalise on the strengths of the nuclear research initiatives. There are very few downstream applications and benefits of nuclear energy due to limited progress in involving the private sector.

The DSI has noted the high-level recommendations of the report. The report comes at an opportune time, providing opportunities to reshape policy; propose mechanisms to strengthen policy direction and coordination; build a robust monitoring and evaluation system; and strengthen communication, public awareness, outreach and partnerships with universities, especially historically disadvantaged institutions.

The DSI congratulated ASSAf, the expert panel, contributors and reviewers for dedicating their time on a voluntary basis to produce an excellent report that will hopefully steer the formation of a national nuclear RDI agenda. The DSI considers the report to be strongly aligned to the strategic imperatives outlined in the department's Decadal Plan, and a potential means to advocate public–private partnerships and strengthen interdepartmental collaboration.

The DSI remains committed to enhancing radiation protection, nuclear safety and a regulatory framework abiding by the highest safety standards and responsible nuclear stewardship. This includes redesigning and refocusing programmes to support the skills development pipeline, especially for women, youth and people with disabilities, and providing training and employment opportunities in the nuclear industry. Furthermore, marginalised communities need to be involved to develop an equitable workforce, not only in areas of innovation and scientific development, but also in the handling, transportation, warehousing and safe disposal of nuclear products. A transdisciplinary approach would contribute to all-Africa engagement, underpinned by equity, responsibility and a shared vision for a sustainable future.

[3] https://www.iaea.org/services/rays-of-hope/anchor-centres

Vote of thanks and closure (Prof Himla Soodyall)

Prof Soodyall noted that it was ten years ago, on 5 December 2013, that former president Nelson Mandela passed away. He had been a strong supporter of ASSAf, and through his vision the Academy was established in 1996. The launch of the report on this anniversary is therefore significant and fitting to commemorate the values of Nelson Mandela and his dedication to education for the betterment of society, which the study embodies.

SESSION 1: Human Capacity and Skills Development (Chair: Dr Van Zyl de Villiers)

Opening outline and introducing panellists (Dr Van Zyl de Villiers, Consultant on nuclear safeguards and peaceful applications of nuclear energy)

The purpose of the workshop session was to get feedback from stakeholders and their views on the implications of the report, especially for human resource and skills development.

Respondent: Industry (Ms Lerato Makgae, South African National Liaison Officer, IAEA)

There is clear alignment between the ASSAf report and the work of the IAEA. The IAEA National Liaison Office is the interface between the IAEA and government, ensuring skills transfer and promoting nuclear technology in both energy generation and non-energy applications.

The IAEA Technical Cooperation Programme (TCP) forms part of the DMRE's strategic plan and annual performance plan. The IAEA also works closely with the DSI, which funds the TCP and ensures that initiatives are executed. The TCP comprises a national programme, regional programme (AFRA) and inter-regional programme.

The recommendations of the ASSAf report are incorporated in South Africa's Country Programme Framework for the 2024–2029 cycle and are currently under review by the IAEA. Key recommendations that resonate with the IAEA are highlighted, most importantly strengthening integration and intergovernmental approaches to nuclear technologies. Government departments, industry and academic institutions have been brought together in the South African Network for Nuclear Education (SANEST) to assess and present human resource requirements in the nuclear sector. In the past there has been a strong focus on the energy-generation aspects of nuclear, but the current focus is more on non-energy aspects. The report's recommendation for a human resource strategy is receiving attention, and SANEST has been tasked to compile a human resource development plan.

As mentioned in the report, nuclear technologies are not included in the strategies of other government departments. The Department of Higher Education and Training (DHET), for example, made no mention of nuclear in its Human Resource Development Strategy for South Africa. The IAEA has therefore established a national programme steering committee to work with government departments in this regard.

South Africa is currently participating with the IAEA on five national projects in the fields of health, agriculture, environment, water and sanitation. The two regulatory bodies, Necsa and the Southern African Radiation Protection Association (SARPA), have embarked on training programmes with the IAEA to strengthen capacity in collaboration with many departments. In this way, gaps are being identified and addressed, and IAEA's relationships with the role-players are being strengthened.

