Evaluation of the Implementation and Impact of the National Equipment Programme

Full Report

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This report has been independently prepared by DNA Economics. The Evaluation Steering Committee comprises the Department of Science and Innovation, National Research Foundation and Department of Planning, Monitoring and Evaluation. The Steering Committee oversaw the operation of the evaluation, commented and approved the reports. The members included:

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CONTENTS

Figures

Tables

GLOSSARY

ADG	Average Daily Gain
AM	Additive Manufacturing
APRs	Annual Programme Reports
ARC	Agricultural Research Council
CPAM	Collaborative Programme in Additive Manufacturing
DA	Designated Authority
DALRRD	Department of Agriculture, Land Reform, and Rural Development
DESE	Department of Education, Skills, and Employment
DHET	Department of Higher Education and Training
DMLS	Direct Metal Laser Sintering
DOH	Department of Health
DSI	Department of Science and Innovation
EMU	Electron Microscope Unit
ESC	Evaluation Steering Committee
FDI	Foreign Direct Investment
GMSA	Grants Management and Systems Administration
HAIs	Historically Advantaged Institutions
HDIs	Historically Disadvantaged Institutions
HICD	Human and Infrastructure Capacity Development
MOA	Memorandum of Agreement
MRC	Medical Research Council
MTEF	Medium-Term Expenditure Framework
NDP	National Development Plan
NEP	National Equipment Programme
NHMRC	National Health and Medical Research Council
NNEP	National Nanotechnology Equipment Programme
NRDS	National Research and Development Strategy
NRF	National Research Foundation
NSI	National System of Innovation
POPIA	Protection of Personal Information Act
PRs	Progress Reports
R&D	Research and Development
RFI	Residual Feed Intake
RI	Research Infrastructure
RISE	Ramen Integrated Scanning Electron
RSIP	Research Infrastructure Support Programme
S&T	Scientific and Technical
SAASTA	South African Agency for Science and Technology Advancement
SARCHI	South African Research Chairs Initiative
SARIR	South African Research Infrastructure Roadmap
SEM	Scanning Electron Microscopy
SET	Science, Engineering, and Technology
SGC	Science Granting Council
SMEs	Small-medium enterprises
SRE	Strategic Research Equipment
SRIP	Strategic Research Infrastructure Programme
TDF	Technology Development Fund

TIA	Technology Innovation Agency
ToC	Theory of Change
TPP	Technology Platform Programme
UPS	Uninterrupted Power Supply
WRC	Water Research Commission

EXECUTIVE SUMMARY

1. Introduction

South Africa's ability to eradicate poverty, stimulate job creation, and generate wealth continues to be constrained as a result of various factors. Technological and scientific innovation offers a unique opportunity to stimulate economic development, improve standards of living, and foster employment opportunities within the country through the development of new services, products, and technologies. In order to transform South Africa into an internationally competitive knowledge-based economy, several key pre-requisites are required, including state-of-the-art infrastructure and a highly skilled labour force.

Like other emerging economies, South Africa has struggled to achieve sustainable growth through the development of knowledge-based strategies. Against a background of high unemployment, slow social reform and economic growth, and volatile exchange rates, it became necessary to identify system drivers of innovation that society and government control. These drivers stem from various sources, including knowledge management, knowledge generation, research, technology, and innovation (all of which fall under the ambit of the Department of Science and Innovation or DSI). Only in an environment equipped with relevant and high-quality infrastructure, including major and specialised equipment, can South African research begin to competitively generate new knowledge and technologies. However, the acquisition, operation, and maintenance of research infrastructure of this nature requires significant financial investment, which is often too expensive for individual research institutions to afford without support. Inadequate funding has therefore been identified as a key barrier to innovative research and development.

The DSI has developed several policies and strategies over the past two decades that inform national priorities around research development and the provision of research infrastructure, including the Ten-Year Innovation Plan, the South African Research Infrastructure Roadmap, and the White Paper on Science and Technology. Funding for research infrastructure is provided through the National Key Research and Technology Infrastructure Strategy, which covers programmes that aim to advance the national Research and Development (R&D) agenda. One such programme is the National Equipment Programme (NEP).

2. Overview of the intervention

The NEP was established with the goal of providing state-of-the-art research infrastructure to South African research institutions to advance the country's R&D agenda. It is funded by the DSI and implemented via the National Research Foundation (NRF). Funding is allocated to research institutions through a competitive peer-review process to acquire, develop, or upgrade state-of-the art research equipment in the fields of science, engineering, and technology. The focus is specifically on large pieces of equipment that support multi-disciplinary and inter-disciplinary research and that require significant capital investment. The targeted beneficiaries for the NEP include universities, science councils, national research facilities, and museums, although universities have been the largest beneficiaries to date.

Successful applicants who receive the equipment funding enter into contracts with the NRF. The conditions of the grant stipulate that the host institutions also contribute funding towards the purchase of equipment at a ratio of 2:1. Thus, the NRF covers two-thirds of the total cost of acquisition of the equipment, which is capped at an amount of between R1 million and R10 million. This includes VAT and a three-year maintenance plan. In addition to covering one-third of the acquisition cost, recipient institutions must ensure that they can provide appropriate building infrastructure to house the specialised equipment and that they can provide for a maintenance plan for a further two years.

The NEP grant awards are expected to yield returns on investment through the usage of the equipment, measured by an increase in the number of publications produced in the South

African body of science and technology literature. These publications extend towards those found in books, book chapters, peer and no-peer reviewed articles and conference outputs, as well as patents and technical reports. Expected returns on investment also include the upskilling of, access to, and usage of equipment by researchers, students, operators, technicians, and collaborators. Finally, the return on investment is also measured in terms of a financial model for the maintenance, upgrade, and other related operational costs for the equipment's sustainable management.

3. Background to the evaluation

In 2021, the DSI commissioned DNA Economics to conduct an implementation and impact evaluation of the NEP for the period spanning 2014/15 to 2019/20 (six financial years). The evaluation was designed to address five of the six evaluation criteria specified by OECD's Development Assistance Committee (DAC), namely programme relevance, efficiency, effectiveness, impact, and sustainability. In addressing these criteria, the evaluation assessed:

- Whether the NEP was implemented as envisioned;
- Whether the implementation of the NEP had been efficient;
- How effective the NEP has been in achieving its objectives;
- The outcomes produced by the NEP during this period; and
- The impact of the programme relative to its initial goals.

A mixed methods approach was applied for the evaluation, which collected both quantitative and qualitative data. At the start of the project a literature review was undertaken to understand the literature underpinning the design of the NEP, namely that considering research infrastructure at higher learning and research institutions, its impact on research output, economic growth, human capital development and training, and the potential for local and international collaborations. This was followed by a comprehensive review of programme documentation to understand the NEP's purpose, design, and performance, and included a review of strategic documents, funding application databases, annual progress reports, previous evaluation reports, and grant holder databases, among others. A benchmarking exercise of local and international research infrastructure programmes, guided by a set of questions that were agreed upon at the project's inception, was also conducted. A workshop was then held with key programme stakeholders to develop a programme Theory of Change for the NEP. The review process informed the development of an evaluation framework that guided the study and the development of the data collection tools.

Key informant interviews were conducted with small groups of stakeholders from the DSI and NRF to understand the design, objectives, and institutional arrangements for administering the NEP, as well as to obtain feedback on the implementation successes and challenges, using semi-structured interview guides. A total of 9 programme stakeholders were interviewed virtually in small groups of 2-4 participants each.

A digital survey was conducted among successful grant awardees for the period under review to assess their experiences around the NEP application process, commissioning of the equipment, grant reporting, and challenges with the process. Of the 120 grant holders targeted for the survey, 67 participated (56%). The grant holders were also asked to provide the contact details of up to 5 equipment users. The equipment users identified by the grant holders were invited to take part in a different digital survey to assess their experiences of using the equipment, training received, the outputs achieved, and broader satisfaction and challenges with regard to the equipment. Of the 179 equipment users invited to the survey, 99 responded (55%).

Semi-structured interviews were conducted among a sample of 24 grant holders to assess their experiences with the NEP, the costs and benefits of participation in the NEP for their institution (including any unintended consequences), the challenges, emerging successes, outcomes, impacts, and recommendations for programme improvement. The interviews also probed whether the funded equipment was leveraged for additional grants, as well as the measures in place to sustain the RI/ equipment post the NEP. Semi-structured interviews were also conducted with a sample of 7 university management teams, namely Deputy Vice Chancellors and Research Officers involved in research development at the selected institutions. The interviews focused on the costs and benefits of the NEP relative to other grants administered by the university, the efficiency and effectiveness of the relationships between the institution and the NRF and DSI, how the programme has affected the pool of skilled operators, technicians, and engineers, whether the equipment has been leveraged for additional grants, and the measures put in place to sustain the equipment post the NEP.

The evaluation team conducted site visits to 7 institutions across 6 provinces to view the equipment and observe its management and use. During the site visits, the evaluation team interviewed 3 non-grant holding equipment operators and technicians that were on site at the time. Finally, the evaluation team conducted a focus group discussion with equipment users from one institution.

An inductive thematic analysis approach was undertaken to analyse the qualitative data collected via the key informant interviews and the focus groups discussion. Recordings from these discussions were transcribed and analysed thematically based on the evaluation themes. Follow-up calls were had with grant holders and other respondents where additional clarity was needed. The quantitative data collected via the digital surveys was cleaned and analysed descriptively using Excel. Further, the outputs reported in the grant holder annual progress reports were captured into an Excel database and analysed descriptively.

4. Key evaluation findings

Relevance

The evaluation finds that the NEP is well defined in its programme design and is aligned with the broader research infrastructure programme that is being driven by the DSI. The NEP fulfils an important and unique role in South Africa's R&D programme - it is clear from the results that in its absence, most institutions would not have access to state-of-the-art equipment. Almost all of the stakeholders from beneficiary institutions involved in the evaluation indicated that their institution would not have been able to attain the equipment in the absence of the NEP grant, since the lack of funds was the primary barrier in acquiring state-of-the-art equipment. The findings also indicate that universities align their research equipment acquisition and upgrade strategies with the NEP. The NEP does not duplicate the efforts of other government activities and was found to align with international programmes in the benchmark review.

The majority of the evaluation respondents noted the difficulties institutions experienced in covering the operational costs of the equipment, including consumables and the salaries of technicians and operators, as well as extended maintenance plans and policies. The challenges in providing for these costs was reported to compromise the optimal usage of the equipment, which ultimately impacts the achievement of intended programme outcomes and impact.

Efficiency

Overall the NEP was implemented as planned, although several challenges were identified. In terms of applying for NEP grants, researchers from well resourced, historically advantaged institutions (HAIs) and combined universities were found to benefit most from the support provided by their institutions, which wasn't the case for those from historically disadvantaged institutions (HDIs). Programme implementers also noted the difference in the quality of proposals received from the two different types of universities, with HDIs submitting proposals that were less rigorous and with grant applicants who did not always demonstrate the required track record of publications and research history in their fields. Some of the grant holders noted the onerous nature of compiling the grant application and felt that the time provided was not sufficient to collect all of the required information.

The grant award process was found to be efficient, with the majority of successful applicants having received the first grant payment within 6 to 12 months of their initial application. The majority of grant holders had been able to commission the equipment within the two-year period after winning the grant, with most delays being due to institutional procurement processes or factors outside of the programme, such as delays in importing equipment.

Several challenges were noted with regard to the annual progress reporting system, including several shortcomings identified with the report templates, as well as with the reporting period in that some grant holders indicated that outputs may only be seen after the end of the reporting timeframe due to extended data collection periods. Programme managers noted that funding for the NEP had been significantly affected by the budget cuts instituted by National Treasury, which resulted in a reduction in budget for the infrastructure programme and resulted in NEP grants not being made available in 2017. Despite this, the NEP invested a total of R572.5 million in research equipment during the six-year review period, which covered 54% of the value of funding requested from applicants. This is a significant increase from the findings of the previous evaluation conducted in 2011, where an investment of R166.7 million was made over the four-year period, and which met 38% of the requested funding value. With respect to the institutions, some of the DVCs and grant holders reported that it was difficult for their institutions to source funding for the one-third cost contribution required by the grant. This was of particular concern among grant holders from poorly resourced universities.

Effectiveness

The evaluation finds that the NEP has enabled the expansion of institutional capacity for research, training, and innovation at public universities and recognised research institutions. The evidence demonstrates that human resource capacity has been developed at South African institutions through the programme, predominantly among postgraduate students. Grant holders were still predominantly White, although there has been positive growth in the number of Black grant holders over time; the proportion of White male researchers funded through the programme decreased from 56% in the previous evaluation to 42% in the current evaluation, while the number of male researchers of colour (Black, Indian, and Coloured) increased from 14% in the previous evaluation to 27% in the current review. Despite a slower transformation rate among grant holders, almost half of all users capacitated using the equipment were Black, and almost half of all users were female, indicating progress towards objectives. However, despite the progress made, gaps still remain with regard to the transformation and capacitation of HDIs. The placement of the equipment was found to foster research collaborations and there are clear examples of how it enabled beneficiary institutions to undertake world class research, which has resulted in a range of research outputs for grant holders and students alike. Finally, many grant holders successfully leveraged the equipment to attain further funding for their own research and for their institutions.

During the period under review, a total of 126 grants were made to 120 grant awardees (four awardees held multiple grants). Of the R1 billion requested in funding over the period under review, a total of R572.5 million was awarded across 28 institutions (57%). The vast majority of funding (92%) was awarded to higher education institutions with the remainder awarded to other science institutions (8%), which represents an increase from the previous evaluation where 84% of the funding was channelled to higher education institutions.

Of the R906.7 million requested by universities in the grant applications, the grants allocated provided for more than half (58% or R527.4 million) of the expressed need. Five universities, of which three were HAIs were awarded two-thirds of the grant funding they applied for, while HDIs were awarded 43% of the grant funding they applied for, with only four of the eight HDIs being successful in their applications. The combined universities were awarded 53% of grants they applied for. No grant applications were received from the two newly established universities during the period under review (University of Mpumalanga and Sol

Plaatjie University). With regard to the success rate by type of university, academic universities were awarded the most funding from their applications (63%), followed by comprehensive universities (55%) and then universities of technology (42%). Of the R144.8 million requested by science institutions in the grant applications, the grants awarded provided for just less than a third of the expressed need (31% or R45.1 million). Two-thirds of the total funds allocated to science institutes went to three science councils, namely ARC, the CSIR, and NECSA. The NHLS and SASRI were not successful in any of their applications to the NEP.

The majority of grants were awarded to White males (42%), followed by White females (25%), and then Black males (18%). More than two-thirds of grant awardees were male (69%), with only 6% of grants awarded to women of colour. The demographic profile of unsuccessful grant applicants indicates that the majority of unsuccessful applicants were White males (36%), followed by African males (25%) and then White females (17%). While the demographic pattern of unsuccessful applicants generally follows that of the grant holders, it indicates that African males were slightly less successful in attaining a NEP grant during the period under review. More than two-thirds of the grant holders were aged 50 years and older, of which 21% were over the age of 60 years. While all grant holders hold a doctoral degree, the age profile of awardees indicates a high success rate amongst senior academic staff.

A total of 2 422 equipment users were reported in the APRs, including the grant holders themselves. Almost half of the users of the funded equipment were Black / African (43%), followed by White users (38%) with fewer Indian (7%) and Coloured (7%) users. A quarter of the users reported during the period under review were Black males. In terms of the student users of the equipment funded by the NEP, the majority were studying towards a PhD (27%) or Masters degree (32%). The remainder of students were in Postdoctoral positions (15%) of completing an Honours or undergraduate degree. In terms of the number of users reported by type of institution, half of all reported equipment users were from HAIs (51%), a third were from combined universities (33%), 10% were from science institutions, and 6% were from HDIs. Thus, while HAIs had an average of 310 users per university, combined universities had 73 users, science institutions had 32 users, and HDIs had 41 users each on average. This indicates a gap in capacity development among students at HDIs, which likely relates to the broader capacity issues at these institutions.

Impact

While the impact of the NEP could not be definitively assessed using the methodology applied in this evaluation, the findings point towards the positive impact of the NEP given the achievement of several long-term outcomes. A good return on investment has generally been seen for the NEP over the review period. The provision of the equipment has advanced research efforts at research institutions, enabled the development of human capacity, while enabling collaboration and innovation.

There is evidence that the NEP has contributed to the development of a supportive research environment. Access to state-of-the-art equipment is regarded as a necessary condition for the development of competitive and novel research outputs, and several grant holders reported that the attainment and use of the NEP-funded equipment enabled them to make improvements to existing research methods, existing databases, and that these research outputs have contributed to the existing body of knowledge in their relevant sectors.

Despite the gaps identified with regard to institutional transformation on the whole, there is evidence that the NEP has fostered institutional transformation in some respects. For example, Prof Shonhai Addmore, from UNIVEN used the equipment attained through the NEP to establish their unit as one of the leading laboratories in protein biochemistry on the continent. Further, there is evidence that the NEP has enabled the establishment of new research areas. Prof Bux Faizal from DUT reported on their ability to contribute to novel and important scientific research that will advance current knowledge in the field of epidemiology in terms of understanding the factors associated with the failure of anti-retroviral drug resistance in HIV strains in Africa as a result of the equipment funded by the NEP. The research endeavour involved a collaboration with an international team of researchers from the UK and USA.

There is also evidence that the NEP has contributed to improving both the quantity and quality of research outputs at public South African institutions. While little is known about the research performance of these faculties prior to attaining the NEP-funded equipment, and setting a baseline against which to quantitatively measure the impact of the NEP is challenging given the multiple factors that determine research performance, the overwhelming majority of grant holders reported that these research outputs would not have been possible had they not been awarded the grant. The placement of the equipment has helped researchers to overcome a range of challenges including delays in using other equipment due to long waiting lists, the contamination of study samples in transit, as well as user fees and transportation costs.

Sustainability

The benefits from the outputs and outcomes achieved by the NEP to date are likely to be sustained going forward, however, there are several important considerations in terms of sustaining the programme in future. These relate to funding from National Treasury; ensuring that investments and focus areas are strategic; human capital needs; succession planning; life cycle planning for equipment end-of-life; and financial succession planning.

One of the main threats to the programme’s sustainability is the funding made available by National Treasury for the research infrastructure programme. A key consideration for attaining this funding is the demonstration of tangible outputs that translate into socioeconomic development and the improvement of citizen’s lives. A key aspect of this lies in the commercialisation of processes and products stemming from the use of the equipment, around which there is room for improvement. Another key consideration is that of transformation, both at the researcher and institutional level, for which several gaps have also been found during this evaluation.

Going forward, more strategic investments will need to be considered, particularly due to broader budgetary limitations, to ensure alignment with the country’s research agenda and to address gaps in the RI landscape. In addition, human capital needs to be nurtured. Given that many grant holders awarded during the review period are close to retirement, there is a risk with regard to the continued operation of the equipment in the absence of these specialist skills. Succession planning and the development of human capacity for the future is critical; one way in which this can be achieved is through mentorship. There is also a need for life-cycle planning for RI. The useful lifespan of most equipment procured through the NEP is between 5 and 15 years. Once those time horizons have passed, technological advancement will most likely have made the equipment less relevant, or the passing of time will have made the equipment itself obsolete. Either way, the decommissioning of the equipment in question poses serious risks to the sustainability of research

There is also a need for financial succession planning with regard to maintenance. Without maintenance, the useful life of the equipment might be cut. In other cases, respondents suggest that consumable costs are prohibitively high. Cutting into the useful lifespan or the potential up-time of the equipment inevitably jeopardises the number of research outputs produced and opportunities for collaboration. Beyond these steps to ensure continued equipment operation, the equipment has and can continue to be used to secure further funding. Using the equipment obtained through NEP grant funding as the basis of advertising for one’s research capabilities ensures that the equipment can be used outside of NEP-backed research, allowing researchers to diversify away from the grant funding, and hopefully commercialising some of their research. Of course, such indirect advertising is not wholly effective on its own. As a result, grant holders also need to advertise the use of their equipment to potential collaborators, as well as use the NRF Research Equipment Database for promotion of equipment availability, as appropriate. Those collaborators (either internal or external to their research institution) can pay a user fee (covering maintenance, consumables, and a slight profit mark-up) to produce their research with the help of those trained to use the equipment. If usage trends are sufficient, some of these user-fees can be put away to replace componentry and even entire equipment pieces.

5. Recommendations

Several recommendations are made based on the findings of the evaluation, in an effort to maximise the value gained from the programme. Recommendations include those that relate to the programme design or are strategic in nature, and those that relate to operational considerations. Within each of these broad categories, recommendations are further grouped thematically.

5.1 Strategic recommendations

Funding gaps

R1: Address concerns related to funding for extended maintenance contracts, running costs, training, and salaries of operators and technicians to maximise the use of funded equipment through engagement with the institutions and grant holders.
Some of the grant holders reported limitations in covering other equipment and research related costs, which in some cases they felt impacted negatively on the extent to which the benefits of the equipment could be maximised. These included the costs for medium-to-long-term maintenance of the RI once the initial 3-year maintenance plans and policies expired, as well as operational costs associated with using the equipment, including consumables and salaries for part- or full-time operators and technicians, particularly at poorly resourced institutions.

Whilst not denying these challenges faced by grant holders, given that the programme budget is already constrained, it is understood that it is not an option for the DSI or NRF to allocate additional funding to the NEP for supplementary funding (as is done in some of the other countries considered in the international benchmarking review). In addressing this concern, it needs to be reiterated that the NEP is a partnership between the DSI, NRF, and the institution that receives the equipment. Institutions thus need to take greater ownership in helping fulfil the funding needs of their researchers. As such, it is recommended that institutions assess the options to fill these funding gaps using other funding sources, such as directly using subsidies received from publications and student graduations towards equipment-related needs. HDIs and poorly resourced institutions are able to negotiate with the NRF to waive the one-third contribution to the equipment costs. Where the one-third contribution is waived, funding that would've been used for this purpose should be put towards equipment running costs or operator costs. The NRF should engage with Research Officers at the individual institutions to assist them in planning to fill the funding gaps.

A further suggestion offered here for consideration is to link the additional maintenance provision commitment required from the institution to be linked to the expected life of the equipment, rather than making it a fixed two years. This could help ensure that funding is available to maintain equipment for the full duration of its' useful life.