Respondent: Research corporation (Dr Pradish Rampersadh, Group Executive: Research and Innovation, Necsa)

From the perspective of Necsa, the report is thorough and comprehensive in covering the relevant issues. Necsa, whose mandate is to perform research on nuclear energy and radiation science, is pivotal in these discussions. Shifting international political and economic directions in relation to nuclear fuel cycles offer opportunities for Necsa. South Africa is a signatory to the protocols on nuclear technologies, and is seen as a leader in the responsible use of nuclear technology.

Necsa is also focusing on power-generation aspects through small modular reactor technology, and is engaging with government to revitalise aspects of the PBMR programme. The laboratories that worked on this technology are considered pockets of excellence of world-class standard, and the international community could be served through South African expertise. Necsa is planning to bring more people into these areas and to develop skills accordingly.

The SAFARI-1 nuclear reactor has been in place for more than fifty years and has served South Africa well in commercial as well as research aspects. There is now a need to replace and upgrade the reactor, and Cabinet has approved a new multipurpose reactor. Necsa is engaging with universities and international partners to exploit the significant opportunities that this offers for the development of skills and infrastructure. A new neutron facility to assist nuclear research in South Africa with neutron refraction, tomography and other applications is planned. Panels of experts led by academics will assist Necsa to develop scientists and operators for these platforms.

Necsa has established the company NTP Radioisotopes SOC Ltd for the commercial production of medical and industrial isotopes. This is the biggest supplier of medical isotopes in the world and is focusing on increased production of new medical isotopes. The production of industrial isotopes offers the opportunity to create another company that will focus on industry requirements and can potentially become a global leader.

Necsa has been engaging with academic institutions, including North-West University (NWU), for skills development. Some Necsa staff have academic posts and are involved in student training. Other institutions, including the University of Johannesburg and Tshwane University of Technology, use Necsa as a base to develop their academic programmes and research agendas. In this way, Necsa is able to make meaningful contributions outside the nuclear energy sphere and add value to the academic sector.

The recommendation in the report for enhanced national coordination is welcomed, and Necsa is committed to becoming involved in more collaborations.

Respondent: Nuclear medicine (Prof Kgomotso Mokoala, President: South African Society of Nuclear Medicine)

In the view of the South African Society of Nuclear Medicine (SASNM), the ASSAf report is comprehensive and accurately highlights the challenges in nuclear medicine. SASNM acknowledges progress in the development of nuclear medicine in South Africa, and the support that this discipline has received from the DMRE and DSI.

The recommendation to have nuclear medicine facilities in level 2 (regional) hospitals is singled out as very important. This is also a priority project of the SASNM. Currently, only six of the nine provinces have access to nuclear medicine in their facilities, and patients in the remaining three provinces have to travel long distances for access to oncology and nuclear

medicine services. Analysis is required to compare the cost of transporting such patients to facilities in other provinces against the cost of investment to expand the infrastructure in regional hospitals to offer nuclear medicine services.

Human resource development is another important challenge. There is a lack of facilities to absorb the skills of trained nuclear professionals and technicians. The expansion of nuclear medicine in level 2 hospitals will create more opportunities for the employment of graduates and for collaboration between facilities and institutions in placing graduates.

South Africa needs to develop its own guidelines with relevance to local industry, using data generated by the national nuclear sector.

Infrastructure is also highlighted as an important area for improvement, especially the need for better planning. Many existing facilities have not been planned to accommodate nuclear medicine but could be repurposed, and space could be allocated to host nuclear medicine facilities. Nuclear medicine is generally seen as a very expensive modality, but there are opportunities to repurpose old equipment or reassign existing equipment that is due for upgrade so as to prolong the lifespan of the infrastructure.

South Africa currently has three cyclotrons[4], but capacity to produce radiopharmaceuticals must be increased to service the needs of the population. Furthermore, scaling up the imaging capacities will avert many cancer-related deaths.

SASNM supports the concept of a comprehensive cancer network with nuclear medicine at its core. Capacity building and development of human resources are critically important to avert the loss of skills through the exodus of professionals. The need to accredit the training of radiopharmacists is especially pertinent to stem the loss of professionals, who are leaving the country due to difficulties in registering with the Health Professions Council of South Africa (HPCSA).