R2: Introduce flexibility in terms of the minimum NEP funding cap (R1 million) to cover smaller pieces of equipment.
Feedback received from the grant holder interviews indicates that while most grant holders found the R10 million funding cap to be sufficient to procure state-of-the-art equipment, the lower cap of R1 million was in some cases restrictive. For example, some state-of-the-art equipment costs just less than R1 million, or equipment pieces that either perform enabling functions for larger equipment or improve the efficiency or competitiveness of the research, is excluded from the grant, but it still unaffordable for many researchers. Smaller equipment pieces under R1 million were anecdotally reported to make up the lion's share of equipment needs in certain fields and the competition for this niche funding is high.

It is recommended that a provision be introduced into the design of the NEP to allow for grant holders to apply for funding for certain pieces of equipment costing between R500 000 and R1 million to be considered on a case-by-case basis. Grant holders will need to demonstrate that this equipment is critical for their research, either on its own or as a complement to another larger piece of equipment funded by the NEP, and that they are unable to source other funds for it. Different lower threshold levels could also be considered for “plug and play” equipment versus custom-built equipment.

Transformation

R3: Capacitate HDIs to be better positioned to access NEP funding and equipment.
One of the core objectives of the NEP is to drive transformation by ‘developing human resource capacity that is focused on historically disadvantaged institutions, women, and people with disabilities.’ Despite this objective, the data shows that HDIs submit far fewer grant proposals than HAIs or combined universities, and had a lower success rate in securing funding. Only 9% of the overall grant value allocated during the period under review went to HDIs (spread across five institutions), and HDIs received 43% of the grant funding they applied for (as compared to HAIs who received 75% of the funding requested).

Discussions with DSI and NRF suggest that this observation is largely not due to a lack of funding, and as noted above there is an opportunity for HDIs to negotiate the one-third contribution to the equipment cost if they are constrained by funding. The issue instead lies with the fact that HDIs lack the institutional capacity and support that is available at better resourced universities, including that offered through research offices, which impacts on the number and quality of proposals submitted. Researchers at these institutions also lacked the required track record needed to secure grants, and in some cases did not have the long-term research programmes in place to warrant large strategic equipment investments, with them rather focusing on shorter term and contract research.

As such, it is recommended that the NRF helps to build the capacity of HDIs in two ways. The first of these is training to provide research offices with the skills to provide improved support to their academics in building research portfolios and preparing successful grant applications. The roles of these offices could include communicating grant information to researchers (including closure dates and requirements for grant preparation), providing support in identifying equipment needs, offering internal review of grant applications prior to submission to the NRF, and assisting the institution to strategically plan for equipment that will be required over the medium term. The second is providing direct academic support directly to researchers to help them write stronger proposals. It is noted that the DHET has provided substantial investment into programmes that are aimed at capacitating and supporting HDIs, and the assistance to research offices could form part of this investment.
A further recommendation here is that the NRF could facilitate partnerships between HAIs and HDIs, where the HAIs can provide mentorship to HDI researchers on developing grant proposals and through reviewing the proposals in an effort to improve proposal quality and to transfer grant writing skills. Alternatively, a small review committee could be appointed by NRF, made up of individuals considered by them to be best suited for the task, that provides mentorship, guidance, and review or quality assurance support to researchers from HDIs to improve their proposal development skills and chance of success – this panel would serve the function of internal review panels at HAIs. This panel could also provide in-depth feedback to unsuccessful applicants from HDIs to assist them in strengthening future applications.

The final suggestion here is to introduce a mechanism to increase the access of HDIs to NEP-funded equipment via mobility and support grants (as opposed to purchasing the equipment). A competitive grant funding mechanism could be introduced to cover, for example, user fees and travel costs for researchers and students to access equipment at other institutions. This will allow them to develop their track records and enhance capacity over the short-term, which would in turn strengthen the grant applications from HDIs over time. However, if this provision is introduced, it should be streamlined with the Equipment-Related Travel and Training Grants funding instrument offered by NRF, which only applies to researchers fitting a certain profile.

Strategic planning

R4: Institutions need to strategically plan for the equipment they require.
As mentioned above, the NEP is a partnership between the DSI, NRF, and the funded institutions. To this end, institutions need to take a leading role in strategically planning for the equipment they will need over the short and medium term (over two to five years). Planning institutional priorities for RI ahead of time will allow institutions to be better prepared to submit grant proposals when grant calls are released as they can begin to collate some of the information required and can divide requests for multiple pieces of equipment over different years. Institutional planning and commitment are important for both HDIs and other universities to maximise the benefit to be derived from the NEP. Such planning can be led by a steering committee appointed by the institution and should include the DVC. The NRF could facilitate the establishment of these steering committees, particularly at poorly resourced institutions.

R5: The NRF could facilitate the establishment of research consortia to help institutions collaborate and strategically plan for the equipment required in their province.
As noted in the findings of the study, the Western Cape has an interesting approach to applications for NEP funding. All of the institutions in the province meet to discuss and prioritise the pieces of equipment they require in the province, after which individual institutions are assigned the responsibility of leading the grant application for individual equipment pieces. This model could be applied in other provinces through support from the NRF, to improve success rates of applications, strategic placement of equipment, and allow for mentorship and shared learnings between HAIs and HDIs – although at the same time should be designed in such a way as to not hinder transformation through exclusion of certain individuals or institutions.

Sustainability

R6: The NRF should support institutions and grant holders in establishing charge-out models and expanding external equipment usage.
The DVCs and grant holders indicated uncertainty around how to set charge out rates (for both internal and external usage) for the funded equipment. To ensure the efficient recovery of costs, it is recommended that the NRF host workshops to explore cost recovery models, which should in turn inform the provision of guidance to institutions on how to set charge out rates.

Furthermore, to assist with ensuring financial sustainability and to increase collaborations, it is recommended that during this workshop institutions and grant holders be informed of the benefits and importance of proactively advertising the use of their equipment to potential collaborators, who will pay a user fee (covering maintenance, consumables, and a slight profit mark-up). The NRF Research Equipment Database is one channel that could be leveraged in this regard. If external usage is sufficient, some of the user fees can be used to replace components and even entire pieces of equipment. Whilst provision for external usage of equipment is included in the grant application, this is not always maximised in practice, signalling the need for ongoing guidance on this matter.

R7: Institutions and grant holders should prioritise succession planning for the equipment.
The development and nurturing of human capital is critical in sustaining the benefits of the funded equipment beyond the life of the grant, especially since a large portion of grant holders in the study were nearing retirement. This need is provided for in the grant

application, which requires applicants within 5 years of retirement to submit a succession plan as part of the application. Consideration could be given to requiring updates to succession planning to be included in the APRs. Succession planning should also be a key responsibility for funded institutions going forward rather than relying solely on grant holders to ensure it occurs. Institutions, in collaboration with grant holders, should be required to conduct strategic succession planning for each piece of equipment that they acquire through the NEP.

Institutions should appoint at least one secondary or co-grant holder whom the main grant holder can mentor and train to ensure the transfer of skills, in terms of using the equipment, in developing their capacity to secure future grant funding, and in developing a track record through publication. This pairing of researchers will also ensure that there is a ‘second in command’ should the grant holder become incapacitated in any way and could also help to support transformation in the institutions. The same principle can be used to ensure a future pipeline of skilled equipment operators and technicians. Further, retired grant holders and researchers can also be contracted where appropriate to develop the capacity of younger researchers by providing advanced training on specialised equipment or research methodologies.

R8: Align the NEP to DHET policy.

The DHET has classified universities in terms of their focus areas, resulting in some institutions being primarily focused on undergraduate training rather than research or postgraduate development. The DHET has also set institutional targets for the number of postgraduate student graduations expected. The NRF should align the NEP accordingly to ensure that grants are prioritised for research-intensive universities and those focused on postgraduate training. The NEP should also be aligned to DHET policy, particularly with regard to their capacity development objectives and well-founded labs.

R9: TIA, NIPMO, NRF, and TTOs should develop synergies towards increased research commercialisation.

The evaluation has highlighted that one of the main threats to the programme’s sustainability is the funding made available by National Treasury for the research infrastructure programme. Key to attaining this funding is the demonstration of tangible outputs that translate into socioeconomic development and the improvement of the lives of South Africans. This is dependent, in part, on the commercialisation of processes and products linked to the use of the equipment.

Some evidence of the commercialisation of research outputs was identified during the evaluation, such as the case study of the partnership between GrowSafe Pty Ltd and Vytelle to create a “Leader in Bovine Biotechnology”. However, it is suggested that more can be done in the area of commercialisation, which will further contribute to the sustainability of the equipment and the NEP more broadly. It is recommended that seeking out opportunities for the commercialisation of research products and systems be more clearly communicated as a requirement of the grant application process. Furthermore, closer collaboration should be pursued between the Technology Innovation Agency (TIA), the National Intellectual Property Management Office (NIPMO), the NRF and the Technology Transfer Offices (TTOs) at the individual institutions to drive the commercialisation of research undertaken using NEP-funded infrastructure.

R10: The DSI and NRF, in partnership with institutions, could explore opportunities to secure private investment from industry to co-fund the provision of RI.

Given the uncertainty around available funding for the NEP from Treasury, the DSI, NRF, and institutions could explore opportunities to secure investment from the private sector to fund the NEP. This could be done via co-funding of particular pieces of equipment at universities or science councils by the private sector, who in turn would gain access to the equipment and researchers to undertake research and development projects for their products or offerings. For example, industry could make an upfront investment in return for a set amount of hours of access to the equipment for the year, or a set amount of hours of researcher or operator time.

5.2 Operational recommendations

Application process

R11: Ensure that the timing and communication of grant calls is streamlined and communicated clearly, to allow for applicants to plan effectively.
A number of interviewees suggested that there was a lack of clarity and predictability in terms of when and how much funding would be made available under the NEP. It is understood, for example, that this issue arose one year due to the NRF receiving additional funding very close to the end of the financial year which they had to spend immediately, impacting on the awards that were made in two years' funding cycles. To overcome the uncertainty for grant applicants, it is recommended that the NRF engages with the DSI to highlight the importance of ensuring regular funding cycles for the NEP, including communicating the magnitude of funding that will be available each year. The frequency of funding and the amounts available should be clearly communicated through internet channels and direct engagements with potential grant applicants to enable effective planning by applicants.

A further confusion was identified in that grant holders suggested that the timing of grant proposals overlapped with particularly busy periods during the academic year (start or end of the academic year). This finding did not, however, overlap with the information received from NRF, which suggested that grant calls were announced each April. Once again, this appears to point to a communication issue, which suggests a need for the NRF to further engage with research offices at the universities to communicate the information appropriately, and ensure that websites are up to date with the correct information.

R12: The NRF should provide guidance and training for grant applicants to help them write their proposals and understand the post-award process.
The NRF could compile a guidance document detailing best practice and common pitfalls in applications, and a post-award guidance document for new grantees to ensure full understanding of the process. Grant proposal writing workshops could be offered to assist in proposal development, well in advance of the grant closing dates.

Reporting

R13: The NRF should streamline and enhance the annual progress report (APR) process.
Given that the NRF relies upon the APRs to assess grant holder progress and the outcomes of the programme, it is critical that a standardised reporting system is instituted to enable an evaluation of the programme outcomes and impact over time. The evaluation results suggest that the APR process can be improved, given that only around half of the survey respondents indicated that they were satisfied with the APR submission system and the elements covered in the APR.

Many grant holders indicated that they were uncertain about what information was required within each section of the APR as it does not provide guidance, and indeed a lack of standardisation in responses was observed when reviewing the 'research highlights' and 'impact' sections of APRs. The provision of sub-headings and additional guidance on what grant holders are required to report would help to standardise the information for analysis and reporting and for the evaluation of outputs and outcomes. This should be done in line with the Monitoring and Evaluation Framework that was developed as part of this evaluation, drawing on key reporting indicators and the Theory of Change. Grant holders should also be asked to provide photos and other evidence of their usage of and outputs stemming from the equipment as part of the APR. Further, a condition should be added to the funding contract making it compulsory for grant holders to participate in evaluations and other NEP-related research commissioned by the DSI or NRF to ensure good response rates.

In order to track the impact of the NEP more closely, the NRF should require grant applicants to align their proposals to the NRF Impact Framework, describing how their research using the funded equipment will address either knowledge or societal impact, or both. This should also form part of the proposal evaluation scorecard. In addition, impact indicators should be set and measured during the reporting cycles to inform any impact evaluations undertaken in the future.

A further recommendation with respect to the online APR system is that it should be linked to grant holder profiles to remove the repetition required in the forms (such as grant holder details, award details etc). Finally, the NRF should hold grant holders accountable with regard to what they had committed to do in their grant proposals to ensure that they continue work towards these outcomes. This could be achieved by comparing the actual outputs achieved in the APRs against those provided in the proposal.

Some grant holders were concerned about the length of time required to report on outputs, as progress reporting is meant to conclude within five years of the grant holder commissioning the equipment. However, for certain pieces of equipment, the collection of data only concludes after four or five years, which prevents grant holders from having outputs to report on since data collection has been ongoing over several years. A related issue is that it can take several years for certain pieces of equipment to be functional, for users to be trained in its use, and thus for research projects to be completed. This gap can be addressed by allowing, where relevant and appropriate, for an extended timeframe for annual reporting to ensure sufficient time for the completion of outputs and outcomes stemming from the funded equipment.

Evaluation summary

NEP FUNDING 2014/15-2019/20

R1 108 074 174

AMOUNT REQUESTED FROM NRF

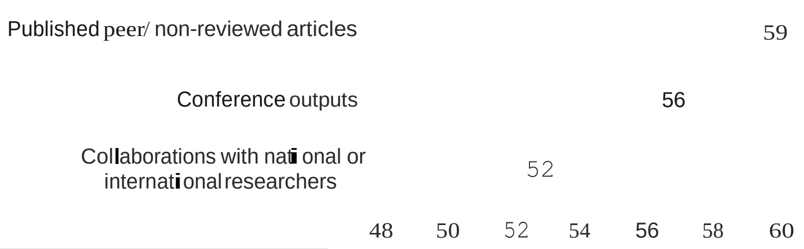
R1 055 746 709

VALUE OF GRANTS AWARDED

R572 510 581

There were 2 422 users over the period under revi %of all uses produced at least one research outputs using the equipmewtth most users having produced multiple outputs.

Top three Grant Holder feedback on outputs stemming from the use of the equipment



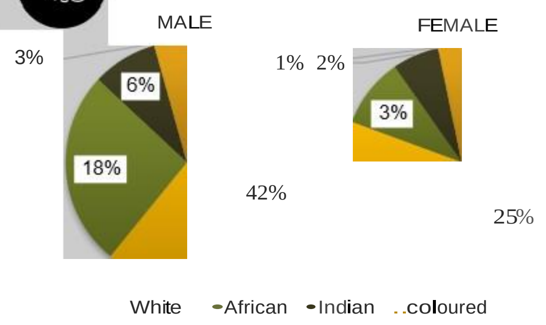
241

Total appl ications received

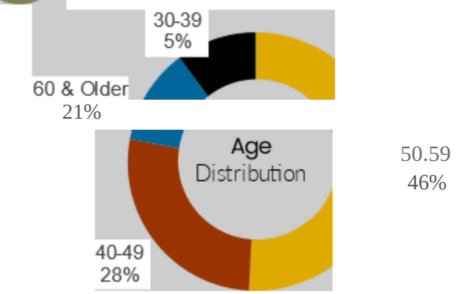
126

Total grants awarded

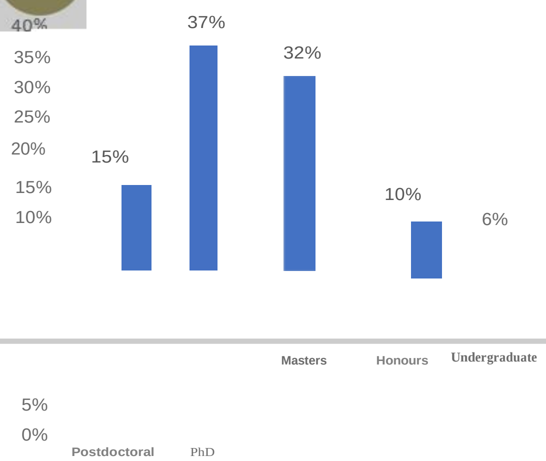
DEMOGRAPHIC PROFILE



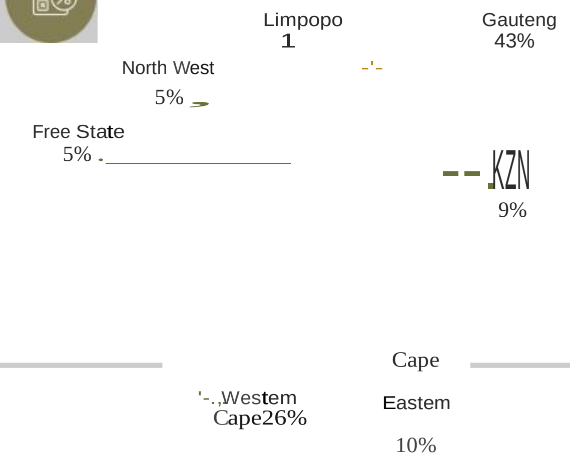
AGE DISTRIBUTION OF GRANT HOLDERS



LEVEL OF STUDENT USERS OF EQUIPMENT



PERCENTAGE OF GRANT VALUE AWARDED BY PROVINCE



1. INTRODUCTION

1.1 Background

Following South Africa's transition from an Apartheid government to a constitutional democracy, the number of people enrolled at tertiary education institutions rose substantially, high-quality research and development outcomes have expanded, and demographic equity has improved.[1] However despite these achievements, the nation's mission to eradicate poverty, stimulate job creation and generate wealth remains constrained, and the country's ability to develop new services, products, and technologies through research and innovation will make a contribution to further progress. Technological and scientific innovation can stimulate economic development, improve standards of living, and foster employment opportunities. Developing and retaining high-end scientific and technological learnings and competencies is key to transforming South Africa into a knowledge-based economy.[2]

State-of-the-art research infrastructure is a pre-requisite for developing internationally competitive knowledge and technologies; often, this development is associated with the emergence of a highly skilled labour force.[3] Research infrastructure (RI) includes "facilities, resources, and services used by the scientific community across all disciplines for conducting cutting-edge research for the generation, exchange, and preservation of knowledge. It includes major facilities, equipment or sets of instruments, collaborative networks, and knowledge-containing resources such as collections, archives, databanks, and biobanks. RI may be single-sited, distributed, or virtual."[4]

Only in an environment equipped with relevant and high-quality infrastructure can South African research begin to competitively generate new knowledge and technologies. World-class research infrastructure may involve major or specialised items of equipment required to bolster research outcomes and achievements. Research infrastructure of this nature often requires significant financial investment for acquisition, operation, and maintenance, and is usually too expensive for individual research institutions to afford without support. As such, funding for such infrastructure is critical to any national research system.[5]

Like other emerging economies, South Africa has struggled to achieve sustainable growth through the development of knowledge-based strategies. Against a background of high unemployment, slow social reform, financial bailouts, volatile exchange rates, and dampened economic growth, it became necessary to identify system drivers of innovation that society and government can control. These drivers stem from various sources, including knowledge management, knowledge generation, research, technology, and innovation (all of which fall under the ambit of the Department of Science and Innovation or DSI).[6] It was recognised that inadequate funding posed a significant challenge to more innovative research and development.

In recognition of both the gap in funding and the benefit of accessing cutting-edge infrastructure, the DSI allocated funds supporting research equipment through the National

[1] Department of Science and Technology, 2017.
[2] A "knowledge-based economy" describes trends of greater reliance on information, knowledge, and high-skill levels. This term also encompasses an increasing need for businesses and public sectors to access all of these in advanced economies - (OECD, 2020)
[3] National Research Foundation, 2020. Infrastructure Funding Instrument:National Equipment Programme (NEP) Framework and Funding Guide.
[4] Department of Science and Technology (DST). (2016). South African Research Infrastructure Roadmap: First edition. Pretoria, DST.
[5] Department of Science and Technology,2016. South African Research Infrastructure Roadmap: First edition. Pretoria, DST.
[6] Department of science and Technology, 2017. & National Research Foundation, 2020. Infrastructure Funding Instrument: National Equipment Programme (NEP) Framework and Funding Guide.

Key Research and Technology Infrastructure Strategy. These efforts enable the advancement of the national Research and Development (R&D) agenda through the establishment of the National Equipment Programme (NEP) in tandem with the National Nanotechnology Equipment Programme (NNEP).[5]

1.2 The National Equipment Programme

The National Equipment Programme (NEP) – which is funded by the DSI and implemented via the National Research Foundation (NRF) – allocates funds to research institutions through a competitive peer-review process to acquire, develop, and upgrade cutting-edge research equipment in the fields of Science, Engineering, and Technology (SET). While such equipment supports inter-disciplinary and multi-disciplinary research, it often requires substantial capital investment, specialised operators, and dedicated maintenance personnel.[7] Funding for the NEP instrument is made available under the Research and Development Infrastructures Platform contract offered by the DSI, and NEP applications are subject to the Medium-Term Expenditure Framework (MTEF) budget allocations.

Successful applicants who receive equipment funding enter into contracts with the NRF. The conditions of the grant stipulate that the host institution provides funding towards the purchase of equipment at a ratio of 2:1. Put differently, the NRF covers two-thirds of the total cost of acquisition of the equipment, with the total grant value falling between R1 million and R10 million. This includes VAT and a three-year maintenance plan. In addition to covering one-third of the acquisition cost, the recipient institution is to ensure that it can provide:

- appropriate building infrastructure to house the specialised equipment and ensure that the equipment may be fully commissioned within two years of the awarded grant.
- for a maintenance plan for a further two years.

The NEP grant awards are expected to yield returns on investment through the usage of the equipment. This is measured, firstly in terms of the number of resultant publications in the body of science and technology literature. These publications include those in books, book chapters, peer and non-peer reviewed articles and conference outputs, as well as patents and technical reports.[8] A further measure of return on investment is the upskilling of, access to, and usage of equipment by researchers, students, operators, technicians, and collaborators.[9] Finally, the return on investment is measured in terms of a financial model for the maintenance, upgrade, and other related operational costs for the equipment's sustainable management beyond the life of the grant.

1.3 Purpose of the evaluation

In 2021, the DSI commissioned DNA Economics to conduct an implementation and impact evaluation of the National Equipment Programme (NEP) for the period spanning 2014/15 to 2019/20[10] (six financial years) to assess:

1. Whether the programme was implemented as envisioned;
2. Whether and how the effectiveness and efficiency of the NEP can be improved;
3. The outputs of the programme by the scientific sectors funded by the NEP; and
4. The impact of the programme relative to its initial goals and objectives.

[7] *(NRF, 2011; NRF, 2020)*
[8] *(NRF, 2020; DSI, 2021)*
[9] *(NRF, 2020)*
[10] *Though no funding was disbursed in 2017*

1.4 Evaluation questions

The key evaluation questions used to guide this study are provided in the table below. More detail about the evaluation questions is provided in Annexure 1.

Table 1: Evaluation questions

Primary questions	**Criteria**
1. To what extent has the design of the NEP enabled the achievement of its intended objectives?	Relevance Theory of Change
2. To what extent has the design of the NEP enabled the achievement of its intended objectives?	State of implementation
3. How effective has the NEP been in achieving its objectives?	Effectiveness
4. Has the implementation of the NEP been efficient? How well were resources used in the programme?	Efficiency
5. What difference is the NEP making? What has the impact of the programme been?	Signs of change Impact
6. Will the benefits of the NEP last or how can they be sustained?	Sustainability

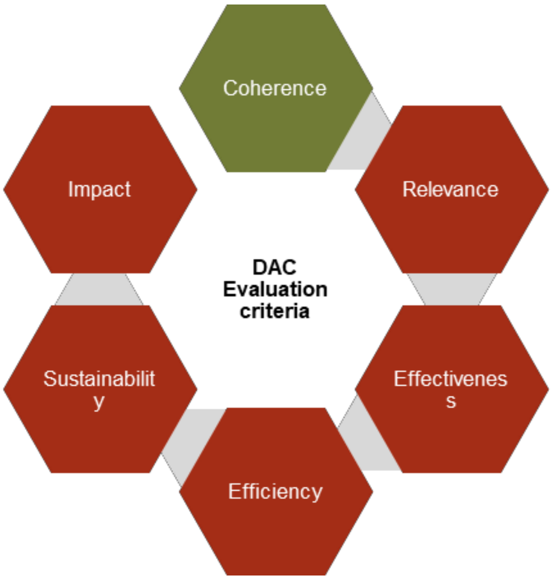
2. METHODOLOGY

The methodology used in the evaluation is described in terms of the evaluation framework applied, the evaluation methods, the limitations encountered, and the activities undertaken to support capacity development at the DSI.

2.1 Evaluation framework

The implementation and impact evaluation was designed to address five of the six evaluation criteria specified by OECD's Development Assistance Committee (DAC)[11], as presented in Figure 1 below (with the criteria covered by the evaluation denoted by the red blocks).

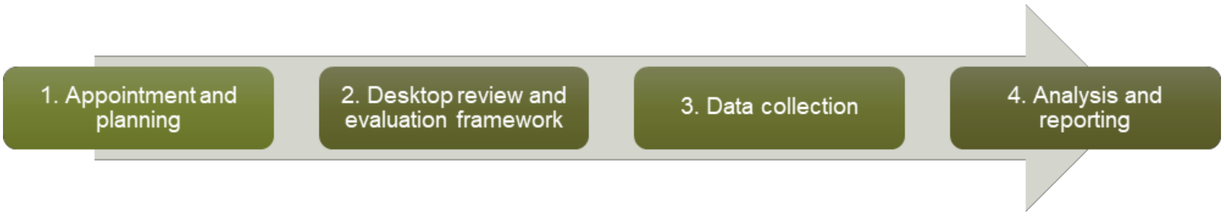
Figure 1: DAC Evaluation Criteria



2.2 Evaluation methods

To achieve the objectives and respond to the evaluation questions above, the study adopted a four-phase research methodology, with each stage consisting of multiple tasks and activities.

Figure 2: Evaluation phases



Phase 1: Appointment and planning

Evaluation and planning workshop

An inception meeting was held between the Evaluation Steering Committee (ESC) and DNA Economics on 24 June 2021 to scope the project. The objective of the meeting was to ensure a solid foundation and mutual understanding of the plan for this evaluation. DNA

[11] *OECD DAC Network on Development Evaluation. (2020). Better Criteria for Better Evaluation: Revised and Updated Evaluation Criteria.*

Economics prepared an inception report in response to the feedback received during the meeting on the initial project proposal. The report summarised the revised approach and methodology for the evaluation and responded to the verbal and written comments received from the ESC.

Phase 2: Desktop review and evaluation framework

A literature review was undertaken at the start of the project to understand the literature underpinning the design of the NEP, namely research infrastructure at higher learning and research institutions, its impact on research output, economic growth, human capital development and training, and the potential for local and international collaborations. This was followed by a comprehensive review of programme documentation to understand the programme's purpose, design, and performance, and included a review of strategic documents, funding application databases, annual progress reports, previous evaluation reports, and grant holder databases, among others. A benchmarking exercise of similar local and international research infrastructure programmes was also conducted, guided by a set of questions that were agreed upon during project inception. A workshop was then held with key programme stakeholders to develop a programme Theory of Change. The review process informed the development of an evaluation framework that guided the study and the development of the data collection tools.

Phase 3: Data collection

A summary of the data collection is provided by method below, with more detail about the sampling provided in Annexure 3.

Key informant interviews

Key informant interviews were conducted with small groups of stakeholders from the DSI and NRF using semi-structured interview guides to understand the design, objectives, and institutional arrangements for administering the NEP, as well as to obtain feedback on the implementation successes and challenges. A stakeholder matrix indicating the persons to be interviewed from each organisation was shared with the ESC for approval and sign off. A total of 6 programme stakeholders were targeted for the interviews although 9 were ultimately reached (150%). The interviews were conducted virtually in small groups of 2-4 participants each.

Digital survey among grant holders

An online survey was conducted among successful grant awardees for the period under review to assess their experiences around: the NEP application process, commissioning the equipment, grant reporting, and challenges with the process. Of the 120 grant holders targeted for the survey, 67 participated (56%). The grant holders were also asked to provide the contact details of up to 5 equipment users for further engagement. It is likely that the response rate was affected by the time of the year during which the survey was run (November to January), when several grant holders were either on extended leave or had several other deadlines, including the annual reporting and an opening of the NRF ratings call.

Digital survey among equipment users

An online survey was also conducted among the equipment users, identified by the grant holders above, to assess their experiences of using the equipment, training received, the outputs achieved, and broader satisfaction and challenges with regard to the equipment. Of the 179 equipment users invited to the survey, 99 responded (55%).

Grant holder interviews

Semi-structured interviews were conducted among a sample of grant holders to assess their experiences with the NEP, the costs and benefits of participation in the NEP for their institution (including any unintended consequences), the challenges, emerging successes, outcomes, impacts, and recommendations for programme improvement. The interviews also probed whether the funded equipment was leveraged for additional grants, as well as the measures in place to sustain the equipment post the NEP. All 24 grant holders sampled for the interviews were reached (100%). Due to their unavailability, 7 grant holders that were initially selected into the sample had to be replaced with other grant holders awarded grants of a similar value in order to ensure a meaningful sample size.

Interviews with Deputy Vice Chancellors and Research Officers

Semi-structured interviews were conducted with university management teams, namely Deputy Vice Chancellors and Directors involved in research development at the selected institutions. The interviews focused on the costs and benefits of the NEP relative to other grants administered by the university, the efficiency and effectiveness of the relationships between the institution and the NRF and DSI, how the programme has affected the pool of skilled operators, technicians, and engineers, whether the equipment has been leveraged for additional grants, and the measures put in place to sustain the equipment post the NEP. Although a target of 7 interviewees was initially set, a total of 11 people were engaged, due to research officers being included in the DVC interviews (160%).[12]

Site visits

The evaluation team conducted site visits to 7 institutions across 6 provinces to view the equipment and observe its management and use. The arrangement of site visits was delayed by grant holder non-response as well as student protests at some of the university campuses. One of the sites initially selected into the sample had to be replaced with another site as the equipment was out in the field and therefore not at the institution. However, all of the site visits were completed despite the challenges experienced.

Interviews with equipment technicians and operators

During the site visits, the evaluation team interviewed a total of 3 non-grant holding equipment operators and technicians that were on site at the time. Since some grant holders were also responsible for the operation of the equipment, there was some overlap between this grouping and the grant holder surveys conducted above.

Focus group discussions with equipment users

The evaluation team had planned to conduct focus groups with equipment users from 4 institutions. Given challenges around grant holder non-response, student protests, as well as a lack of response from the equipment users themselves, only one focus group discussion was completed (25%).

Despite the challenges mentioned above, a relatively high response rate was achieved for the study with rich data collected across the various methods. The demographic profile of the online survey participants is provided in Figure 3 and Figure 4 below.

A total of 67 grant holders responded to the survey (56%). The majority of the respondents to the grant holder survey were male (73%), White (63%), and based at the universities that had received the greatest proportion of NEP funding.

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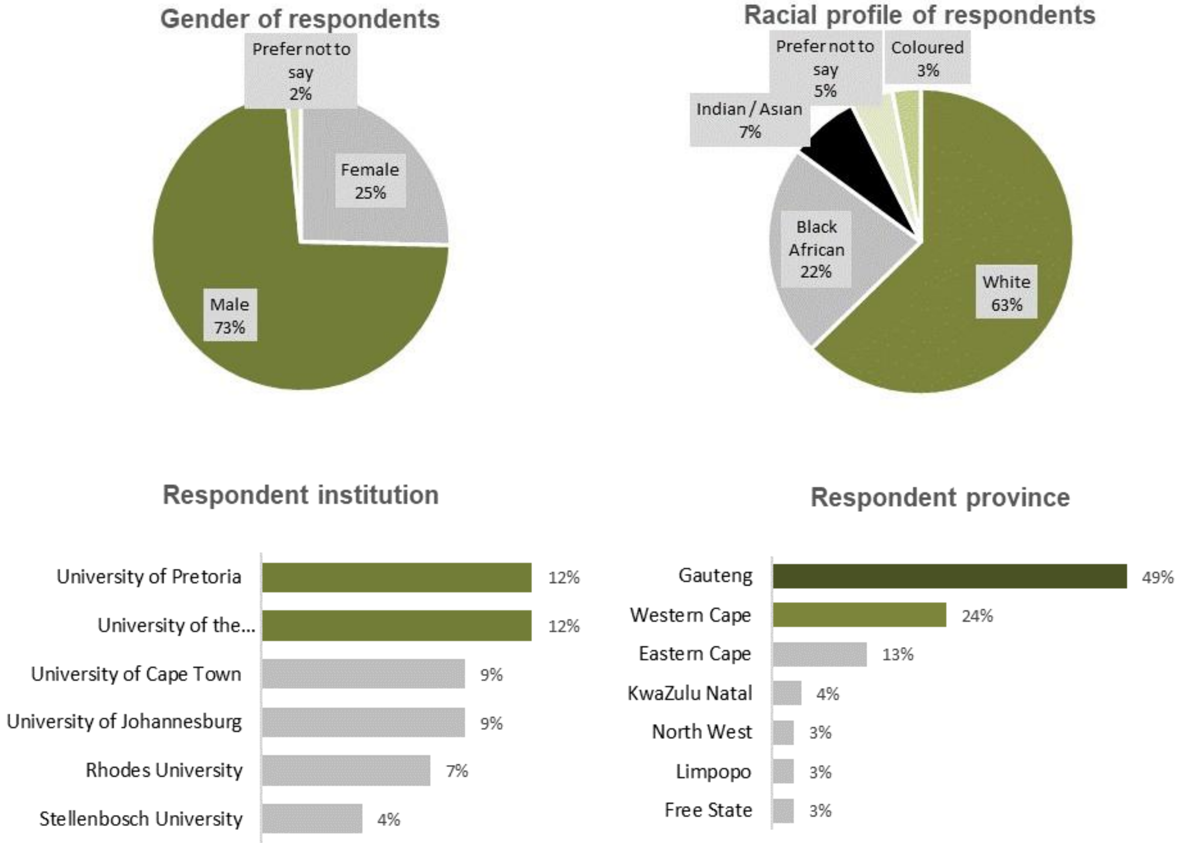
[12] *Research Officers were included in the interviews with DVCs, resulting in more respondents reached than what was initially planned.*

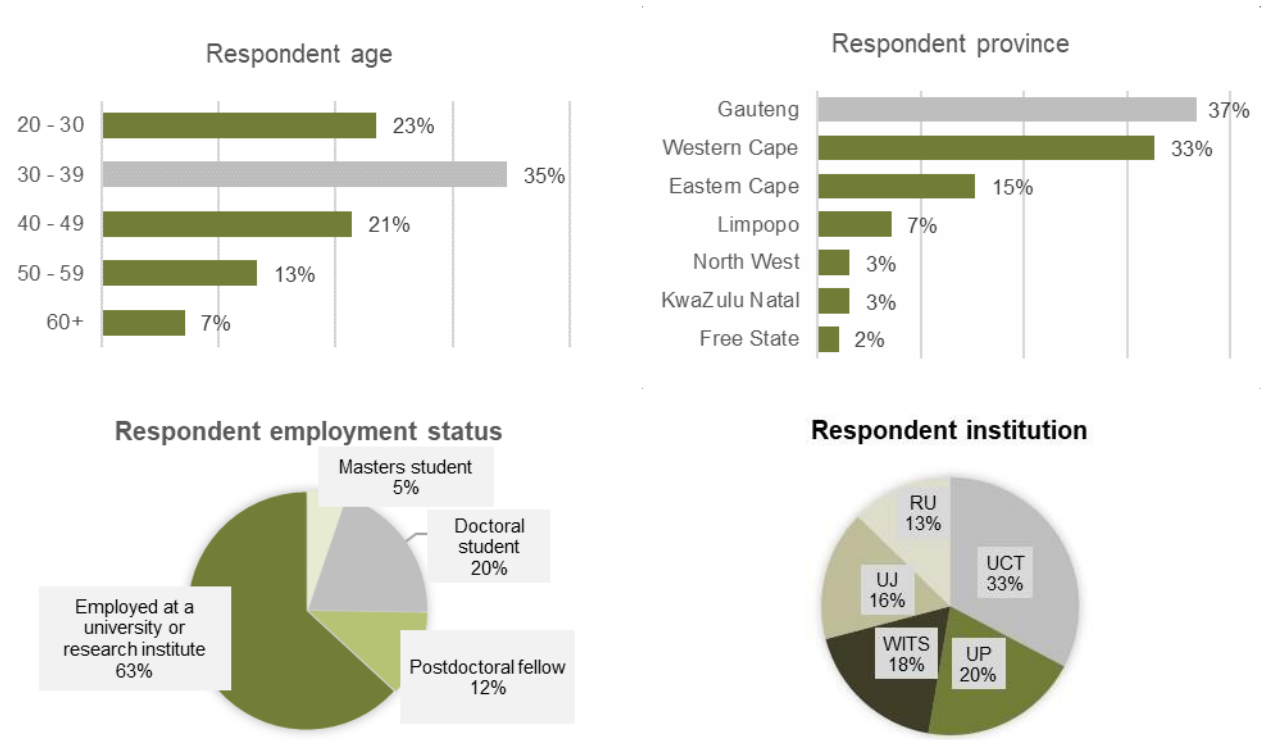
Figure 3: Survey respondents – Grant holder digital survey



Source: NEP Evaluation 2022: Grant holder digital survey
n=67

With regard to the equipment user survey, slightly more female (52%) than male users responded, with almost half of the respondents being either Black / African (42%) or White (40%). The respondents were 40 years old on average and mostly resided in Gauteng (37%) or the Western Cape (33%). More than half were employed at a university or research institute (63%), with a third (33%) being from UCT.

Figure 4: Survey respondents – Equipment user digital survey



Source: NEP Evaluation 2022: Equipment user digital survey
n=99

Phase 4: Data analysis reporting

An inductive thematic analysis approach was undertaken to analyse the qualitative data collected during the interviews and focus group discussion. Recordings from these discussions were transcribed and analysed thematically based on the evaluation themes. Follow-up calls were had with grant holders and other respondents where additional clarity was needed. The quantitative data collected via the digital surveys was cleaned and analysed descriptively using Excel. Further, the outputs reported in the APRs were captured into an Excel database and analysed descriptively.

2.3 Limitations to the evaluation

The timing of data collection for the evaluation coincided with the December holiday period and the start of the academic year, which may have affected the response rate of the grant holders in the survey. Fewer focus groups were conducted with equipment users than had been planned given the Covid-19 restrictions and other challenges experienced in recruiting participants. In addition, while it would have been useful for the evaluation team to speak to some of the unsuccessful NEP grant applicants, they were unresponsive to requests for a meeting despite several attempts. Finally, the evaluation relies on the grant holders' reports of the outputs achieved in the APRs, particularly around user training, as these were not independently verifiable.

2.4 Capacity development

A monitoring and evaluation intern from the DSI was appointed to the evaluation team to contribute to capacity development in the area of monitoring and evaluation. Several challenges were noted around his involvement. The intern often had connectivity problems and was not able to participate fully in the virtual team meetings. Further, the intern did not have much knowledge of monitoring and evaluation, such that it was difficult to find ways for him to contribute meaningfully to the study. In addition, given confidentiality concerns, the intern was not able to join the interviews held with grant holders as having a DSI-affiliated stakeholder in the room violated the guarantee of confidentiality with regard to the feedback provided by the respondents.

Despite these challenges, the intern was able to contribute to the data collection process by identifying key stakeholders from the DSI and NRF to be engaged. He also contributed to the compilation of the literature review. In order to optimise the capacity development element in future projects, it is recommended that interns be appointed to undertake discrete pieces of work during the life of the project, based on their qualifications and areas of interest.

3. LITERATURE REVIEW

This section provides a brief overview of the policies underpinning the development of the NEP, followed by a review of the literature regarding research infrastructure at higher learning and research institutions, its impact on research output, economic growth, human capital development and training, and the potential for local and international collaborations. The section concludes with an overview of the higher education landscape in South Africa and the role of the NRF in developing the science and research fields in South Africa.

3.1 Brief policy review

South Africa's political transition to democracy projected the country into the global arena, resulting in a requirement for innovative planning and monitoring to address pressures and challenges brought about by global market forces and ever-evolving information and communication technologies. The increased flow of information has transformed many of the world's societies into knowledge-based economies where international competitiveness depends upon their ability to maximise the creation and use of knowledge and technological advancements. In order for South Africa to both integrate into global systems while still addressing local needs, the new government adopted a number of policies and strategies. This section provides an overview of key policies that inform national priorities around research development and the provision of research infrastructure.

3.1.1 The White Paper on Science and Technology (1996)

The 1996 White Paper on Science and Technology[13] defined a vision for how science and technology (S&T) could be used to support the development of the country and its citizens within a national system of innovation (NSI).[14] It focused on enhancing global competitiveness and addressing the needs of citizens towards ultimately:

- Promoting competitiveness and employment creation;
- Enhancing quality of life;
- Developing human resources;
- Working towards environmental sustainability; and
- Promoting an information society.

The White Paper introduced the term 'science and technology infrastructure' which refers collectively to national research facilities (including universities and science councils), libraries, regulatory frameworks, and physical structures such as telecommunications networks, and is focused specifically on the need for highly specialised infrastructural platforms at national facilities to undertake cutting edge scientific research. The White Paper also made provision for a mechanism to be introduced to support the purchase and maintenance of expensive research equipment provided that:

- It was made accessible to the wider research community, with a specific focus on researchers from historically disadvantaged institutions;
- It was placed at institutions with high achieving researchers in a specific discipline, which would allow for advancement; and
- The institution would co-invest in the procurement or development of research equipment.

[13] *Department of Arts, Culture, Science and Technology. (1996). White Paper on Science & Technology. Pretoria, DACST.*
[14] *The 'national system of innovation' refers to the country's collective efforts towards fostering technological innovation.*

3.1.2 The National Research and Development Strategy (2002)

A National Research and Development Strategy (NRDS) for South Africa was then published in 2002, which outlined national goals for economic development and the improvement of quality of life for all citizens. The NRDS operates within the context of the White Paper and aimed to strengthen key elements of the NSI that were identified as requiring specific attention and focus.

The NRDS focused on three pillars, namely: innovation; science, engineering, and technology (with a focus on transformation and human resource development); and creating an effective national science and technology system. It articulates country priorities for: technology missions, intended to meet national and social objectives around poverty reduction and to promote advanced manufacturing, resource-based industries, and new technologies; and science missions, indicating where South Africa could contribute to global knowledge, including areas in which the country has a geographic advantage and where it acquired a knowledge advantage.[15] The strategy notes the need to develop the human capital base in the country by providing scientific equipment to train students, provide an enabling environment for scientists and researchers to conduct high quality research, and to strengthen international science and technology networks. The NRDS also highlights the existence of an "innovation chasm" in South Africa, which speaks to a failure to convert innovations within the science and technology system into new products and services for the marketplace.

3.1.3 The Ten-Year Innovation Plan (2008)

The DST's (now DSI) Ten-Year Innovation Plan, published in 2008, builds on previous efforts by the department in helping to "drive South Africa's transformation towards a knowledge-based economy, in which the production and dissemination of knowledge leads to economic benefits and enriches all fields of human endeavour."[16] The plan follows on from government's wider mandate to accelerate and sustain economic growth and builds upon the NSI. It identifies the key challenges and gaps in transforming South Africa into a knowledge-driven economy, which include a failure to commercialise the results of scientific research and the inadequate production of knowledge workers skilled in building a globally competitive economy. The plan identifies four elements required to drive progress towards a knowledge-based economy, namely:

- Human capital development;
- Knowledge generation and exploitation;
- Knowledge infrastructure; and
- Enablers to address the "innovation chasm" between research results and socioeconomic outcomes.

It also identifies five areas (termed 'grand challenges') of strategic importance for innovation, namely: the "Farmer to Pharma" value chain to strengthen the bioeconomy; global space science and technology; energy security and the development of clean energy; climate change science; and "human and social dynamics". The plan notes the need for state-of-the-art infrastructure, modern laboratories and research institutions, and a NSI that is linked to the global scientific community in order to meet its goals.