SASNM endorses the report and thanks ASSAf and the expert panel for producing an important and useful document.

Respondent: Research infrastructure (Prof Victor Tshivhase, Managing Director, iThemba LABS)

Prof Tshivhase represents the perspective of the accelerator-based research infrastructures. He emphasised that nuclear research involves long-term projects and requires long-term commitments. iThemba LABS is an important producer of isotopes, specifically the production of C-70 isotopes at the flagship South African Isotope Facility (SAIF).

iThemba LABS supports the Southern African Institute for Nuclear Technology and Sciences (SAINTS) programme, which empowers students and staff through the provision of excellent education, training and practical opportunities in collaboration with universities, thus ensuring skills development in nuclear technologies. There is a need to revisit the Centre for Applied Radiation Science and Technology (CARST) programmes, and provide better support for universities that are not yet involved in nuclear technology training and research.

iThemba LABS has a strong focus on research, and is collaborating with a number of leading organisations and institutions, both nationally and internationally.

[4] https://nucleus.iaea.org/sites/accelerators/Pages/Cyclotron.aspx#InplviewHashd5afe566-18ad-4ac0-8aeb-ccf833dbc282=

iThemba LABS endorses the content of the report and is committed to support industry and the medical field by continuing to produce isotopes. The facility serves all South Africans and will continue to perform research for the betterment of society.

Respondent: Nuclear engineering (Prof Dawid Serfontein, School of Industrial Engineering, Renewable Energy Research Group, North-West University)

Prof Serfontein closed the feedback session with by confirming that the higher education sector strongly supports government programmes in nuclear engineering. The University of the Witwatersrand is the national leader in academic nuclear research and training of professionals and personnel in the nuclear energy sector to manage aspects of nuclear engineering. Other universities, including Stellenbosch University and the University of Pretoria, have smaller programmes in selected fields.

The NWU has established the School of Nuclear Energy under the auspices of the PBMR to support research in this field. The focus in this programme has been on building and designing a nuclear reactor based on locally developed technologies. When South Africa considered importing reactors from abroad, there was no longer a need to design and build the PBMR, and the project was discontinued. The focus of the NWU then shifted to nuclear technology management, which entails decision-making on the cost-effectiveness and viability of nuclear infrastructures, the economic aspects of nuclear in comparison with other renewable energy sources, and project management of large nuclear projects.

A major challenge is the long-term nature of nuclear research programmes, as indicated by Prof Tshivhase. Furthermore, NWU studies have shown that small failures and miscalculations in the development of a nuclear energy programme would lead to significantly higher costs compared to alternative energy sources.

The university sector should be more supportive of the government in policy-making around nuclear technologies. When making policy decisions, there is often a lack of consultation with stakeholders. It is essential for academics to be involved in policy development from the start of any new envisaged programme to ensure that it will be profitable and productive.

Q&A moderated by Dr de Villiers

Question: In oncology treatments using nuclear medicine, the non-nuclear medical team is often not familiar with nuclear treatment techniques and is unable to advise on proper procedures. This contributes to a silo culture in academia and medical spaces. There is a need for medical doctors to be trained in theragnostic and nuclear techniques, which could form part of continuing professional development (CPD) programmes.

Response: This is an important and valid comment. Doctors are becoming increasingly aware of nuclear medicine. There is more emphasis on nuclear medicine in the training of young professionals, but it should be incorporated in curricula at a much earlier stage.

Comment from the DSI: There is no mention in the report or the presentations of who will fund the implementation of the recommendations. Government departments are subject to budget cuts, and stakeholder organisations are therefore asked to consider co-funding some of the proposed recommendations.

Response: Facilities such as Necsa generate funds as a return on investment that are used to invest in research. An example of the economic potential of nuclear technologies is the revenue generated through the production of radioisotopes, a semi-commercial

endeavour that realises healthy profits. A percentage of the profit is channelled back to R&D in nuclear medicine. The Agricultural Research Council (ARC) similarly has projects with commercial potential in insect pest control. There should be general caution around approaching the private sector for funding in the nuclear energy field due to complexities around collaborations, but the civil applications of nuclear technology are less problematic and should be pursued.