With regard to research infrastructure, the plan emphasises the need for life cycle planning for research and development (R&D) infrastructure, including depreciation, skills needs and running costs, as well as strengthening the country's infrastructure development through international partnerships to make it a preferred destination for S&T investment

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[15] Department of Science and Technology (DST). (2002). National research and development strategy. Pretoria, DST.
[16] Department of Science and Technology (DST). (2008). Ten-Year Innovation Plan for South Africa (2008-2018). Pretoria, DST.

3.1.4 The Research, Development, and Innovation Infrastructure Funding Framework (2010)

The DST's Research, Development, and Innovation Infrastructure Framework, published in 2010, identified five priority investment areas, namely: scientific equipment, high-end infrastructure, specialised facilities, access to global infrastructures, and cyber infrastructure.[17] A number of aspects critical to these areas of investment were identified, including the need for skilled operators, technicians, and engineers to optimally utilise and maintain cutting edge research equipment; the access to and management of large datasets that are produced or collected from the use of the research equipment; and the need to re- use or exploit this data to enable the exploration or other areas or fields of study.

3.1.5 The National Development Plan (2012)

The National Development Plan (NDP) was launched by the National Planning Commission in 2012 with a vision to reduce inequality and eliminate poverty in South Africa by 2030.[18] The Plan identifies science, technology, and innovation as a primary driver of economic growth and socioeconomic reform and emphasises the need for government, universities, and the private sector to work together in translating basic research into commercially viable products, services, and processes. The NDP highlights the need for more investment in R&D and notes the critical role of research infrastructure in enabling innovation. It also calls for collaboration between government and the private sector to raise the level of R&D and in building research infrastructure required by a modern economy.

The NDP is aligned with the Sustainable Development Goals (SDGs) and the African Union (AU) Agenda 2063 and is integrated into planning systems and processes of the government at national, provincial, and local level. According to the NDP, "Developments in science and technology are fundamentally altering the way people live, connect, communicate, and transact, with profound effects on economic development. Science and technology are key to development, because technological and scientific revolutions underpin economic advances, improvements in health systems, education and infrastructure."[19] The NDP further notes that:

- Science and technology are key to improving the lives of poor people in countries that are still in the development stage;
- Technology has the potential of increasing productivity and unlocking access to affordable healthcare and education; and
- Challenges around technological revolutions need to be managed, for instance, early and extensive technology access by the wealthy has the potential for worsening inequality in the country.

To support technological advancements, the NDP highlights that developing countries must invest in high-quality education for youth, ongoing skills training for workers and management, and ensure that knowledge is disseminated widely across society

3.1.6 The South African Research Infrastructure Roadmap (2016)

The South African Research Infrastructure Roadmap (SARIR), published in 2016, provides guidance to the DSI on the strategic development, acquisition, and deployment of research infrastructure (RI) to enable research, development, and innovation in the country. The Roadmap provides strategic guidance on providing RI across the entire public research system, building on existing strengths and capabilities, and mapping future needs. It recommends that investment is made in 13 key areas across five scientific domains. The 13

[17] Department of Science and Technology (DST). (2010). Research, development and innovation funding framework. Pretoria, DST.
[18] National Planning Commission. (2012). National development plan. Pretoria, NPC.
[19] National Planning Commission (2012) National Development Plan. Pretoria: NPC

areas were selected based on their strategic importance for South Africa, local and global impact, scope and range of science, potential for success, maturity and state of readiness, and policy, and are provided in the table below.[20]

Table 2: The 13 areas and scientific domains identified for funding in the SARIR

Scientific domain	Identified research infrastructure
Humans and society	• South African network of health and demographic surveillance sites • National centre for digital language resources
Health, biological, and food security	• Distributed platform for "omics" research • Biobanks • Nuclear medicine research facility
Earth and environment	• South African marine and Antarctic research facility • Biogeochemistry research infrastructure platform • Expanded national terrestrial environmental observation network • Shallow marine and coastal research infrastructure • Natural sciences collection facility
Materials and manufacturing	• Nano-micro manufacturing facility • Materials characterisation facility
Energy	• Solar research facility

Source: The South African Research Infrastructure Roadmap, DST

3.1.7. The White Paper on Science and Technology (2019)

The 2019 White Paper on Science and Technology builds on successes and lessons learnt since the adoption of the previous White Paper in 1996. An extensive review of the NSI indicated substantial progress in many areas. Key achievements include a threefold increase in the number of publications within South Africa, significant growth in the participation of Black people and women in the R&D workforce, and a rise in doctoral graduation rates. However, South Africa has not yet fully benefitted from the potential of science, technology, and innovation (STI) to advance the objectives of the NDP; the NSI is still not fully inclusive, and the country's innovation performance in terms of patents and products has been relatively flat. The world has also changed significantly from the previous White Paper, having become more technologically advanced, thereby requiring a new policy approach.[21]

The main factors inhibiting the performance of the NSI that were identified include: insufficient policy coherence and coordination, weak partnerships between NSI role players particularly business and civil society, inadequate and non-collaborative means of setting the STI agenda for the country, inadequate high-level science, engineering and technology and technical skills for the economy, inadequate monitoring and evaluation, an undersized research system, significant levels of underfunding, and a poor environment for innovation. The new White Paper lays out the long-term policy approach of the STI sector and identifies the Fourth Industrial Revolution as a key focus. It places STI at the centre of South Africa's economic development agenda to overcome the legacy of apartheid and is aimed at:

- Increasing the focus on inclusivity, transformation, and linkages in the NSI;
- Enhancing the innovation culture in society and government;
- Improving policy coherence and budget coordination across government;
- Enabling an environment for the support of social and grassroot innovation;
- Expanding and transforming the research enterprise;
- Expanding and transforming human capabilities; and
- Increasing STI investments.

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[20] *Department of Science and Technology (DST). (2016). South African Research Infrastructure Roadmap. Pretoria, DST.*
[21] *Department of Science and Technology. (2019). White Paper on Science, Technology, and Innovation. Pretoria, DSI.*

The policy aims to help local researchers to collaborate and compete with foreign counterparts, while mitigating ethical and environmental concerns. In order to "realise the intended impacts of STI in terms of sustainable and inclusive development (as envisaged in the SDGs and the NDP), progress will be measured in inputs (for example, investment in STI), outputs (increases in graduates, publications, and patents) and outcomes (improved partnerships between NSI actors and increased policy coherence, yielding improved innovation performance)".

3.1.8 Science, Technology, and Innovation Decadal Plan (Draft)

The Science, Technology, and Innovation Decadal Plan, which was in draft format at the time of this report, has been developed by the DSI to implement the vision of the 2019 White Paper on Science and Technology. The Decadal Plan provides a projection for the next decade regarding where South Africa's NSI should be. It aims to increase the positive impact of the NSI on South Africa's socioeconomic and environmental priorities, and to maintain the balance between a focus on impact and the continued investment and development of the NSI. The Decadal Plan identifies three Societal Grand Challenges, namely climate change, future-proofing education and skills, and the future of society. It also identifies several STI initiatives to which the NSI can contribute in order to transform human resources and research systems and to deepen international collaboration, namely: sector modernisation particularly in agriculture, mining and manufacturing, health innovation, energy innovation, innovation in support of socioeconomic progress, and an innovation-enabled capable state. The key enablers to addressing these challenges include human resources, international collaboration, infrastructure, and investment. The Plan also sets out a monitoring and evaluation framework listing indicators that will be used to measure the progress realised as a result of the proposed initiatives. The Plan is framed within an inclusive innovation approach, in which all citizens can share in the benefits created by the NSI. The Plan also proposes new a new Strategic Management Model, budget coordination, and an Innovation Compact.

3.2 Investing in research, development, and innovation

3.2.1 Research infrastructure

Despite the importance of RI in achieving the vision set out in the White Paper, several challenges exist around its provision, identified therein, namely:

- A lack of long-term planning by institutions to meet the high demand for research and laboratory equipment.
- Inadequate funding to upgrade and replace old RI, lack of national accredited health (preclinical) research facilities, and the need to improve the overarching governance of distributed RI.
- Inadequate specialised skills related to RI, for example, for maintenance.
- Inadequate coordination across institutions in providing data-intensive RI, and lack of digitisation facilities.
- The challenges and gaps arising from the emerging imperatives for a competitive NSI, including a lack of capability to exploit the convergence of ICT fully.
- Insufficient access to RI for grassroots innovators.
- Inadequate provision of RI to support social research.
- The significant costs associated with innovation infrastructure and the lack of fully developed financial decision-making systems, and partnership and financing models related to such infrastructure.

3.2.2 RI and research output

Ongoing developments in STI rely heavily on state-of-the-art RI, which is put in place to enable universities and research institutions to conduct advanced and globally competitive scientific research. Evidence demonstrates that investments in RI have a positive impact on both the quality and quantity of research outputs.[4] Many governments have recognised the benefits associated with Research and Development (R&D) and have committed to increasing gross domestic expenditure on these activities, establishing policies to enact such commitments.[22]

National expenditure on research and development (R&D) has become a key aspect of infrastructure development in Africa, predominantly via universities and public research institutions. Having said that, to date, investment in scientific and technological infrastructure has been very limited in Africa, which has led countries on the continent to fall behind in terms of global research and technology advancements.

Access to RI also enables the training of skilled personnel in both the public and private sector, in addition to the generation and application of knowledge. Teng-Zeng (2015) notes that the poor state of RI in many universities and technical institutes across Africa hamper training and research, while compromising research quality. While the number of scientific publications in Africa has increased in recent years, there are concerns about the quality of these publications. The lack of research capacity is one of the reasons for reduced research output and quality identified in the literature.[23]

While many developing countries are striving to build their research capacity in an effort to understand their needs and goals to solve their fundamental problems, the opportunity for research education and training remains low. Memon argues that in order to improve the research being produced in developing nations, education ministries should work on building such capacity among students.[24]

In South Africa, the policy and strategic documents described above were developed with the objective of proposing interventions for improving the capacity to undertake competitive research and training by investing in human capital development and the procurement and upgrade of RI. The NRF measures the performance against the objectives by measuring both financial indicators (e.g. financial spend of grants awarded to grant recipients) and non-financial indicators (human capital development and research outputs).[25,26]

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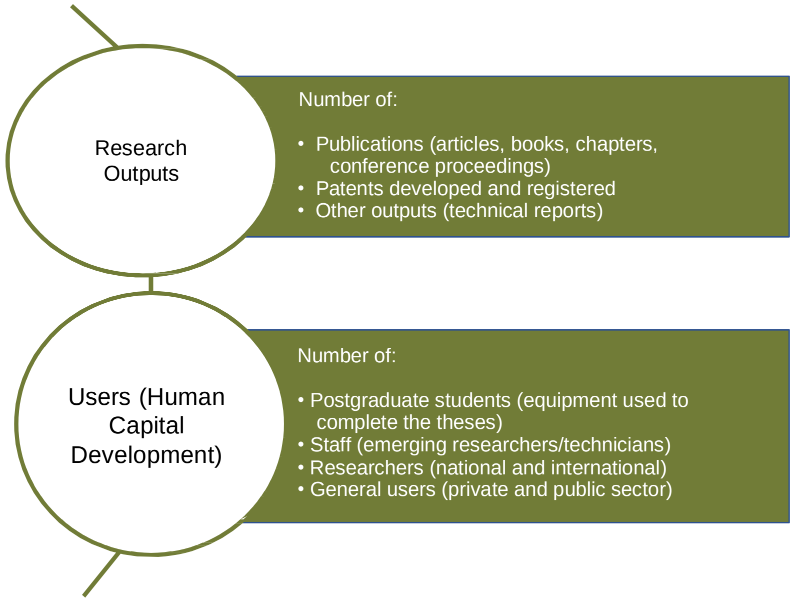
[22] *Teng-Zeng, F. K. (2015). Research infrastructure and innovation system in Africa: Enhancing higher education sector research. Stellenbosch Centre for Research on Science and Technology Retrieved from www.researchgate.net/publication/242274888*

[23] *Rahman, M. M., Ghoshal, U. C., Ragunath, K., Jenkins, G., Rahman, M., Edwards, C., . . . Taylor-Robinson, S. D. (2020). Biomedical research in developing countries: Opportunities, methods, and challenges. Indian Journal of Gastroenterology, 39(3):292–302.*

[24] *Memon, G. R. (2007). Education in Pakistan: The Key Issues, Problems and The new challenges. Journal of Management and Social Science, 47-55.*

[25] *Ramoutar-Priesch, R., & Hachigonta, S. (2020). Management of Research Infrastructures: A South African Funding Perspective. Springer: Switzerland.*

[26] *National Research Foundation. (2018b). Infrastructure funding instrument: National equipment programme framework and funding guide.*



Source: Infrastructure Funding Instrument: National Equipment Programme (NEP)

3.2.3 Research output and economic growth

There is a large body of literature examining the linkage between a country's research output and economic productivity. Using indicators such as the number of journal articles published, the number of journal articles per capita, total number of citations, and the number of citations per journal, research has shown evidence of a relationship between research output and economic growth for some nations.[27] However, not every country exhibits a strong positive correlation between research output and economic growth. There was a mutual causal relationship in South Korea, Singapore, Taiwan, and Japan. While research output is a causal factor for economic growth in Australia, Germany and the Netherlands, economic activity affects research production in Spain, Israel, Norway, and the USA.[27]

In contrast, results from BRICS countries (i.e. Brazil, Russia, India, China, and South Africa) show no causality in any direction between research papers as a share of world economic growth, except for India. Hence, although the BRICS countries present certain similar characteristics and ideas of improving the global economic situation, their policies regarding the investment on R&D activities should not be homogeneous.[28]

"Each country has its own particular research strength, there are also ways in which investing in particular scientific disciplines can help improve the economy. Countries that are exporting natural resources can import technology and expertise, but only until these resources are exhausted. For them, sustainability should imply investment in alternative agricultural and technological capabilities through improvements in their skills base. The

[27] *Lee, L.-C., Lin, P.-H., Chuang, Y.-W., & Le, Y.-Y. (2011). Research output and economic productivity: a granger causality test. Scientometrics, 89:465–478.*

[28] *Inglesi-Lotz, R., Chang, T., & Gupta, R. (2013). Causality between Research Output and Economic Growth in BRICS countries. Forthcoming*

cycles of poverty and dependence will only be broken by capacity-building between nations of high and low science intensity, often characterized as the North and the South".[29]

Whether research output significantly impacts economic growth, and which research field of science matters the most to improve the economic performance, are fundamental questions of scientific inquiry.[30] The impact of research output on economic growth occurs mainly through structural change processes involving the reallocation of resources towards the industrial sector.[31] The impact of research output on economic growth needs to be determined for specific research areas; countries can then identify and invest in areas of scientific research in which they may excel. In most cases, the global impact of research output is particularly high in the fields of engineering and technology, social science, and physics.

New and more advanced knowledge created through scientific research and reflected in research publications is likely to provide a country with numerous advantages with regards to its innovation, development, and economic growth. Moreover, the volume of research activities shows the capabilities of a country's labour force, and the attractiveness of its economy in terms of foreign and domestic investment.[32] Therefore, investing in advanced RI does not only improve the quality of research output, and the number of papers published; if the nation has at its disposal the required human capital that can generate new knowledge and technologies through research, it can attract foreign direct investment and increase economic growth.

3.2.4 Impact of RI on human capital

Human capital is defined as the economic value of workers' experience and skills, including education, training, intelligence, health, and other things that employers find valuable. Countries and organizations are forced to seek new ways to maintain a competitive advantage due to technological evolution, the knowledge-based economy, and globalization. In this context, human capital refers to scientific and technical (S&T) human capital, which includes human capital endowment, formal education and training, and social relations and networking that binds scientists and the users of science together for collective knowledge value.[33] S&T human capital is thus the unique set of inherent capabilities the individual brings to his or her own work as well as to collaborative efforts.

By investing in human capital, industries can also receive a greater return on investment from new technologies and process innovations, as employees are better equipped to absorb and utilize both the codified and tacit knowledge through which the benefits of such investments are largely delivered.[34] In the modern economy, human capital is an important factor for national economic growth. Education is key to poverty reduction as it ensures the supply of human capital, which is paramount to sustained economic growth. In the physical and life sciences, where the basic RI is the laboratory, the path to human capital

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[29] King, D. A. (2004). The scientific impact of nations: What different countries get for their research spending. Nature, 430, 311–316.
[30] Pinto, T., & Teixeira, A. A. (2020). The impact of research output on economic growth by fields of science: a dynamic panel data analysis, 1980-2016. Scientometrics, 123:945–978.
[31] Jeong, S., Choi, J., & Kim, J.-Y. (2013). On the drivers of international collaboration: The impact of informal communication, motivation, and research resources. Science and Public policy, 520-531.
[32] Kumar, R. R., Stauvermann, P. J., & Pate, A. (2016). Exploring the link between research and economic growth: an empirical study of China and USA. Qual Quant, 50:1073–1091
[33] Bozeman, B., & Corley, E. (2004). Scientists' collaboration strategies: implications for scientific and technical human capital. Research policy, 599–616.
[34] Rastogi, C., & Gaikwad, S. M. (2017). A Study on Determinants of human development capital in BRICS Nations. FIIB Business Review.

development entails undergraduate and graduate training in science, with increasing specialization and original research graduate programmes.[35]

Universities have to prepare quality graduates that are able to find employment in R&D and adequately trained to perform research both individually and as part of a collaborative.[36] Studies focused on strategies that involve mentoring graduates, students, and junior faculty researchers, have found that those who pursue a "mentor" collaboration are more likely to be tenured.[20] People are increasingly being recognised as assets, and companies can improve human capital by investing in their employees' education, experience, and abilities, which can in turn accelerate company performance and the economy as a whole.

Human capital also plays an extremely important role in the growth and development of a country, and the impact of human capital of economic growth has attracted the attention of a wide range of influential people, including academics, researchers, politicians, and economists. While human capital is an intangible asset, which makes it difficult to measure, a number of methods have been used in trying to quantify it. In a study of human capital investment by Small-medium enterprises (SMEs), it was found that investments in employee human capital are critical for labour productivity. Human capital investment is also crucial for companies that want to globalise, particularly when it is efficiently calibrated with the chosen internationalization strategy.[37]

Researchers have measured the impact of human capital development on foreign direct investment (FDI) for developing countries, and the results indicate a positive and mutually reinforcing relationship between both factors. An increase in tertiary enrolment rate leads to a relatively larger increase in FDI and vice versa, implying that human capital is now becoming an important determinant of FDI inflows in the long run.[38] The literature suggests that policymakers should coordinate their FDI and human capital policies to maximize the benefits to society. "For developing countries aiming to follow the successful models of countries like Costa Rica, Ireland, and Singapore, it is imperative that attention is also focused on the development of human capital. FDI alone may not be able to lead sustainable economic growth".[24]

Investment in RI is one of the determinants of S&T human capital development. Poorly equipped laboratories do not improve the skills and expertise of students and graduates, as they are unfamiliar with advances in research technology. Local and international research collaborations also rely heavily on the level of education of researchers, funding, and RI. Well-trained domestic researchers can attract international collaborations and funding, which can in turn improve the quality and quantity of research output. Well-trained researchers that are familiar with new technology also have the opportunity to advance their careers in other countries through postgraduate development programmes.

Researchers being familiar with new technology also depends on the availability of the technical staff members (technicians, service engineers etc.). The technical staffs` responsibilities in today's universities are far more complex and involved than they were fifty years ago. Support staff in higher education institutions play a significant role since they must give high-quality service to all of their customers, including students, professors, and other

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[35] Blackburn, J. A., Videka, L., & Mora, J. R. (2021). Building Research Infrastructure in Schools: A University Perspective. Johannesburg: University of Witwatersrand.
[36] Belas, J., Kmecova, I., & Cepel, M. (2020). Availability of human capital and the development of the public infrastructure in the context of business activities of SMEs. Administratie si Management Public, 34, 27-44.
[37] Onkelinx, J., Manolova, T. S., & Edelman, L. F. (2016). The human factor: Investments in employee human capital, productivity, and SME internationalization. Journal of international management.
[38] Onkelinx, Manolova, & Edelman (Miyamoto, 2003) (2016) & Lucas (1990).

employees.[39] According to the CHE website, only 17,838 full-time academics were employed in the South African higher education system in 2013, with 28,260 administrative support staff, technical staff, and service staff (inclusive), 2,016 senior management, and 771 tradespeople.[40]

With the rapid advancement of technology in universities, there appears to be an overlap of technical staff responsibilities, since they routinely teach students how to utilize new software, computer programs, and equipment so they can give academic staff more time to work on other tasks. This appears to be an expansion of their job description, as these workers were previously only employed to set up laboratories for students.[41] In order for researchers and students to be able to properly use new technologies, there needs to be a clear structure specifying the roles of technical staff members at the institutions and how the RI Users and the technical staff should work together.

Thus, investments in RI are inextricably linked with the development of human capital and are required to enable students and researchers to develop the necessary skills and experience to perform scientific and technological research. The acquisition and maintenance of advanced RI is costly and requires collaborative partnerships between government, universities and research institutions, and the private sector. There are several initiatives aiming to propel research output in South Africa as well as in Africa, these initiatives are discussed later in the report.