South Africa's IAEA National Liaison Office is funded by the DSI under the Technical Cooperation Programme and receives support from the DMRE to participate in AFRA. Contributions from institutions and organisations need to be offset by return on investment for the country. An example is a schools programme run by the National Liaison Office, which supports two schools with equipment (radiation detectors) and has trained the teachers to use the equipment in the classroom.

The facilitator observed that, apart from financial investments, there are other ways to contribute, for example, the investment of time through collaborations. A greater drive is required to encourage stakeholders to invest their time through networking and strengthening partnerships. A key finding of the report is insufficient integration and leveraging of strengths in the various programmes. The industry needs to make use of the available mechanisms to obtain more in-kind support, for example by pooling existing expertise to draw up strong proposals that will generate more support and collaborations.

SESSION 2: Policy and Governance (Chair: Prof Sampson Mamphweli, Head: Energy Secretariat, SANEDI)

Opening outline and introducing panellists (Prof Sampson Mamphweli)

The chair introduced the panel members for the session and gave an outline of the topics.

Respondent: Water and sanitation (Mr Zacharia Maswuma, Director: National Hydrological Services, Department of Water and Sanitation)

The National Hydrological Services Unit of the Department of Water and Sanitation (DWS) is responsible for monitoring networks for surface water and groundwater across the country. In 2020, they were invited by the DMRE to participate in the AFRA programme, which provides an opportunity to consolidate the monitoring programmes and gain an overview of the state of water resources in the country.

In terms of hydrological monitoring, the report is welcome and deals with several imperative issues. Addressing national water security is of critical importance but cannot be viewed in isolation from within South Africa's borders, because of the transboundary water resources shared with neighbouring countries.

Some of the recommendations of the report are related to gaps identified by the DWS through participation in the AFRA programmes.

South Africa is facing pressing issues in meeting water demand and achieving the Sustainable Development Goals (SDGs) associated with water. Upscaling the use of groundwater is one way to fulfil those demands. The Water Research Commission (WRC) conducted studies and produced a consolidated report on the use of isotopes in hydrology, which relate to a recommendation of the report to conduct further research on deep aquifers using radioisotopes.

The challenges of climate change, increased pollution and inadequate infrastructure

management demand new approaches with a focus on mentorship, encouragement of learning, and knowledge sharing. Mr Maswuma suggested that this could be addressed through an isotope research community of practice (CoP). The creation of such a CoP and the establishment of a regional centre for water analysis through the use of isotopes are essential to bridge the skills gap and ensure a more sustainable water future for the region.

Respondent: Energy (Mr Katse Maphoto, Chief Director: Nuclear Safety and Technology, DMRE)

The Department of Mineral Resources and Energy congratulated the panel on the valuable study. In 2017, the DMRE identified disparities in the Nuclear Energy Policy of 2008, which was focused on energy generation. A committee was formed to work together in the nuclear R&D arena. The DMRE developed a position paper that addresses a number of issues highlighted in the ASSAf report.

The innovation gap between research and translating the outcomes into practice is pertinent. In the past, projects were proposed and pitched at a commercial level (for example, the PBMR), rather than emphasising R&D. The DMRE is in the process of transferring the PBMR technology from Eskom to Necsa. Cabinet will be approached to lift the care and maintenance status of the project so that the DMRE's Integrated Resource Plan can in future include nuclear generation through technologies such as the PBMR.

In South Africa, there is considerable contestation around energy sources, and nuclear energy has been sidelined for political and financial reasons. However, there is a drive to start afresh with nuclear energy generation projects. Necsa is spearheading the multipurpose reactor project, and a ministerial task team has been appointed to ensure sustained progress in this initiative. Furthermore, there are long-term operational plans for Koeberg, which entail replacing generation units to extend its lifespan for another 20 years.

Over-reliance on research funding from the Technical Cooperation Programme is potentially risky and calls for the creation of innovative revenue-generation models to feed back into the nuclear sector. The ASSAf report is important in helping the DMRE to finalise policy and strategy documents regarding nuclear generation in South Africa.

Respondent: Nuclear regulations (Dr Sifiso Nhleko, Director: Centre for Nuclear Safety and Security, National Nuclear Regulator)

The NNR's Centre for Nuclear Safety and Security was established in 2017 to serve the sector in the regulation of nuclear activities. The centre is premised on the understanding that nuclear regulation is a science-based activity that needs to be underpinned by scientific evidence.