3.2.5 Impact of RI on local and international collaboration

Research activities have been considered crucial to innovation since they foster technological advantages by creating new and differentiated ideas. Since research collaboration boosts productivity and increases the impact of such research activities, it has received considerable attention in recent decades.[13] Local and international research collaborations are imperative as they can help academics develop expertise to address existing and emerging challenges. Countries that have achieved the highest overall research outputs, such as China, United Sates, Brazil, India, and Japan have become the blueprint for improving the quality and quantity of science research for Africa.[22] The literature points to an increase in research output due to a rise in collaboration between Africa and China. South Africa and Egypt were also found to be leading collaborators, with productivity scores higher than other African countries.[42]

South Africa has had an impact on various disciplines through its international collaborations. Some of these include being part of the Global Research Council, which comprises of Heads of Science and Engineering funding agencies from all around the world. Within the council, countries are given an opportunity to share data and best practices for high-quality collaboration among funding agencies worldwide. South Africa is also a member of the International Institute for Applied Systems Analysis (IIASA), IIASA conducts policy-oriented research focused on problems of a global nature that are too complex to be addressed by an individual country or academic discipline. Since joining the Institute, South Africa has been able to develop a range of collaborative research and capacity building initiatives through support from South African (NRF, DSI) and international (IIASA, the British Council and national universities) organizations. Other collaborations include South Africa`s engagement

[39] Barkhuizen, N., Mogwere, P. and Schutte, N. 2014. Talent Management, Work Engagement and Service Quality Orientation of Support Staff in a Higher Education Institution. Mediterranean Journal of Social Sciences, 5(4): 69-77.
[40] Education Data. 2013. Staffing. Retrieved from: http://www.che.ac.za/focus_areas/higher_education_data/2013/staffing
[41] Dearing, R. 2014. The Changing Roles and Responsibilities of administrative and support staff (online). Available: http://www/leeds.ac.uk/educol/ncihe/ (Accessed 30 April 2015)
[42] Eduan, W., & Yuanqun, J. (2019). Patterns of the China-Africa research collaborations from 2006: a biblometric analysis. Springer Nature, 77:979–994.

in international forums such as the Belmont Forum, SDG Forum of Funders, and the International Science Council through the NRF[43].

South Africa also contributed to research done on the Covid-19 vaccines through conducting vaccine trials. By the second quarter of 2020, it was reported that only less than 2,5% of all vaccine clinical research trails were done on the African continent. South Africa through Wits University conducted research trials on the Oxford Covid-19 vaccine and the Novavax vaccine and contributed towards the global research on these vaccines[44].

Low-to-middle income countries are typically characterized by fewer qualified researchers, a lack of funding, and poor RI. Another challenge for these countries is the emigration of qualified researchers to high-income countries for career advancements. Having advanced research equipment can help to retain qualified researchers, promote technological transfers, and joint research projects with developed countries. Moreover, many collaborations are made possible with funding capacity, well-trained staff, and advanced research equipment.[45] An increase in local and international collaboration can contribute greatly towards growth for both developing and developed economies.

Another benefit of domestic and international collaboration is that it broadens the audience and enhances the possibilities for international visibility. Internationally co-authored papers have a higher impact than domestically co-authored and single-authored papers. Further, internationally co-authored papers receive twice as many citations as domestic papers.[46] International recognition can assist in the advancement of Africa's research capacity and career prospects.

While partnering with international colleagues and institutions with advanced technology enables the flow of funding, expertise, and inherent capabilities to Africa, some researchers are concerned about the potential power imbalances in these partnerships. "Much of the research carried out in Africa is led, funded, and published by high income country researchers without equal collaboration from low-middle income country colleagues. Researchers from high income countries have been accused of extractive research, flying to developing countries to obtain data or samples, and leaving with the recognition and benefits".[47] Critical questions thus arise around the equity of such collaborations, surrounding how African universities and public research institutions can benefit from research collaborations without being exploited by their research partners, as well as how policy makers can prioritise the needs of developing countries, while committing funds to address inequitable collaborations. Much of the funding for global research is secured by high income countries, who habitually dictate the agenda, which can lead to projects that are inappropriate and unrelated to local research needs, and that derive conclusions that do not have any direct local benefits.

For collaborations to be more equitable, researchers argue that partners should have the same values and objectives. "Local ethics review boards are needed to provide additional oversight and to ensure that all studies comply with International Ethical Standards, including protection against exploitation of vulnerable local populations".[48] When research is performed

[43] *National Research Foundation.2021. Accessed from: https://www.nrf.ac.za/spp/about-strategic-partnerships*

[44] *University of the Witwatersrand. 2021. Accessed from: https://www.wits.ac.za/covid19vaccine/oxford-covid-19-vaccine-trial/*

[45] *Hoekman, J., Frenken, K., Tijssen, R., & Scherngell, T. (2013). Acquisition of European research funds and its effects on international scientific collaboration. Journal of Economic Geography, 13(1): 23-25.*

[46] *Raan, V. A. (1998). The influence of international collaboration on the impact of research result. Scientometric, 42: 423-8.*

[47] *Chu, K. M., Jayaraman, S., Kyamanywa, P., & Ntakiyiruta, G. (2014). Building Research Capacity in Africa: Equity and Global health collaboratives. pmed, 11(3).*

[48] *Edejer, T. T.-T. (1999). North-South research partnerships: the ethics of carrying out research in developing countries. Global Programme on Evidence for Health Policy, World Health Organization.*

in developing countries, local researchers need to take an active role in leading or directing research collaborations in order to maximize the benefits and minimize exploitation. Developing countries also need to set their own research agendas to address these imbalances; policymakers should balance the needs of local researchers with other collaborators and commit funds to minimize these imbalances.

3.2.6 The role of RI in supporting interactions between enterprises, universities, and public research institutions

There has been consistent growth in the number of research institutes, centres, technical colleges, and universities in Africa, which is due to both public and private efforts. Deák and Szabó [49] note that in developing countries, while much R&D work is undertaken at universities, the benefits accrue on a much larger scale. They argue that business-academia collaborations are nowadays viewed as a key requirement for bringing R&D results to companies, through universities' "third role" of supporting economic development and national competitiveness. University-industry partnerships are known to improve the quality of research outputs and modify day-to-day processes for organizations, which in turn improves production output. [49]

The importance of state-of-the-art infrastructure in supporting these partnerships is emphasized by several researchers, who argue that in order to advance to the next level of research productivity, access to the latest research technologies and the classification of strategic goals is required.[50] Advanced research equipment allows scientists and researchers to both produce scientific knowledge, and to identify questions that require further examination. Further, their research outputs can then largely be absorbed by companies, which can in turn inform strategies that effectively enhance total production. In their paper, De Negri et al (2015) note that the size and quality of university or institutional laboratories significantly impacts university–enterprise interactions, with larger, better equipped laboratories more likely to interact with the industrial sector.[51]

On the other hand, obsolete research equipment hinders researchers' ability to conduct industry-related research given constant and rapid technological advances. The acquisition of globally competitive RI thus promotes interaction between universities and enterprises.[3] University-industry interaction gives companies access to highly qualified scientists, which enables them to keep up to date with new ideas that support labour and capital services, including access to new discoveries and inventions, which can boost enterprise performance. Industry-related research also encourages companies to fund lab advancements in universities and institutions.

"Interactions among the actors involved in technology development are as important as investment in research and development, and they are the key to translating the input into outputs".[52] The acquisition, operation, and maintenance of world-class infrastructure for research and innovation requires a substantial financial investment, which necessitates a collaborative effort from the government, research institutions, universities, and the private sector. Many universities have made it their mission to create links with users of technology, through the establishment of technology transfer centres, licencing and patents, commercialization, consulting, and collaboration with industry research projects, to ensure academic impact in the economy and society. For universities that emphasize practical and

[49] *Deák, C., & Szabó, I. (2016). Assessing Cooperation between Industry research infrastructure in Hungary. Technology Innovation Management Review, 6(7): 13–20.*
[50] *Teng-Zeng, F. K. (2005); Mouton, J., et.al (2014); Blackburn, J. A., et.al (2021)*
[51] *De Negri, F., Cavalcante, L. R., & Alves, P. F. (2015). University- Enterprise interaction: The role of public research infrastructure. Rio de Janeiro: Ipea.*
[52] *OECD. (1997). National Innovation system. OECD publications; Pohjola, M. (2000). Information Technology and economic growth: a cross country analysis. Helsinki: World Institute for development economics and research.*

technical relevance as part of their mission, knowledge-related collaborations are now a norm, which also helps to generate income and enhance employment opportunities both within and outside universities.

In South Africa, the government and business sector are the primary investors in R&D. The government continues to be the country's largest R&D funder. To enhance business sector R&D, the government has entered into innovation partnerships with joint funding as well as introduced an R&D tax incentive.

In 2018/19, the business sector continued to fund its own research almost exclusively, funding 94.9% of its R&D expenses (Table 3). Funding for both the science councils and the higher education institutions decreased in 2018/19 as seen in the table. R&D funding in the science council sector from the Business sources decreased by 41,8% (from R355 million in 2017/18 to R207 million in 2018/19). Similarly, funding of R&D from business sources to higher education decreased by 31.8% (from R679 million in 2017/18 to R463 million in 2018/19). This could indicate that there was decreased interaction between universities and business in this period. In 2018/19, the not-for-profit sector received the same amount of funding (R72 million) as it did in 2017/18. R&D investment from the business sector to the government sector showed an increase from R519 000 in 2017/18 to R4 million in 2018/19, demonstrating improvement in collaborative efforts.

Table 3: Business-funded R&D by sector of performance (R'000), South Africa, 2014/15 to 2018/19

Sector	2014/15	2015/16	2016/17	2017/18	2018/19
Business	10 810 428	11 384 709	12 586 109	14 963 198	8 630 505
Non-for-profit	63 084	55 584	68 705	68 747	71 937
Government	290	41 109	1 261	519	4 614
Science councils	222 892	326 647	483 166	354 820	206 648
Higher education	885 280	770 448	906 651	679 563	463 413
Total (Constant Rand value)*[53]	9 515 357	9 513 948	9 957 895	10 771 991	9 377 117

Source: National Survey of Research and Experimental Development, 2014/15 to 2018/19.

Well-trained students who are familiar with the latest technology can also bring a fresh perspective to industry. In South Africa, the overall number of post-doctoral fellows and postgraduate students (doctoral and master's students) engaged in R&D has increased over the years. The National Survey of Research and Experimental Development reported that in 2018/19 there were 2 727 post-doctoral fellows, 23 842 doctoral students, 29 554 master's (full research) and 30 272 masters' (coursework plus thesis with research component) in the country. To continue this trajectory, national policies aimed at enhancing local technology need to address the provision of advanced RI and promote university-industry collaborations. However, research has found that the nature of such collaborations is key. In their study of university-industry collaborative and non-collaborative projects supported by government grants in the United Kingdom between 2002 and 2007, Banal-Estañol et al (2013), found that while universities tend to focus on more basic ventures when developing projects alone, the collaboration with companies only increased the quantity and quality of research outputs when companies had specific characteristics, such as past record of publications, that made them valuable partners.[54]

[53] GDP deflator values derived from Stats SA (2019b) were used to calculate constant 2010 Rand values for R&D expenditure.

[54] *Banal-Estañol, A., Macho-Stadler, I., & Pérez-Castrillo, D. (2013). Research Output from University–Industry collaborative projects. Economic Development, 27(1) 71-81.*

"Universities are not only responsible for teaching and R&D activities, but they are expected to commercialize the research result and also establish spin-off companies". Technology investment has been found to be one of the crucial factors that influences the success of the commercialization process. According to Khadem and Ismail[55], spin-off formation requires technologies that have made significant advances in the scientific field and that are economical; technology needs to be cutting edge and should not duplicate exiting technology. Thus, the commercialization of technological and scientific knowledge generated within universities, research centres, and laboratories that are publicly funded, is increasingly regarded by policymakers as a key input for regional economic growth, and for sustainability and development.[56]

3.2.7 Higher education in South Africa

One of the persisting legacies of apartheid is the entrenched inequality within the higher education system, which continues to be characterised by historically advantaged institutions (HAIs), which were predominantly white, and historically disadvantaged institutions (HDIs), which were historically non-white institutions; or a combination of the two which resulted from the restructuring in the higher education system where HAIs were merged with HDIs or HDI campuses. Most HDIs were established as separate institutions of higher learning for non-white communities following the enactment of the Extension of University Education Act (No. 45 of 1959). They were mostly established in geographically remote areas with students coming from disadvantaged socioeconomic backgrounds and poorly performing schools. The funding model applied for higher learning institutions during this period both generated and perpetuated inequities, with HAIs receiving larger subsidies as a result of having 'greater natural science enrolments, better student throughput rates, more postgraduate students, producing more research outputs, and having better management capacities'.[57]

At the end of apartheid, HDIs shared several characteristics, namely: their location in isolated rural or urban peripheries, a narrow range of academic programmes focused on non-science and teaching-related fields at lower education levels, stunted infrastructural and administrative capacity, and poorly developed educational facilities, with most students originating from disadvantaged backgrounds.[58] Many of these challenges have persisted and HDIs continue to experience financial difficulties and are under-developed as compared to HAIs. Their geographic locations and unequal funding affect their ability to attract and retain highly skilled staff who are able to lead research projects and supervise postgraduate students; they face higher costs for procuring supplies and services given their remote locations; and they are often plagued by inadequate municipal services.

Geographical location also impacts upon HDIs' academic networking and cooperation with other institutions, as well as opportunities to generate additional income. Further, HDIs have been found to generally lack physical infrastructure and laboratories, and experience management and governance challenges. The higher education sector therefore has marked differences in terms of the status, capacity, and infrastructure of HAIs and HDIs. Among other recommendations made, the report of the Ministerial Committee for the Review of the Funding of Universities (2013) notes the need for the DHET to continue prioritising infrastructure development grants for HDIs until infrastructure and equipment backlogs have been addressed, alongside the provision of research development grants to improve their

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[55] Khadem, T., & Ismail, K. (2013). Commercialization success factors of university research output. Journal of Technology.
[56] Inglesi-Lotz, R., Chang, T., & Gupta, R. (2013). Causality between Research Output and Economic Growth in BRICS countries. Forthcoming.
[57] Council on Higher Education. (2004). South African higher education in the first decade of democracy. Pretoria, CHE.
[58] Department of Higher Education and Training. (2013). Report of the Ministerial Committee for the Review of the Funding of Universities. Pretoria, DHET.

research capacity. One suggestion in the report was for each of the HDIs to develop at least one centre of research excellence based on its strengths, with funding from the DHET.

At the time of South Africa's transition to democracy, the higher education landscape comprised of 21 public universities and 15 Technikons. The subsequent policy, legal, and administrative changes implemented resulted in a total of 26 public universities as of 2018, which are classified into three categories: academic universities, which offer more traditional, theoretically-focused academic training; universities of technology, which stemmed from Technikons and offer vocational-orientated or technical qualifications; and comprehensive universities, which resulted from a merger between academic institutions and Technikons aimed at strengthening synergies between general academic and career-focused qualifications.[59] The table below indicates the classification of the 26 public universities, of which eight are HDIs.

Table 4: Classification of public higher education institutions in South Africa

Province	University	Classification	Status
Eastern Cape	Nelson Mandela University (NMU)	Comprehensive	Combined
	Rhodes University (RU)	Academic	HAI
	University of Fort Hare (UFH)	Academic	**HDI**
	Walter Sisulu University (WSU)	Comprehensive	**HDI**
Free State	Central University of Technology (CUT)	University of Technology	Combined
	University of the Free State (UFS)	Academic	Combined
Gauteng	Sefako Makgatho Health Sciences University (SMHS)	Comprehensive	**HDI**
	Tshwane University of Technology (TUT)	University of Technology	Combined
	University of Johannesburg (UJ)	Comprehensive	Combined
	University of Pretoria (UP)	Academic	Combined
	University of South Africa (UNISA) (national)	Comprehensive	Combined
	University of the Witwatersrand (Wits)	Academic	HAI
	Vaal University of Technology (VUT)	University of Technology	Combined
KwaZulu Natal	Durban University of Technology (DUT)	University of Technology	Combined
	Mangosuthu University of Technology (MUT)	University of Technology	**HDI**
	University of KwaZulu Natal (UKZN)	Academic	Combined
	University of Zululand (UNIZULU)	Comprehensive	**HDI**
Limpopo	University of Limpopo (UL)	Academic	**HDI**
	University of Venda (UNIVEN)	Comprehensive	**HDI**
Mpumalanga	University of Mpumalanga (UMP)*	Comprehensive	-
North West	North West University (NWU)	Academic	Combined
Northern Cape	Sol Plaatjie University (SPU)*	Comprehensive	-
Western Cape	Cape Peninsula University of Technology (CPUT)	University of Technology	Combined
	Stellenbosch University (SUN)	Academic	HAI
	University of Cape Town (UCT)	Academic	HAI
	University of the Western Cape (UWC)	Academic	**HDI**

* *University was established in 2014*

[59] *Department of Higher Education and Training. (2016). Statistics on post-school education and training in South Africa. Pretoria, DHET.*

3.2.8 The National Research Foundation (NRF)

The NRF is an independent statutory body established through the National Research Foundation Act (Act No 23 of 1998). As a government-mandated research and science development agency, the NRF funds research, the development of high-end Human Capacity, and critical research infrastructure to promote knowledge production across all disciplinary fields. The NRF's goal is to create innovative funding instruments, advance the development of research careers, increase public science engagement, and establish leading-edge research platforms that will transform the scientific landscape and inspire a representative research community to aspire to global competitiveness. The NRF promotes South African research and innovation interests across the country and internationally, and together with research institutions, business, industry, and international partners, builds bridges between research communities for mutual benefit that contributes to National Development.[60]

Section 3 of the National Research Foundation Act states that the NRFs objective is to contribute to national development by:

- Promoting, advancing, and supporting research and human capacity development through funds and the provision of the necessary research infrastructure, in order to facilitate the creation of knowledge, innovation, and development in all fields of science and technology, including humanities, social sciences, and indigenous knowledge;
- Developing, supporting, and maintaining national research facilities;
- Promoting the development and maintenance of the national science system and support of Government priorities; and
- Supporting and promoting public awareness of, and engagement with, science.

In order to achieve these objectives, the NRF is responsible for awarding public funds using competitive review processes to public research performing institutions, including, among others, universities, science councils, research hospitals, research laboratories, research museums, and national facilities.[61]

The NRF, by way of a Memorandum of Agreement (MOA), is contracted to manage the NEP within its Research Infrastructure Support Programme (RSIP). Established in 2009, the RSIP also includes a Strategic Research Infrastructure Programme (SRIP). The SRIP was created to address give grand challenges of the DSI.[62] The NEP funding, made available by the DSI, is earmarked for the acquisition, maintenance, and development of the state-of-the-art equipment. This funding originates from the annual parliamentary budget vote which is ring fenced for R&D infrastructure.

60 Accessed from the NRF website (www.nrf.ac.za/about-us)
61 South Africa. (2018). National research foundation amendment bill.
62 The Ten-Year Plan and those research infrastructure requirements that fall outside of the NEP.SRIP, investigations of which will be included in the final deliverable.

4. THE NATIONAL EQUIPMENT PROGRAMME (NEP)

4.1 Overview

The NEP was established with the goal of providing state-of-the-art research infrastructure to South African research institutions to advance the country's R&D agenda. It funds the acquisition, upgrade, or development of state-of-the art equipment in the broad domains of science, engineering, and technology.[63] The focus is specifically on large pieces of equipment that support multi-disciplinary and inter-disciplinary research and that require significant capital investment. The targeted beneficiaries for the NEP include universities, science councils, national research facilities, and museums, although universities have been the largest beneficiaries to date.

The objective of the NEP is to:

1. Improve RI to enable internationally competitive research to be conducted in South Africa;
2. Expand institutional capacity for research, innovation, and training at public universities and recognised research institutions;
3. Develop human resource capacity, mainly postgraduate student training and staff development, that focuses on historically disadvantaged institutions, women, and people with disabilities;
4. Support the acquisition, upgrade, or development of state-of-the-art RI for South African public research institutions to undertake world class research;
5. Promote, through the placement of RI, the development of research collaborations; and
6. Support and strengthen the objectives of the DST's Ten Year Innovation Plan, the National Development Plan, and the National Key Research and Technology Infrastructure Strategy.

4.1.1 Strategic framework

The strategy of the NEP is based on the NRF's National Key Research and Technology Infrastructure Strategy, which is built on two pillars, namely well-founded laboratories and infrastructure. The concept of a well-founded laboratory is focused on providing the minimum level of basic and/or entry level facilities and analytical equipment required for research and postgraduate training. It includes the equipment, infrastructure, and utilities needed for the operation of a scientific laboratory. This is funded by the Department of Higher Education and Training (DHET).

Infrastructure refers to major pieces of equipment for multi- and/or inter-disciplinary research that demand a significant financial investment in terms of acquisition and operational costs and are thus usually too expensive for institutions individually or collectively to acquire. World-class research infrastructure can also refer to large or specialized pieces of equipment that are required to further advance research and student training. RI is funded by the DSI through the NRF, with co-investments from the applicant's institution. The DSI provides financing for the NEP funding instrument through the Research and Development Infrastructure Platforms contract. The DSI's budget allocations for the Medium-Term Expenditure Framework (MTEF) governs the opening of NEP calls for applications.

The NEP provides funding for single instruments or multiple complementary instruments that together form a single analytical research system. The NRF also promotes the local design and development of the next generation of research equipment and therefore provides

[63] *National Research Foundation. (2020). Infrastructure Funding Instrument: National Equipment Programme (NEP).*

funding for the design, procurement, construction, testing, and certification of such equipment.

4.1.2 Application and review process

The NRF circulates NEP grant calls to the research offices of the targeted institutions and also posts calls to the NRF website. The application proposal for a NEP grant is detailed and requires substantial forethought and groundwork from the applicant to justify the investment for the equipment. The grant request must make provision for three years of a maintenance service contract. Further if the primary grant holder applicant is within 5 years of retirement, a co-applicant is to be identified to ensure continuation. Institutions are limited to a maximum of five applications each to ensure a manageable amount of applications for the review process, and are asked to rank their applications in order of priority.

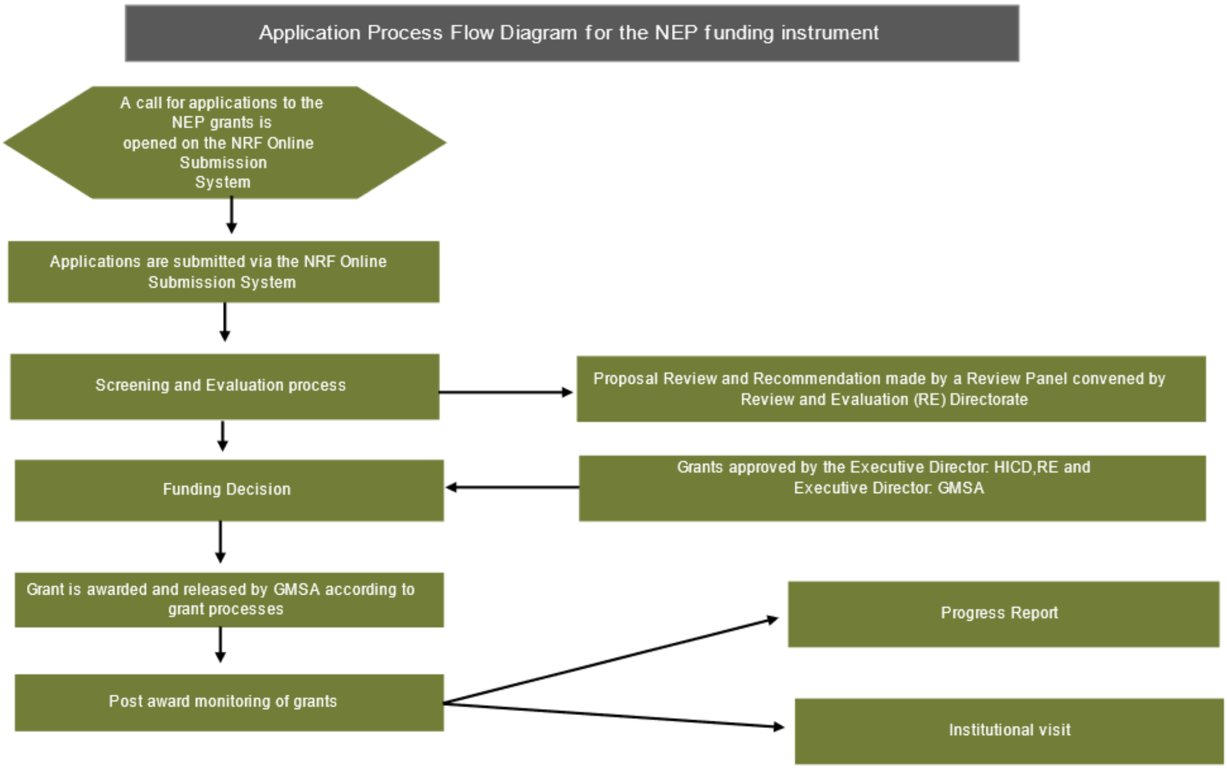
Host institutions are required to provide funding for the:

- One-third contribution towards the procurement of the equipment committed to in the proposal;
- Regular servicing and maintenance of the equipment for its full lifecycle beyond the NRF committed 3-year service contract; and
- Funding for operational costs, technical staff, and training costs required for the sustainable management of the equipment.

The key components of the online application include the grant applicant's curriculum vitae, the application proposal, which includes management and project plans, co-user information, and the financial commitment by the institution. The CV section is an important element of the application because it shows the applicant's track record in terms of research outputs, research experience, and student training. The proposal requires a description of the equipment, its intended usage, envisaged collaborations, and proposed impact. The management plan includes information on the physical infrastructure for housing the equipment, training of operators and technicians, and five (5) year service and maintenance contracts. The project plan is focused on outlining the timeframe for the procurement and installation process.

Grant holders are required to be duly authorised and approved by the Designated Authority (DA) of the research administration unit at the institution that submits the application. Only one application per applicant is allowed, however, previously rejected applications can also be revised and resubmitted. In order to align with their transformation strategies, the DSI and NRF require that at least three of the five applications submitted have a primary applicant that is from a South African designated group classified as black (African, Coloured, or Indian) or female. Figure 6 below maps the application, award, and reporting process for the NEP.

Figure 6: Process flow diagram for the application process of the NEP funding



Source: NEP Framework and Funding Guide

The NRF Grants Management and Systems Administration (GMSA) staff review and screen all applications for completeness upon submission. If the application does not meet the required standards, it is rejected and is not approved for panel peer-review.

Panel peer-review of qualifying proposals

Once the applications have been screened, reviewers are selected by the Reviews and Evaluation Directorate based on the focus areas of the proposals. Reviewers have expertise in both the scientific fields of application and/or the use of the specific equipment. A team of two reviewers is appointed for each application, who are required to provide a detailed written report and present their findings on the proposal to a broader review panel. A discussion is facilitated by the chairperson of the panel, and an agreement regarding the scores for all of the parameters is reached. While the review panels are specific to the focus areas of the proposals, there are usually four disciplinary panels, namely physical sciences, chemistry, biological and environmental sciences, and engineering and astronomy. At least two international reviewers are invited to both the discussion panel and to review some of the proposals to ensure that the review process is aligned with international benchmarks and to assist in improving the evaluation scorecard.

Proposals are reviewed using a range of technical evaluation criteria, including scientific merit, the track record of the Principal Investigator (PI) and co-PI, the human capital development plan, the proposed co-users of the equipment, and whether its cost can be justified in terms of the proposed usage. Thus, the technical review determines scores around the scientific merit, the proposed outputs, the risk factor, and the financial cost. The proposals are also reviewed in line with the NEPs target criteria, including the race and gender of the applicant, institutional profiles, historical awards made to the institution including whether a grant was awarded to the grant holder in the previous call, whether the institution has the necessary infrastructure to house the equipment, the geographical spread of applicant institutions and existing equipment, the institutional commitment and funding required, and the available NEP budget. Where proposals from the same institution have scored similarly, the priority ranking by the institution is considered. Based on the review and deliberations, the panel makes recommendations for the allocation of funding, as per Table 5 below. Where proposals are re-submissions, comments from the previous panel are made available to the review panel. The DSI act as observers on the panel and provide clarity on policy priorities, such as transformation, for consideration by the review panel but do not influence the recommendations and final decisions for funding.

Table 5: Funding recommendation outcomes

Recommended for Funding	The proposal does not have any gaps or weaknesses apart from minor changes (e.g., to the management plan that may be addressed without requiring any further peer review).
Conditionally recommended for funding	The proposal meets all the necessary requirements however, there are some minor issues that should be addressed by the institution before an award is made.
Revise and resubmit for subsequent review	The proposal contains some gaps and issues which must be addressed. The panel recommends that the application be revised and resubmitted to the NRF for further review before an award may be made.
Not recommended for Funding	The proposal contains numerous inconsistencies and gaps which renders it non-fundable

Source: NEP Framework and Funding Guide

Grant awards

Successful applicants are provided with a grant award letter from the NRF and required to sign a Conditions of Grant and Master Funding Administration Agreement contract, which is concluded between the NRF, the grant holder, and the institution. Institutions are required to appoint a designated authority (DA) to take responsibility for all NRF-related matters, such as validating applications, progress reports, and transactions.

The grant is only deemed valid when the following conditions have been met, after receipt of the grant award letter:

- The contract has been dually signed (within 30 days)
- The institution has provided a management plan and Gantt chart (within 30 days)
- The institution has provided a pro-forma invoice and covering letter from the Deputy Vice Chancellor (DVC) of Research declaring the institutions commitment towards addressing the additional requirements for installing and maintaining the equipment (within 6 months).

The NRF contributes two-thirds (2/3) of the total acquisition cost (with the NRF contribution being between R1 million and R10 million) which includes the total cost of the equipment cost plus VAT, as well as a compulsory three-year maintenance service plan. The host institution must provide one-third (1/3) of the total cost of the equipment, as well as the additional cost for a further two years of the maintenance plan with the preferred supplier. The NRF does not cover the operational costs associated with the installation and functioning of the equipment. The NRF is also not responsible for any additional costs, including those incurred because of currency depreciation.

The disbursement of grant payments are made in accordance with the NRF's standard award rules. The grant is distributed over two (2) years, with 80% of the funds disbursed in the first year upon receipt of the required documentation, and the remaining 20% after installation and receipt of the required documents.

Host institutions are responsible for ensuring the following:

- Adequate building infrastructure to house the state-of-the-art equipment to ensure that the equipment is completely commissioned within two years of the award being made.

- Insurance arrangements are included in their equipment application plan.
- Proposed usage plans are submitted, including by the following users:
    - Own research activities,
    - Researchers from the same institution,
    - Researchers from HDIs,
    - Academic users from public research institutions, and
    - The private sector.

The grant funding may only be used solely for the approved research proposal submitted by the grant holder, for the procurement, upgrade, or development of the equipment. Deviations in terms of downgrading the specifications of the type of equipment are not permitted. Should the grant holder leave the host institution, the NRF must be informed in writing, and a new grant holder nominated by the institution for approval by the NRF. Should the grant holder transfer to another institution, an application can be made to the NRF to transfer the relevant equipment prior to the grant holders departure. In both instances, a revised management plan and conditions of grant contract are required. Upon completion of the grant the equipment remains the property of the host institution.

4.1.3 Grant reporting

Reporting requirements for grant recipients

All grant holders are required to submit Annual Progress Reports (APRs) from the year of receipt of the grant award letter up until five consecutive years after the equipment has been commissioned. Grant holders are required to submit APRs in a specified format, against the deliverables outlined in the funding guide and contract, which address the work conducted in the previous calendar year, milestones achieved, and problems encountered. An APR is required for each and every grant and is due to the NRF on 15 February each year. The purpose of the APRs is to report on performance, to support the release of further funding within the grant period, to request carry forward of unspent funds, and to support the next round of applications.

APRs also report on the development of human capital in the form of personnel who have been trained to utilize the equipment, and postgraduate students who have been trained and/or obtained a postgraduate degree as a result of using the equipment. Equipment users include postgraduate students, postdoctoral fellows, technicians, private sector users, researchers, collaborators, grant recipients, staff, and other users.

Depending on the category of user selected, the following information must be provided:

- Full name
- Race and gender
- ID number / student number / staff number
- Citizenship
- Institution and country
- Department.

4.1.4 Findings from previous evaluations

In 2011, Techno Scene conducted a study to evaluate the NEP and the National Nanotechnology Equipment Programme (NNEP) on behalf of the DSI.[64] The purpose of this study was to determine the impact that both programmes have achieved since inception, with regards to their objectives, as well as the geographical and demographic distribution of

[64] *DSI & Techno Scene. (2011). A Study to Review and Evaluate the Roll-Out Progress of the National Equipment Programme (NEP) and the National Nanotechnology Equipment Programme (NNEP). Pretoria, Techno Scene.*

equipment in South Africa. This section will only focus on the findings and recommendations relevant to the NEP programme.

The evaluation was focused on the first contract period between the DSI and the NRF, between the financial years 2006/7, 2007/8 and 2008/9. The funds made available by the DST and the NRF in 2005/6 were also included in the review. Both qualitative and quantitative methodologies were used in the evaluation, which involved a review and analysis of existing documentation, conducting site inspections and assessments, interviews, and consulting with the NRF team on processes and procedures. The evaluation focused on three of the six OECD DAC evaluation criteria, as discussed in Section 2.1, namely relevance, effectiveness, and efficiency.

Relevance
Evaluation findings revealed that the NEP is appropriate in terms of government policy, to advance science and technology, to increase human capability in research, and to prepare people for the knowledge economy. Both the 2003 National R&D strategy, and the DST Ten-Year Innovation Plan note the lack of appropriate investments in research equipment. The majority of the Higher Education institutions that were interviewed during the evaluation also expressed gratitude for the significant increase in research equipment investment made possible by the NEP. They could link these investments to a significant rise in research outputs, particularly for those who had a high success rate with their applications but a low baseline for publication output.

A number of these institutions also highlighted that they would not be able to finance the research equipment without the NEP grants. Based on the feedback, the evaluation concluded that the NEP has made a significant contribution to the development of a RI base during the previous four years, which is critical in providing the capacity for research at a globally competitive level.

Effectiveness
The evaluation team considered the NEP objectives to determine the effectiveness of the programme. The findings demonstrated that the NEP was able to support the procurement of state-of-the-art equipment for researchers to conduct world-class research by purchasing or upgrading instruments, and provided infrastructure for the growth of research capability, primarily postgraduate student training, as well as staff development. Through research collaboration and training workshops, the NEP was also able to assist in the development of technical and application expertise related to the procurement of research equipment. The evaluation found little evidence that the NEP was able to create a long-range planning culture for research equipment utilisation, maintenance, and replacement. This might be because the NEP had only been running for a short period of time when this evaluation was conducted. The NEP was also able to support institutional priorities. However, there was still a need for coordinated and facilitated user engagement in terms regional and national priorities to fully address this objective. The evaluation also alluded to the fact that the geographic distribution of research equipment was aligned with the distribution of the more research-intensive universities, as one might expect.

Efficiency
In the evaluation report, the evaluation team mentioned that the NRF should be applauded for putting in place protocols and procedures to *efficiently* handle two major programs, the NEP and the NNEP, in a relatively short period of time. This appeared to have been working well at the time, and grant recipients and research administrators expressed their gratitude for the support and assistance provided by the NRF.

Recommendations
TechnoScene indicated in their evaluation that it was the right time for the NRF to concentrate its efforts on a range of value adding aspects of the management of programmes. Although the NRF's yearly reporting requirements include a number of relevant

indicators to assess grant recipients' performance and delivery of equipment in accordance with the primary objectives, there are a number of additional measures to consider. The evaluation provided a number of recommendations that are listed in Table 6 below.

Table 6: Evaluation recommendations

R1. A split in funding model to cater for entry level expensive equipment and state-of-the-art expensive equipment.
R2. Promoting the establishment of centralised and independent, national, or regional multi-user equipment facilities that provide ready access to users.
R3. Optimising the sustainability and utilisation of expensive research equipment.
R4. Improving the assessment procedures of the environment where expensive research equipment is being placed, particularly where competitive research outputs depend critically on the availability of other equipment items.
R5. Facilitating processes linked to both the planning of future acquisitions of world-class multi-user equipment within disciplinary context, and from the perspective of clusters of equipment around specific technologies, as well as the conceptualisation of competitive user platforms of research equipment.
R6. Discouraging competition of prestige of ownership and promoting competitive science through sharing and collaboration.
R7. Developing research environments at HDIs through equipment placement.
R8. Promoting technological innovation and commercialisation, which was not on the agenda of equipment owners at the time of the study.
R9. Optimising the interplay between the equipment life cycle and the learning curve to achieve maximum impact from equipment investments.
R10. Intervention by the NRF on issues pertaining to suppliers and their agents to negotiate special service and maintenance deals, conduct due diligence on unknown, smaller suppliers, and to introduce reporting on supplier service quality.
R11. Improving application processes, by providing an online application environment and to introduce a two-stage application process that would include a short pre-proposal and on the basis of which full proposals are to be invited.
R12. Introducing additional evaluation procedures such as site visits and equipment ecosystem audits.
R13. Revising the reporting requirements to support future analysis of outcomes of the programmes and streamlining the reporting process by introducing an online real-time booking, logging, billing, and reporting environment to support researchers to use equipment more efficiently.

Source: Techno Scene NEP and NNEP evaluation report

The previous evaluation report serves as a form of baseline measure for the current evaluation. The findings highlighted in the current evaluation are compared to those outlined in the prior report to assess the progress made within the NEP over time.

5. THEORY OF CHANGE

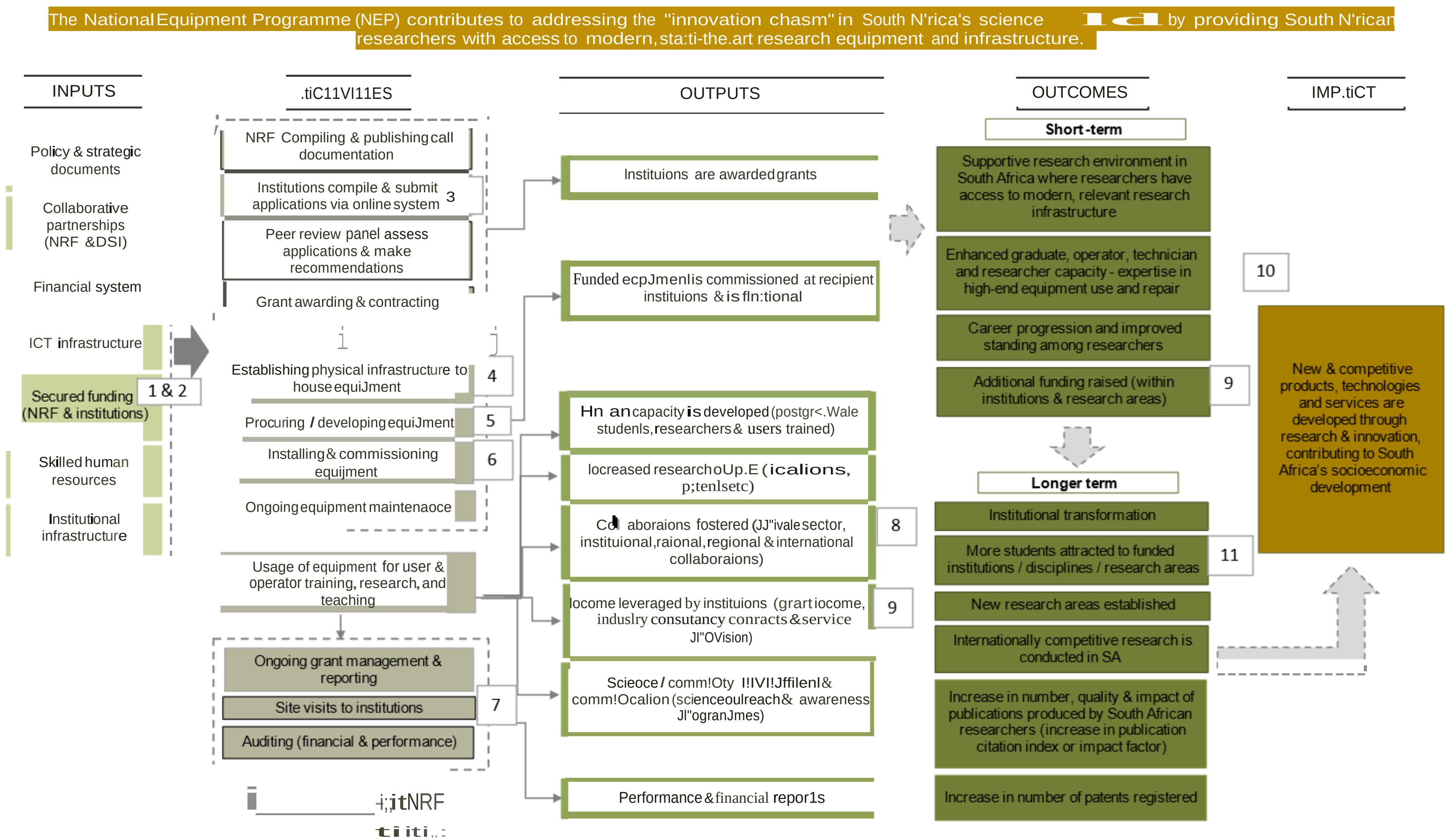
A Theory of Change depicts the building blocks of an intervention and shows how the activities will ultimately lead to its desired result. It is a graphic representation of the initiative and illustrates how an initiative translates its inputs into activities and outputs that lead to the desired outcomes. It also represents the assumptions made about the initiative. Within the Theory of Change, impacts represent higher order development outcomes that cannot be attributed to the initiative alone, but rather result from collective action, as well as broader societal factors.

Box 1: Components of a Theory of Change

- Inputs: The resources needed to undertake the activities in the programme.
- Activities: The collection of functions and processes (actions, jobs, tasks) that consume resources required to produce outputs (how the programme is delivered).
- Outputs: Final outputs are the goods or services – the “products” – a programme delivers. These services are delivered to or for the direct benefit of an individual or group.
- Outcomes: The immediate, intermediate, and long-term changes that result from outputs. Immediate outcomes are achieved at an individual level in the short- to medium-term.
- Impact: Generally country or societal-level changes that happen over the long-term.
- Preconditions (assumptions): The conditions that need to be in place to achieve the programme objectives. These preconditions are found in each of the five layers above.

The Theory of Change for the NEP is illustrated in Figure 7 and provides details on how the programme activities and outputs are envisioned to translate into the desired outcomes. A virtual workshop was held with key programme stakeholders from the DSI and NRF in November 2021 to brainstorm and develop the Theory of Change for the National Equipment Programme. A logical framework (Logframe) has also been developed for the programme, with a core set of measurable indicators, which is provided in Annexure 3.

Figure 7: Theory of Change: National Equipment Programme



5.1 Narrative description

The Theory of Change (ToC) set out above depicts the expected change pathways produced by the National Equipment Programme, which aims to contribute to addressing the innovation chasm in South Africa's science and technology system by providing researchers with access to modern, state-of-the-art research equipment and infrastructure. Each component of the ToC is described in more detail below, while the extent to which the ToC is working in practice is explored in the evaluation findings.

5.1.1 Inputs

Programme inputs set the foundation for the programme and must be in place prior to implementation. Key inputs for the implementation of the NEP include:

- The **policy and strategic documents** that inform the design of the programme and provide guidance on the development of a national system of innovation (NSI) in the country, including the National Development Plan (R&D agenda), the revised White Paper on Science and Technology, and the Ten-Year Innovation Plan.
- A **collaborative partnership** between the DSI and the NRF. The DSI is responsible for developing policies and strategies, such as the White Paper, and allocating funds under the Research and Development Infrastructure Platforms contract. The NRF was responsible for conceptualising and developing the design of the programme and is responsible for its implementation and monitoring on an ongoing basis.
- **Funding** for the NEP is required prior to the opening of NEP calls, which is subject to the Medium Term Expenditure Framework (MTEF) budget allocations from the DSI. Applicant institutions also require their own funding to co-invest in the requested equipment.
- **Financial, human, and other resources** (including financial systems, ICT infrastructure, institutional infrastructure, and staff members) are critical for programme implementation and grant management.

5.1.2 Activities

Programme activities include those undertaken by both the NRF and the institutions that have been awarded grants, and consist of different phases:

- Grant application and award process
    - The NRF compiles the call for grant applications, which consists of a range of documents including the grant framework, guide, among grant conditions, among others. The NRF sends grant calls to institutional research offices and they are also posted on the NRF website.
    - Grant applicants are required to submit their applications on the online NRF system and usually have a two-to-three-month period to compile the proposal.
    - Once received by the NRF, applications are initially screened for completeness by the NRF Grants Management and Systems Administration (GMSA) team. Reviewers are then selected to the review panel based on the applications received and a review process is undertaken. The recommendations of the panel are considered alongside the availability of funding, the strategic programme objectives, and the targeted groups in selecting awardees.
    - Grant awards are made to the successful grant applicants via a contract with the host institution. NEP grants are made for amounts of between R1 million and R10 million per grant. The NRF provides two-thirds of the cost of the equipment and the host institution provides the remaining one-third. Eighty percent of the grant value is released by the NRF at the time of the grant award and the remaining 20% is provided once the equipment is fully commissioned and operational.