The NNR's comments on the ASSAf report are strongly in line with the mandate of the NNR regarding the safety and security of nuclear technology. The NNR applauds the initiative to commission and conduct the study, which was well-timed because it coincides with a global nuclear renaissance. The South African government is aware of the importance that nuclear research plays in the energy industry.

The NNR supports the finding of the study that there is a need for increased research on safety and security in the industry. More projects focusing on security and addressing skills development and human capacity building should be undertaken through the IAEA Technical Cooperation Programme (TCP). The NNR recommends that the sector should look further than the TCP and also consider instruments of the European Commission and the African Commission on Nuclear Energy (AFCONE).

The NNR proposes that the IAEA National Liaison Office should have access to these platforms.

An important recommendation of the report is the need for more public–private partnerships for education and training with a specific focus on radiation (subsection 6.1). A central authority will be required to coordinate such training.

The NNR acknowledges the recommendation on the need to harmonise the radiation protection regulatory functions of the NNR and the DoH (subsection 6.2). The NNR Amendment Bill, which is being tabled in Parliament, addresses this aspect.

Some initiatives of the NNR were highlighted to demonstrate its readiness to regulate emerging technologies. Firstly, the NNR has revised and modernised the current National Nuclear Regulator Act (No. 47 of 1999) in line with current industry practices. The NNR is involved in capacity-building initiatives related to small modular reactors. The NNR hosted the IAEA review mission in 2016, and has addressed the subsequent recommendations. The NNR remains committed to its mandate to regulate the safety of existing and emerging nuclear technologies.

Respondent: Nuclear Waste and Environmental Management (Dr Margaret Mkhosi, CEO, National Radioactive Waste Disposal Institute)

The National Radioactive Waste Disposal Institute (NRWDI) is the newest of the nuclear-related organisations in South Africa, regulating the end processes of the nuclear fuel cycle, namely the management and disposal of nuclear waste. The waste is generated mostly by Necsa, Koeberg, hospitals and universities. Another form of nuclear waste is abandoned 'ownerless waste', which also has to be managed. The Radioactive Waste Management Policy and Strategy of 2005 provides for the formation of a radioactive waste management fund, but this has not yet been established. Once the NRWDI Bill has been passed in Parliament, funds will become available for the NRWDI to perform its mandate.

The NRWDI is designated by the IAEA as the regional competent authority for radioactive waste management. The National Radioactive Waste Disposal Institute Act (No. 53 of 2008) empowers the NRWDI to conduct research and collaborate with organisations and institutions in a wider context than just nuclear technologies.

The disposal facilities of the NRWDI are located in rural areas, giving rise to concerns and objections from the agricultural sector. Communication strategies are therefore vital to assure farmers of the safety of the programme. Current programmes undertaken by the NRWDI include a feasibility study for off-site storage of spent nuclear fuel from Koeberg and Necsa. Other studies are addressing the disposal of used nuclear materials from sources such as hospitals and universities, in collaboration with the IAEA, looking at borehole disposal of such waste. Another project is investigating options for the disposal of replaced reactor components.

The NRWDI invites stakeholders and partners in the sector to work together and collaborate, as recommended in the ASSAf report.

Respondent: Human health and nutrition (Mr Setlhare Bakhane and Ms Bilqees Sayed, Department of Health)

The Department of Health (DoH) welcomes the report, which has aroused interest and stimulated constructive discussion around nuclear medicine and technology.

The department fully supports the report and its recommendations.

The core challenge that the DoH is facing is the accessibility of healthcare services to the majority of South Africans, especially those in rural areas. In recent years, the DoH and DMRE have collaborated on various programmes, which highlights the importance of government departments interacting to enhance service delivery as endorsed in the ASSAf report. Inter-departmental cooperation is also important in relation to policy alignment.

Through the DMRE, the DoH is collaborating with the IAEA, most notably in the Rays of Hope initiative, and the Minister of Health has endorsed Steve Biko Academic Hospital as an anchor centre of the programme.