- Procurement & commissioning infrastructure

- The successful host institutions are responsible for ensuring that adequate physical infrastructure is available to house the equipment, whether using existing facilities or building new facilities prior to the procurement of the equipment.
- The host institutions then procure the funded equipment from a supplier or oversee the development of the equipment. They also oversee its installation and commissioning in order to ensure that it is ready for use.
- The grant proposal for NEP funding must include a 3-year maintenance service contract, and the host institution must make provision for a further 2 years of maintenance beyond this (self-funded).

- Equipment usage
  - The funded equipment is then used for training, research, and teaching. Depending on the type of equipment that is procured, grant holders, operators, and technicians may be trained by the supplier on the equipment's use.
  - Grant holders utilise the equipment to conduct research and to teach and train students.

- Grant management & reporting
  - Grant holders are required to submit annual progress reports to the NRF for a period of five years after the commissioning of the equipment, using a reporting template via the online system. The reporting period runs between December and February each year, although the online reporting template is available throughout the year for information to be captured on an ongoing basis prior to submission.
  - The NRF undertakes ongoing grant management, monitoring, and reporting by reviewing the annual progress reports, conducting performance and financial audits, and commissioning periodic evaluations.

5.1.3 Outputs

The initial outputs that are generated from the activities and inputs of the NEP include that institutions are awarded grants and that the funded equipment is commissioned and functional. Successful grant awardees are expected to commission the equipment within two years of receiving the grant. Outputs stemming from the usage of the equipment include:

- Students and operators are trained to use the equipment (institutions are expected to train a minimum of 10 postgraduate students per year)
- Training interventions are undertaken on the equipment's use
- Users use the equipment to conduct research
- Users use the data generated from the use of the equipment to conduct research
- Postgraduate students graduate as a result of using the equipment in their research
- Research outputs are generated using the equipment, which include books, book chapters, peer and non-peer-reviewed articles, conference outputs, technical reports, policy briefs, and patents (a minimum of 4 publications in international peer reviewed journals per year)
- Collaborations are established between researchers, institutions, and with the private sector
- Services are provided to industry (using the equipment)
- Institutions are able to leverage the equipment to attain additional income
- Engagements and communication is undertaken within the science sector and with the broader public, including that of the South African Agency for Science and Technology Advancement (SAASTA)
- Programme performance and financial reports are generated
- NEP grantees are expected to take part in public awareness and science communication programs, such as those offered by the South African Agency for Science and Technology Advancement (SAASTA).

5.1.4 Outcomes

Outcomes refer to the desired changes that the DSI and NRF want to achieve through the NEP. **Short-term outcomes**, which are typically achieved within a year or two of the completion of outputs, include the establishment of a supportive research environment in which researchers can access modern and relevant research infrastructure. It is also envisioned that human capacity will be enhanced in that graduates, operators, technicians, and researchers will have expertise in the use (and repair) of the equipment. These skills will enhance their career progression and enable researchers to improve their standing and ratings. The placement of the equipment will also allow the host institutions to leverage additional funding and grants, thereby also attracting more funding to the research area. As well as leveraging additional income through user charges (Charge Out rates) for the equipment.

In the **longer term**, it is envisioned that the provision of the grants will enable institutional transformation, with historically disadvantaged institutions housing cutting-edge equipment, which will in turn enable them to attract staff, students, and additional funding. With the placement of equipment institutions will also attract more students to the related disciplines and research areas. Having access to the equipment will also allow researchers to uncover or pursue new research areas, and to conduct research that is internationally competitive. This will in turn boost the number and quality of their publications, while also allowing them to train students. It is expected that researchers will also be able to register new patents from this research.

Thus, several components are required for the development of a robust research enterprise. Research infrastructure is required to enable grant holders to conduct research. Equally important is the human capital to undertake the intellectual and innovative work. Finally, financial resources are needed for operational costs.

5.1.5 Impact

The ultimate impact of the NEP is to enable the development of new and globally competitive products, technologies and services through research and innovation. This will contribute to broader efforts aimed at boosting South Africa's socioeconomic development, alleviating poverty, and improving standards of living.

5.1.6 Assumptions

In order for the Theory of Change to work, several key assumptions must hold true:

Inputs/Activities to Outputs

1. The DSI makes funding available for the programme
2. Grant recipients have the required one-third (1/3) co-investment to contribute towards the cost of the equipment.
3. Applicants respond to the grant call with feasible proposals.
4. Grant recipients have the infrastructure, financial, and human resources to house, maintain, and operate the equipment.
5. Contextual factors at the funded institutions don't inhibit the implementation of the programme.
6. Institutions are able to commission the equipment within two years of receiving the grant.
7. Grant reporting and programme monitoring is conducted with fidelity.

Outputs to outcomes and impact

8. The provision of state-of-the-art equipment addresses the challenges facing researchers in producing innovative, internationally competitive, and impactful research, and in forming key research collaborations.
9. Recipient institutions will use the equipment to leverage further funding and income opportunities.

10. Having access to state-of-the-art equipment enables users to undertake innovative research and to develop new products and technologies.
11. New and additional students will be attracted to the funded institutions, disciplines, and research areas because of the equipment acquired through the **NEP.**

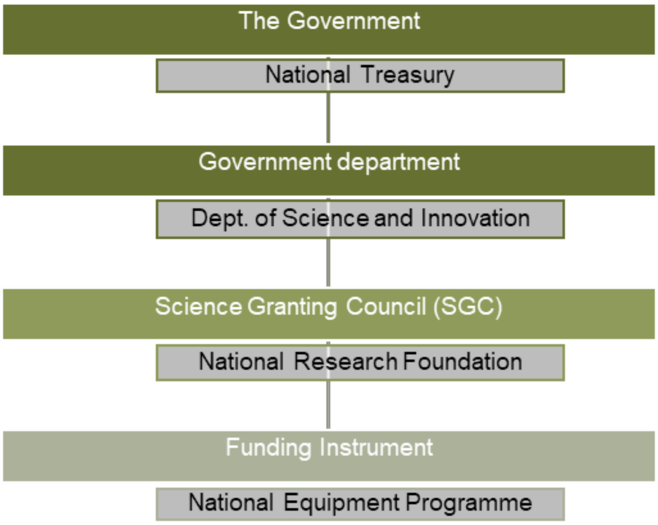
Other

12. Institutions have a succession plan, and the grant holder retirees are replaced

6. BENCHMARKING

The National Equipment Programme (NEP) is a government financed equipment funding instrument, where funding is channelled through a government department, by way of a Science Granting Council (SGC) or research council (see **Error! Reference source not found.**). A benchmarking exercise was conducted to assess how the NEP compares to other publicly financed programmes with similar aims (privately funded equipment programmes fall outside of the scope of the analysis). The full benchmarking report is available separately, with the main findings summarised below.

Figure 8: The funding chain of the National Equipment Programme



A systematic review of SGCs in 17 Sub-Saharan African identified 12 functions[65] of SGCs.[66] Two of these functions are relevant to the National Equipment Programme, namely: (i) funding to acquire infrastructure; and (ii) capacity building and training of researchers. Examples of two of these SGC functions are as follows:

- **Funding Support for Infrastructure Development:** FIRCA in Côte d'Ivoire and the NRF in South Africa were the only examples found across Africa regarding support and funding for scientific equipment or infrastructure.
- **Capacity-building/training of researchers:** Many of the research councils in West Africa are found to prioritise the training of researchers. Considering the limited research culture in many of these countries, this training extends towards proposal writing and technical support. The NRF in South Africa, through its Human and Infrastructure Capacity Development (HICD) directorate, offers a range of fellowships, bursaries, and scholarships that aim to develop skilled human resources in scarce skills areas.[67]

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[65] *Provision of research grants (various categories), provision of scholarships and loans, funding support for infrastructure development, Valorisation of results, supporting scientific publishing/scientific journals, advocacy to the Science, Technology, and Innovation (STI), collect data and statistics on S&T and R&, capacity-building/training of researcher, policy advice, setting research agenda/research priorities, management of scientific collaborations and agreements, coordination of the NIS system (Mouton, Gaillard, & van Lill, 2014)*

[66] *Mouton,J., Gaillard,J. & Van Lill,M., 2014. Science Granting Councils in Sub-Saharan Africa (Available: https://www.researchgate.net/publication/280593060_Science_granting_councils_in_South_Africa*

[67] *Mouton,J., Gaillard,J. & Van Lill,M., 2014. Science Granting Councils in Sub-Saharan Africa (Available: https://www.researchgate.net/publication/280593060_Science_granting_councils_in_South_Africa*

6.1 Criteria for country selection for benchmarking the NEP

The NEP is benchmarked against comparable programmes both locally and internationally, with the following questions used to identify and select comparator programmes: is the programme implemented in a developed or developing country? How do the economic, education, and R&D indicators of the selected countries compare to those of South Africa? (applicable to the international programmes only) Is the programme implemented by the government or through a government funded initiative? Is it a research equipment funding programme? Does the programme target research institutions[68], researchers, or scholars? Does the programme offer funding in the form of a grant?[69] Does the programme aim to encourage and extend cooperative approaches to research? Does the programme aim to promote national and international research partnerships? Are provisions put in place to ensure programme sustainability?

The researchers followed an iterative process when selecting programmes for the benchmarking exercise. In the first round of consideration, programmes in the BRICS countries were investigated. Given the availability of information provided in English, programmes from India and South Africa are included in the review, while programmes from Brazil, Russia, and China are not.

In the case of the South African investigation, a comprehensive list of programmes was considered in the review. This includes programmes that work through four distinct SRCs, namely, (a) The National Research Framework (NRF); (b) The Medical Research Council (MRC); (c) The Water Research Commission (WRC); and (d) The Technology Innovation Agency (TIA).

In the second round of consideration, programmes from larger developed countries were investigated. Given the richness of available information, programmes from the United Kingdom, Australia, and the United States of America were included.

6.2 Benchmarking against local and international programmes

6.2.1 Benchmarking against other South African funding programmes

The programmes identified are shown in the table below.

Table 7: Funding models and modes of South African programmes

Ministry	Research council/ SGC	Funding instrument
Department of Science and Innovation (DSI)	**National Research Foundation (NRF)**	**National Equipment Programme**
DSI	NRF	Nanotechnology Equipment Programme (NNEP)
DSI	NRF	South African Research Chairs Initiative (SARCHI)
DSI	NRF	Strategic Research Equipment (SRE)
DSI	Technology Innovation Agency (TIA)	Technology Platform Programme (TPP)
DSI	Technology Innovation Agency (TIA)	Technology Development Fund (TDF)
DSI	Technology Innovation Agency (TIA)	Seed Fund
DSI	Technology Innovation Agency (TIA)	Pre-Commercialisation Fund

[68] Research institutions include public or private universities and colleges.
[69] Grant in this case refers to the provision of financial support without the need for repayments to be made, as in the case of a loan.

Ministry	Research council/ SGC	Funding instrument
Department of Health	Medical Research Council (MRC)	Self-initiated Research Grants Programme
Department of Water and Environmental Affairs (DWEA) and DSI	Joint initiative by Water Research Commission (WRC) and the Technology Innovation Agency (TIA)	WRC-TIA Water Seed Fund

Source: (South African Government, 2021) (SAMRC, 2021a) (SAMRC, 2021b) (TIA, 2021a) (TIA, 2021b) (TIA, 2021c) (NRD RISA, 2016) (NRF SARChi, 2020) (NRF, 2016)

These programmes primarily fall under the DSI, and are mostly related to the funding of research, which may include providing access to equipment used in the fields of science, technology, and engineering (with some exception for life science- and bioeconomy-related equipment). All the South African programmes included in the comprehensive review have adopted a paradigm principal-agent[70] and sector differentiated model[71]. There is always a research council or agency that reports to a government department. These agencies are charged with implementing various funding programmes. All these programmes are observed to make use of a competitive and project funding model. In this way the NEP is seen to adhere to the norm by adopting the same funding models as those offered by other South African programmes.

- These programmes are all funded through grant facilities, or through the direct provision of funds by the various departments. This is in line with grant funding provided through the NEP.
- In general, target audiences include researchers and students, with a broad focus on developing research by both experienced and budding researchers. Once more, this is aligned with the target audience for the NEP, namely, researchers and scholars at public research institutions and research entities, post-graduate students, and private industry players.
- In the majority of the programme's, project-specific funding is awarded. The NEP's funding window is a period of two years. That is, the purchase of the equipment has to be completed within two years of receipt of the grant letter.
- The NEP is unique in that it is the only programme that provides support specifically for the acquisition, upgrading, or development of research equipment, while others have access to funding for equipment as part of a broader mandate.[72]

6.2.2 International benchmarking

The review identified seven programmes which have been implemented internationally that share similarities with the NEP, as shown in Table 8. One programme from a developed country and one from a developing country were selected for a detailed analysis to identify lessons and best practices that may be relevant to the NEP initiative.

Table 8: Programmes included in the international benchmarking exercise

Country	Ministry	Research council/ SGC	Funding Instrument
South Africa	**Department of Science & Innovation (DTI)**	**National Research Foundation (NRF)**	**National Equipment Programme (NEP)**
Australia	Department of Education, Skills and Employment (DESE)	Australian Research Council (ARC)	Linkage infrastructure, Equipment, and Facilities (LIEF) grant is a sub-programme under the National Competitive Grants Program

[70] *This model involves government delegating its science and research funding responsibility to an autonomous body*
[71] *A model whereby funding councils target specific sectors, operated by specific councils with vested interests.*
[72] *Technology Innovation Agency, 2021a-g, National Research Foundation 2016, National Research Foundation 2021a & b, National Research Foundation 2020, South African Medical Research Council 2021c, National Recruitment Database 2016, and National Research Foundation and the South African Research Chair 2020.*

Country	Ministry	Research council/ SGC	Funding Instrument
South Africa	**Department of Science & Innovation (DTI)**	**National Research Foundation (NRF)**	**National Equipment Programme (NEP)**
			(NCGP).
	Department of Education, Skills and Employment (DESE)	No evidence found of an intermediary SGC or research council	National Collaborative Research Infrastructure Strategy (NCRIS)
	Department of Health (DOH)	National Health and Medical Research Council (NHMRC)	The National and Medical Research Council's (NHMRC): Independent Research Institute Infrastructure Support grants (IRIISS), and Equipment Grants
Côte d'Ivoire	Ministry of Agriculture and The World Bank	No evidence found of an intermediary SGC or research council	Interprofessional Fund for Agricultural Research and Advice. Fonds Interprofessionnel Pour La Recherche et le Conseil Agricoles (FIRCA)
India	Department of Biotechnology (DBT) – Ministry of Science and Technology	No evidence found of an intermediary SGC or research council	Scientific Infrastructure Access for Harnessing Academia University Research Joint Collaboration (DBT-SAHAJ) Infrastructure
Korea Republic	South Korean Ministry of Science and ICT	No evidence found of an intermediary SGC or research council	The national research infrastructure governance system
Singapore	Prime Minister`s office	National Research foundation	National Research Infrastructure
United Kingdom	Department for Business, Energy, and Industrial Strategy (BEIS)	Engineering and Physical Sciences Research Council (EPSRC)	Equipment Accounts and Equipment Grants: United Kingdom Strategic Equipment Process[73]
United States of America	Department of Defense (DOD)	Office of Naval Research	Defense University Research Instrumentation Program (DURIP)
	United Governments Department of Energy (DOE)	Office of Workforce Development for Teachers and Scientists (WDTS).	Laboratory Equipment Donation Program (LEDP)

Of these programmes, the United Kingdom's and the United States' programmes are among the most sophisticated. However, because the UK's programme is more similar to the South African NEP, it is included in for deeper analysis the following section. The developing country chosen for further analysis is the programme in India, given the similarity and availability of relevant information.[74]

There is value is interrogating one of the leading international programmes a little more deeply to look at similarities and differences. The UK SE is comparable to the higher end funding provided by the NEP, with some key similarities but also some distinct differences. Like the NEP, the UK SE uses a paradigm and sector differentiated principal model to fund state of the art equipment via a competitive funding process. However, the scope of the UK SE funding also extends to enabling and enhancing equipment. Funding under the UK SE is

[73] The Strategic Equipment Process is one of several equipment funding accounts and grant programmes that operate under the EPSRC; these are unpacked in greater detail under Section 1.9. In-depth Case Studies

[74] Department of Bio Technology, 2021b&c, Grant Connect, 2021,Agriculture Research Council, 2020a & b, Department of Education Skills and Employment 2021a-c, NHMRC, 2021a & b, University of Newcastle, 2021, Ministry of Science and Technology, 2021, Chinese Embassy, 2021, Engineering and Physical Science Research Council 2021 a-k, UK Research and Innovation 2021 a&b, Labotary Equipment Donation Program 2021a, Duke University, 2021, Grants Gov, 2021, File Classification Infrastructure Alternative Data, 2021, National Research Foundation Singapore, 2021, OECD-Observatory of Public Sector Innovation, 2021.

offered for the acquisition of equipment for an amount of about R8 million at the current exchange rate (approximately R20 per pound), while the NEP offers funding for an amount of between R1 million and R10 million. Like the NEP, the UK SE programme targets local, regional, and national scales of equipment usage, but does not include a maintenance component nor does it allow for the upgrade of equipment like the NEP does. Finally, host universities are encouraged to make contributions to the equipment under the UK SE, but this is not mandatory, while host universities under the NEP are required to contribute one-third of the capital.

In summary, the NEP initiative is directly aligned with the two best international programmes in the following ways:

- Like the *DBT-SAHAJ* and UK *Strategic Equipment*, the NEP offers competitive project funding for state-of-the-art equipment.
    - Given that the disbursements of funds are based on open competition, the submission of proposals, subsequent peer reviewing, and monitoring of project outcomes and deliverables is necessitated. These activities are often administratively intensive and costly, providing a weakness of this type of funding, as suggested in the paper by Mouton, Gaillard, & van Lill (2014).
    - This type of funding reinforces principals of fairness, in terms of accessing the grant support. This funding is based on the principals of transparency, in that proposals and monitoring activities provide an opportunity to bridge information gaps that may exist in terms of performance, expected project outcomes, collaboration efforts and strategies, etc.

- Like the DBT-SAHAJ and UK Strategic Equipment, the NEP offers grant assistance through a host university, single grant holder or research institution.
    - By providing support to researchers through host universities and research institutions one is better able to facilitate cooperative efforts. The NRF and DTI facilitates cooperatives efforts in an effective manner through the online Research Equipment Database. This database is similar to the UK SE.[75]
    - The EPSRC has an "Access supported strategic equipment" channel on their website, through which much of the existing equipment is made available for other researchers to use. Researchers are able to contact the host organisations directly and enquire about the availability and procedures for accessing the equipment.
    - Similar to the NEP, under the UK SE applicants are expected to first check that the equipment they are applying for is not available on this channel. Secondly, they are expected to motivate the usefulness and interest in this equipment beyond their research project (potential for collaborations and future use), as well as provide strategies for enhancing and facilitating access to this equipment.
    - Furthermore, providing support at a higher level allows for the opportunity to aggregate project reporting efforts, which may ease the administrative burden. In this way, universities can compile collated reports, which include the performance of numerous research projects that may stem from the use of the equipment or infrastructure.

Stemming from the in-depth analysis, the following preliminary suggestions can be offered to the DSI for the purposes of improving the NEP initiative. It is important to note that these suggestions stem from the differences identified between the case studies in the in-depth benchmarking review and the NEP in terms of programme design and implementation.

[75] *The Research Equipment Data link: http://eqdb.nrf.ac.za*

- The NEP may wish to offer further training or make non-capital provisions, like the UK Strategic Equipment funding option.[76]
  - Requests for non-capital funding may be included in the equipment proposal and subsequently awarded to successful applicants of the UK Strategic Equipment funding option.
  - Non-capital funding is applicable when there is clear requirement and when such requests are necessary to the support the use of the equipment requested. This support may include technical professionals and training, both of which play an important role in the maintenance, set-up, and use of research equipment.
  - In this regard, the NEP may wish the adopt the design of the SA-SRE programme. In this programme applications undergo two proposal phases whereby management plans are suggested in both phases, including that of required training interventions. The second Call for Applications is a closed competitive call and applications at this phase are expected to provide detailed evidence on the management plan for the equipment including training interventions.[77]

- The NEP may wish to offer supplementary resource grants, like the UK- Strategic Equipment funding option:
  - Only capital items are supported through the Equipment Account of the UK Strategic Equipment funding option. If a university requests resources to share or run an item of equipment, this support is provided through a separate “supplementary” resource funding grant.

- The NEP may wish to categorise its equipment grants along the same categories used by the UK Strategic Equipment funding option:
  - Grants may be categorised according to the scale of use: grants may be differentiated by the type of users which may range from individual researchers to international facilities.
  - Grants may be categorised by level of funding, that is, to provide sub-categories for the NEP funding which ranges from R1 million to R10 million.

[76] *While the UK SE offers non-capital funding options for the costs associated with project specific consumables, support of individual projects, and PI time for research are not eligible for funding under the UK Strategic Equipment process.*
[77] *(NRF RISA, 2016)*

7. CASE STUDIES

The following case studies provide specific examples of the equipment acquired by the grant holders using the NEP grant during the period under review. Three case studies were selected for the report based on the information that was available in the APRs and from the grant holder interviews about the equipment, with one case study chosen from a site visit conducted for the study. The case studies describe what the equipment is being used for, the key successes achieved, and challenges faced around its usage. The case studies have been included in the report to demonstrate the impact that the NEP has had for grant holders and for research undertaken in the country.

7.1 Case study 1: The GrowSafe Feed Intake and Beef System

In 2016, an NEP grant was awarded to the Agricultural Research Council (ARC) for the purchase of the Canadian GrowSafe Feed Intake and Beef System. This system includes 16 feeding bins and 6 water drinking systems, which together, measure individual feed intake and partial animal body weight in real time. At the time of installation, this system was the first complete system of its kind in Sub-Saharan Africa.