The DoH is revising its cancer strategy and invites input from all stakeholders. Furthermore, at the recent BRICS Summit, member states signed collaboration declarations to increase partnerships for infrastructure and human resource development in nuclear medicine.

Q&A moderated by Prof Mamphweli

Question: Since South Africa is classified as a semi-arid country, has DWS investigated reverse osmosis as a possible resource for additional potable water?

Response: Reverse osmosis is carried out in a number of provinces and has been investigated in several pilot studies. It forms part of DWS research programmes and is included in the water mix strategy to increase access to fresh water.

Comment to colleagues in government departments: It is evident from the ASSAf report that there are gaps in coordinating legislative and policy directives between government departments. What could be done to coordinate efforts and ensure that the legislation and policies of the various government departments address the deficiencies identified in the report?

Response: The ASSAf report proposes the formation of a central coordination desk. The DMRE has also made this recommendation in its position paper on R&D. There seems to be convergence and a clear need to achieve this.

Question: Previous DWS policy documents have prioritised desalinisation based on the envisaged nuclear deal. Has this policy been revised since the nuclear roll-out is no longer a reality?

Response: The National Water Resource Strategy identifies key areas for R&D, including research on additional water resources. Whether the policy has been revised is not clear and will be confirmed.

Question: Is nuclear technology included as a policy directive in the DSI White Paper on Science and Innovation?

Response: The policy development has gone through many iterations and is ultimately informed by and subject to the availability of financial resources. The DSI continues to support nuclear RDI, with a current focus on leveraging expertise in nuclear medicine. Some aspects of energy storage research are also funded by the DSI.

Closing comments by (Prof Himla Soodyall, Executive Officer: ASSAf)

Prof Soodyall thanked participants and commented that the collective diversity of the panellists is fitting for the launch of the report. ASSAf will be communicating with stakeholder departments and institutions to request further support and input to the report.

ASSAf is using the quadruple model of harnessing and integrating the initiatives of policy makers, academia, the business sector and civil society. ASSAf's Just Transition Forum is working on the challenges of climate and electricity generation, and another forum is working on water and sanitation. An energy forum will be initiated in the near future. In all these platforms, ASSAf has the convening power to bring together stakeholders and like-minded persons to engage in conversations for maximum cohesive impact on societal issues. ASSAf invites and entreats participants in this launch event to avail themselves of these endeavours.

Vote of thanks and closure (Dr Melusi Thwala, Manager: Science Advisory and Strategic Partnerships, ASSAf)

Dr Thwala commented that the launch has stimulated fruitful engagement and thanked the programme directors, panellists, speakers and audience for taking the time to attend the event. The expert panel was acknowledged for their work on the report. The DSI was thanked for its engagement with ASSAf throughout the process and for supporting the event. The ASSAf secretariat was thanked for the work involved in hosting the event.

The contributions from the panellists from very different sectors demonstrate general agreement on a singular vision for nuclear technology as a tool to advance the mandates of the various institutions and departments. Partnerships and collaborations in the sector are vitally important, and it is ASSAf's role to provide a platform for such engagements.

APPENDIX 1: LIST OF ACRONYMS

AFRA	African Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology
ASSAf	Academy of Science of South Africa
CEO	Chief Executive Officer
CoP	Community of Practice
DDG	Deputy Director-General
DMRE	Department of Mineral Resources and Energy
DoH	Department of Health
DSI	Department of Science and Innovation
DWS	Department of Water and Sanitation
IAEA	International Atomic Energy Agency
iThemba LABS	iThemba Laboratories for Accelerator Based Science
Necsa	South African Nuclear Energy Corporation
NNR	National Nuclear Regulator
NRWDI	National Radioactive Waste Disposal Institute
NuMeRI	Nuclear Medicine Research Infrastructure
NWU	North-West University
PBMR	Pebble Bed Modular Reactor
R&D	Research and development
RDI	Research, development and innovation
RPO	Radiation protection officer
SAHPRA	South African Health Products Regulatory Authority
SANEDI	South African National Energy Development Institute
SANEST	South African Network for Nuclear Education
SARPA	Southern African Radiation Protection Association
SASNM	South African Society of Nuclear Medicine
TCP	Technical Cooperation Programme