Image: The GrowSafe Beef Systems Equipment (post installation)

Equipment application

This equipment has been used to evaluate the heterosis of 12 crossbred and 3 purebred bull genotypes. This is done by measuring daily weight gain, feed conversion ratios, and residual feed intake. The results contribute to developing strategies to lower methane production and combating the effects of global warming on livestock.

To monitor performance of growing animals and pursue the achievement of sustainable genetic gains, data on the average daily gain (ADG) and changes in body weight of growing animals is required. Accurate calculations of ADG necessitate serial measures of body weight for at least 70 days. The data collection can be resource intensive. One approach involves the collection of individual animal partial body weights.

The GrowSafe propriety algorithm was utilised in a recent study that determined the utility of partial body weights in predicting both body weight and ADG. The study also aimed to deduce the optimal length of testing to determine ADG from partial body weight information. Using this equipment, body weight data was recorded for 8 972 growing cattle from breeding type variations in 35 contemporary groups.

On average, 90.7 (roughly 2%) of the variation in recorded animal body weight at the start of the post-weaning gain test was explained by partial body weight, and 87,9 (roughly 2,9%) of the variation in recorded body weight at the end of testing. It was shown that the use of the GrowSafe proprietary algorithm (used to predict body weight from partial body weight), strengthened these co-efficients of determination to 95.1 (roughly 0,9%) and 94,9 (roughly 0,8%) for the start and end testing efforts, respectively. These findings implied that ADG may be measured with sufficient accuracy with a more efficient test period of 50 days, using partial body weights. The application of this equipment to run specialised experiments on the effects of crossbreeding cattle speak to the first of its kind worldwide. The study results have been published in the journal of *Translational Animal Science.*

Impact of equipment

The data collected from this piece of NEP-funded equipment has been used for multiple research activities in the past 6 years, therefore, further contributing to the expansion of academic knowledge in the areas of livestock breeding and climate change. The topics explored have included:

- The use of crossbreeding to mitigate the effects of global warming
- The effects of climate on the post-weaning performance and behaviour of different genotypes
- The effect of climate change and thermal adaptation on the DNA methylation in different genotypes
- The quantification of the effect of weather patterns on behaviour of beef cattle
- The estimation of full body weight from partial body weight for South African genotypes (research collaboration with Vytelle and GrowSafe)
- Investigating the optimal feeding periods for indigenous breeds with the objective of optimizing climate-smart beef production methods
- Developing Temperature Humidity Indices and early warning systems for heat stress f or beef and dairy cattle that are specific to South African Conditions.

The abovementioned research endeavours have direct alignment to *The Climate Change Adaptation and Mitigation Sector Plan* developed by the Department of Agriculture, Land Reform, and Rural Development (DALRRD).[78] In September 2020, the Minister of the DALRRD had quoted the abovementioned research endeavours as part of departments efforts and plans to address the impact and/or challenges of climate change on livestock production and animal health.

The GrowSafe system can measure Residual Feed Intake (RFI), which allows farmers to select bulls that consume less feed for the same level of production. This will improve both profitability and efficiency in production. It has been shown that cattle with low RFI can produce less manure and up to 28% less methane from enteric fermentation relative to their high RFI cattle counterparts. This information, relevant for breeding selection, is now accessible to the farmers for the bulls tested by farmers using the GrowSafe System.

Primary beneficiaries and associated outputs

Students have benefited from this equipment in two ways; (a) students are able to do experimental training with this equipment; (b) Master's and PhD students are able to make use of data collected by this system for their research endeavours. Students completing technical degrees require two years of training and one year of practical application; through the acquisition of this equipment, ARC can accommodate these students for the practical portion of their studies. The table below highlights some key academic outputs and research topics in 2021.

Cumulative GrowSafe related research outputs (2019 – 2021)

Research outputs	Count
Articles in non-refereed/ non-peer-reviewed journals	35
Significant conference outputs	22
Articles in refereed/ peer-reviewed journal	8
Technical report	7

[78] *Parliament of the Republic of South Africa, 2020. National Climate Change Adaptation Strategy*

Book publications	6
Chapters in books	3
Other recognised research outputs	2

Source: Grant holder interviews and progress reports

GrowSafe related research topic highlights

Level of Study	University	Research Topics
Masters Student (AgriSETA funded)	University of South Africa	Made use of the GrowSafe data to carry out a specialised study on animal behaviour and performance among different cattle breeds.
Masters Student (NRF bursary)	Tshwane University of Technology	Made use of the GrowSafe data to develop an equation that uses partial body weight to estimate full body weight of different sized cattle in South Africa. This has also led to a collaborate efforts among experts in New Zealand, Australia, Canada, and the USA to develop a regression equation which can correspond better with indigenous South African breeds (given that the existing equation in the body of literature is specific to Canadian breeds of cattle).
Masters Student (ARC NRF PDP student)	University of the Free State	Made use of samples collected by the GrowSafe system to study the impact of NDA methylation in two diverse genotypes. To date, no other studies have reported on how weather patterns are associated with the DNA methylation patterns in different beef cattle breeds.
Two PhD Students (ARC and Northern Cape Department of Agriculture)	University of the Free State and Cape Peninsula University of Technology	Interest has been shown by two employees of the ARC and Northern Cape Department of Agriculture to make use of the GrowSafe data to complete their PhD studies.

Source: Grant holder interviews and progress reports

Key collaborations and external users

Findings from the grant holder interviews and APRs indicate that private sector collaborations and collaborative efforts with several other universities have come about through the acquisition and use of this equipment system. GrowSafe Pty Ltd has also combined with Vytelle to create a “Leader in Bovine Biotechnology”. The new company seeks to link industry-leader reproduction technologies with genetic evaluations into a single process. The equipment has also been utilised by local farmers to test the performance of 24 of their bulls, so that the best animals are selected for breeding. The table below indicates the number of bulls tested for the Vaalharts crossbreeding project.

The Vaalharts crossbreeding project

Year	Number of bulls tested
2017	90
2018	113
2019	146
2020	135
2021	130
Total	**614**

Source: Grant holder interviews and associated reports

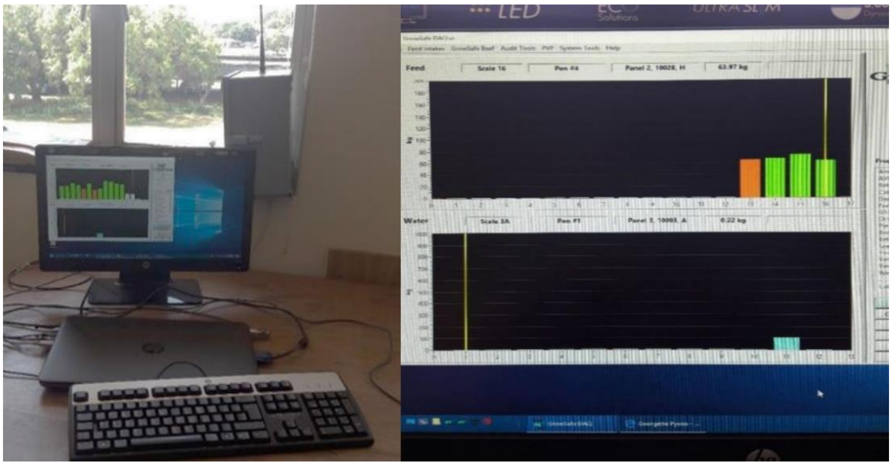


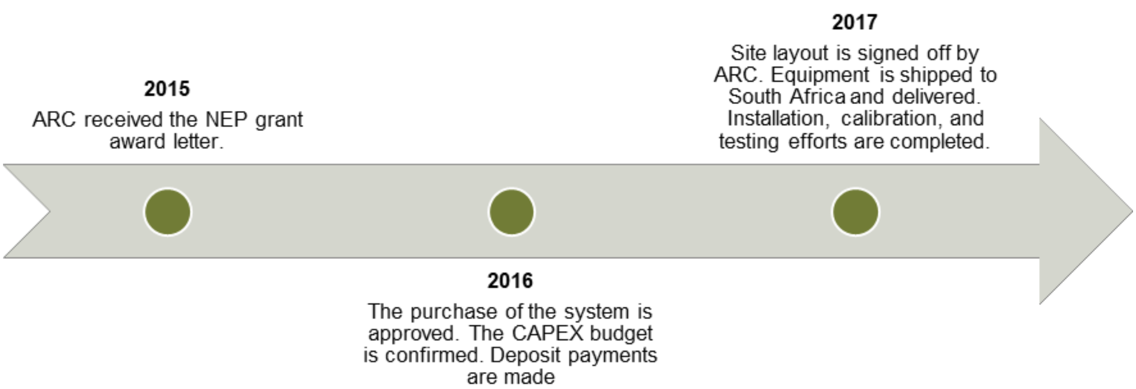
Image: The Software connection and electronic setup of the GrowSafe Equipment System

Key challenges

While the acquisition and use of this equipment has led to several successes and meaningful impact, the following procurement challenges were experienced:

- During shipment, this system was marked as "Agricultural Equipment", however, the equipment contains a large electronic component, which did not fit the definition of this label. This led to a delay at customs upon arrival. Further delays were experienced when the container that was transporting the system from the Durban port to the institution was searched for drugs.
- The Covid-19 lockdown restrictions delayed the transportation of cattle from the Vaalharts Research Station in the Northern Cape to the GrowSafe system in Irene.
- Power failures and scheduled loadshedding posed operational risks, despite the use of back-up generators and batteries. The disruption in the power supply had resulted in additional costs associated with the damage and subsequent need to replace parts of the equipment system. Back-up data storage platforms have been created to combat potential data loss during storms and power outages.
- When power disruptions have resulted in the loss of data, averages from the data collected on the previous and subsequent days have been used to fill in the data gaps.
- The animal ear tags were frequently lost, although the system does notify users when the tag has fallen off and there is a need to retrieve and replace the tag immediately to avoid data loss. A solution to this problem was to place personnel on the campus fulltime, so they may attend to the data-loss issues immediately.

The NEP Grant Award and Procurement Timeline for the GrowSafe System



Source: Grant holder interviews and associated reports

In the 2020 APR, the grant holder reported that the GrowSafe System needs to be upgraded to improve data quality. The upgrade will cost R450 000 and has been included in the CAPEX budget for ARC Animal Production for 2021/22.

7.2 Case study 2: High Vacuum Heat Treatment Furnace for Titanium Alloys

In 2015, an NEP grant was awarded to the Central University of Technology (CUT) for the purchase of a high vacuum heat treatment furnace for titanium alloys. This equipment makes up a vacuum system consisting of a basic furnace, a pump system, and a cooling system. To operate the system, several facilities needed to be in place, including a specialised power supply, and specified water and gas systems. The equipment is used for heat treating to test and understand the quality of 3D printing titanium alloys, used for medical implants. There was a time where this type of treatment could be done at one other South African institute, however, that equipment was outdated and so brought about the need for this equipment, which also has aerospace applications.


Image: The High Vacuum Heat Treatment Furnace for Titanium Alloys

Equipment application

This specialised equipment system has been used to produced customised and certified medical implants through Additive Manufacturing (AM) processes. In 2020, the data generated by the NEP testing equipment was used to further validate the procedures that form part of the ISO 12485 quality management system. It is under this quality management system that manufactured medical implants are certified. The equipment is specifically used to perform heat treatments on the titanium alloys during the manufacturing of 3D printed medical implants. Titanium and titanium alloys are heat treated for several reasons, namely:[79]

- To reduce residual stresses developed during fabrication (stress relieving)
- To produce acceptable combinations of structural stability and ductility
- To increase strength and optimise microstructural and mechanical properties
- To prevent chemical attacks in corrosive environments
- To prevent distortions

The research that has been enabled through the acquisition of this equipment is new and relevant, for example, researchers are currently looking into gas quenching solutions for

[79] *Donachie,D, 2001.Titanium and Titanium Alloys*

materials used in implants that are prone to oxidisation. This equipment is necessary to conduct research on potential solutions that look to combat these issues and ensure safe medical implants.

While the equipment is being fully utilised for its medical purposes, for capacity development and knowledge generation; to benefit the medical patients that receive these locally manufactured implants; to further develop local knowledge by training students; to encourage collaborations among related suppliers and manufactures; to contribute to the existing body of knowledge through research, development, and innovation methods, the equipment is not being utilised for its aerospace applications. The reason being that aerospace standards are stringent and require more frequent replacements of the consumables used to run this equipment (replacement of the couples after every 5 uses). This is a costly endeavour that would require additional funding from that provided under the NEP.

Impact of equipment

During the past five years, directed research data was produced and published to prove that medical implants produced through Direct Metal Laser Sintering (DMLS) can fully comply with the accepted international standards for the material, physical, chemical, and mechanical properties of such parts. The quality management system was established successfully, materials research projects have been executed to generate validation data, and numerous customised titanium implants have been produced to restore the quality of life of patients. Through control of the DMLS process, qualified post DMLS processes, including the vacuum heat treatment of these implants, a qualified process chain, supported by validation data generated through research on processes and products for production of customised medical implants under the ISO 13485:2016 quality management system, has been maintained.

Primary beneficiaries and associated outputs

The NEP equipment is placed at a centre that has two streams of service offerings; (1) the supply for services to external clients or researchers; (2) the research stream for internal users, including students and faculty members. In the former case, the institution has a joint track record with leading orthopaedic and prosthodontic surgeons, of applying AG to produce maxillofacial medical implants used in reconstructive surgeries. Many of the patients that have received these implants have skeletal defects brought about by cancer. The improved quality of these implants has subsequently led to improvements in the quality of life of these patients. Furthermore, having access to the vacuum furnace system in-house enables the grant recipient institution to supply these services in an efficient and cost-effective manner. The institution is also able to embark on research efforts needed to turn their manufacturing efforts into a commercial advantage for the local industry. This can make a valuable contribution to wealth creation in the region and across South Africa through the creation of possible spin-off businesses.

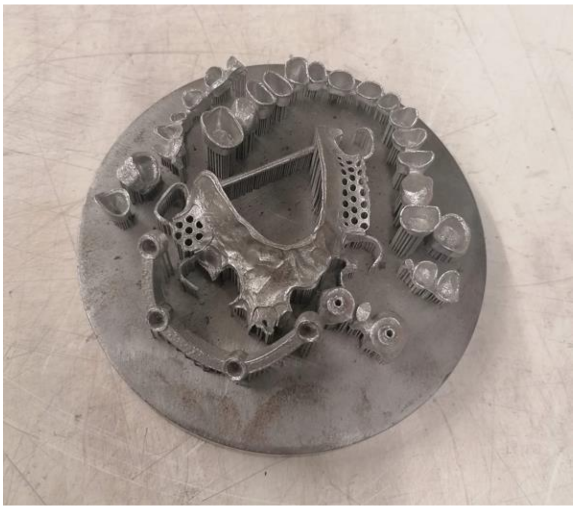


Image: Prototypes produced using the High Vacuum Heat Treatment Furnace

In the case of the latter stream, post graduate students can make use of the subsequent data produced by the equipment system for their own research endeavours, and engage in opportunities for shared learnings in terms of operating this specialised equipment. While students and faculty staff are not able to operate the system themselves, they are able to observe the efforts of the dedicated operators and technicians who are trained to make use of the equipment. In this way, a new generation of young scientists and engineers will be afforded the opportunity to be trained on this state-of-the-art equipment.

Cumulative high vacuum heat treatment furnace related research outputs (2018 – 2021)

Research outputs	Count
Significant conference outputs	-
Articles in refereed/ peer-reviewed journal	19
Other recognised research outputs	3
Prototypes produced	2

Source: Grant holder interviews and progress reports

To ensure continuous improvement of the operation and maintenance of the high vacuum heat treatment furnace system, the project engineer responsible for the day-to-day operation and maintenance of the system also received further training to better equip him for his job. In April 2019 he spent a few days at the CSIR in Pretoria, with specialists that have been responsible for the CSIR heat treatment facilities since the early 1990s. The operator also attended an online training course that is aligned with the ARP1962A: Training and Approval of Heat-Treating Personnel.

Key collaborations and external users

The grant holder has made efforts to operate in a way that links to sub-programmes within this specialised field. The grant holder has engaged in collaborative efforts with four initiatives, each with their own funding stream, namely:

- Collaborative Programme in Additive Manufacturing (CPAM)
- South African Research Chair – Medical product development through AM
- Innovation and Commercialisation of Additive Manufacturing Chair
- Medical additive manufacturing demonstrator programme (MED ADD).

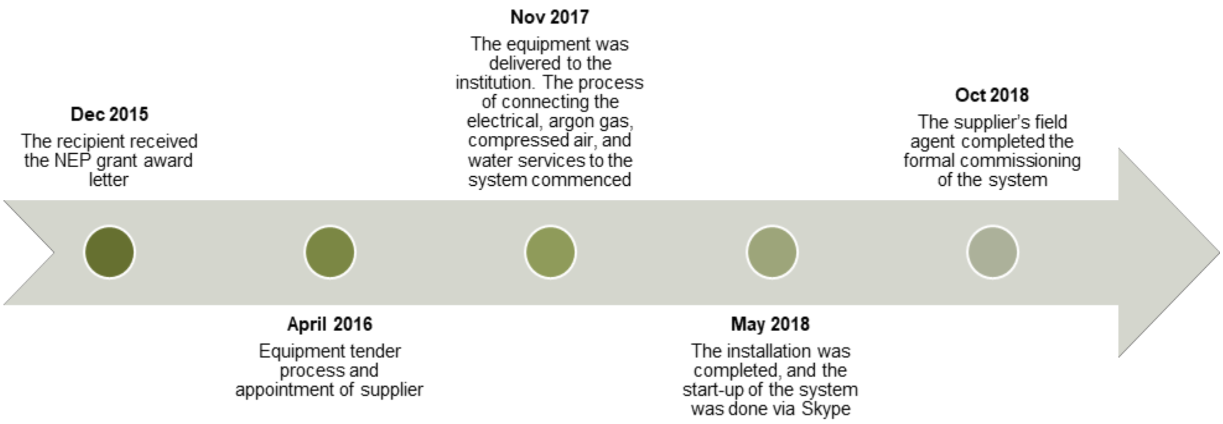
The abovementioned initiatives have allowed for the commercialisation of their manufactured products as well as the development of a production chain for medical products of this nature.

External equipment users include researchers and students from the following institutions:

- Researchers from the CSIR National Laser Center
- Collaborators from the CSIR MSM
- Postgraduate students from the Vaal University of Technology (Vanderbijlpark Campus)
- Researchers from the University of Cape Town
- Private sector clients from Southern Medical and POLYOAK
- Researchers from Stellenbosch University.

Key challenges

The NEP Grant Award and Procurement Timeline for the high vacuum heat treatment furnace



Source: Grant holder interviews and associated reports

While the acquisition and use of this equipment has led to several successes and meaningful impact, the following challenges were experienced:

- It took nine months to get the system released from the supplier and arrive in South Africa. Due to South Africa's poor credit rating, a letter of credit for the last 10% payment had to be provided before the supplier would release it.
- Only upon arrival of the system was it realised that the heat exchanger for the closed loop water cooling system needed a custom-designed structure for mounting it to the outside of the building. Therefore, an external contractor had to be appointed to construct and install the frame to the building and connect its piping to the closed loop cooling system. However, due to the Christmas break this contracting process could not be concluded in December 2017. This installation started in January 2018 was completed in February.

- The supplier's engineer, who is responsible for the on-site commissioning and certification of the High Vacuum Heat Treatment Furnace system, was not available until October 2018. It was agreed with the supplier that a start-up of the system would be done via Skype.
- The tender process for acquiring the equipment was cumbersome and time consuming.
- Difficulties were experienced with regards to meeting the facilities' requirement for storing the equipment. This led to unforeseen and additional expenses, including the installation of a specialised power supply, water, and gas systems to run the system. They also needed to acquire a heat exchanger. Although they had a laboratory facility to store the equipment, the heat exchange system needed a support structure. The external heat exchanger also needed a structure for storage. While most of this could be funded through the NEP grant due to exchange rate changes, there is a need to bring about opportunities to apply for additional funding.
- During COVID-19 all operations came to a standstill when the operators couldn't access the equipment due to the lockdown restrictions.
- The furnace system could not be used from March to August 2019, while the MM200 controller was being repaired by Televac in the USA. This experience led to the decision to purchase a second controller system, an MX200, to ensure uninterrupted heat treatment service even when one of the controllers is being calibrated or repaired.

7.3 Case study 3: Electron Microscope Unit

The University of Cape Town's (UCT) Electron Microscope Unit (EMU) provides a central microscopy service across the university, and to research units at other universities, research institutions and private companies. The EMU houses a number of pieces of equipment, with services including electron microscopy, light microscopy, and digital imaging.

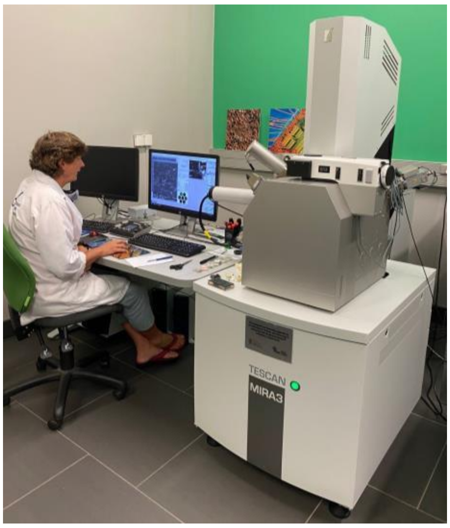


Image: Electron Microscope Unit

The NEP supported the purchase of a Ramen Integrated Scanning Electron (RISE) microscope, along with supporting accessories. The RISE unit combines two microscopy techniques. In Scanning Electron Microscopy (SEM), a focused high energy electron beam is used to scan the surface of a sample and by collecting backscattered and secondary the electrons, the surface structure, morphology, topography, and materials orientation of the sample can be characterised. Confocal Ramen Imaging analyses the chemical bonds in a sample and is able to provide a view on the distribution and characteristics of chemical components of a material, including providing 3D/depth profiles. Including these techniques in a single unit offers a wealth of analytical possibilities.

The RISE unit purchased with NEP support was commissioned in 2017. It is housed in the EMU, which was purpose built for such equipment, including providing the necessary air filters for clean working environments, uninterrupted power supply (UPS), vibration control, cooling, magnetic shielding etc. UCT supported the establishment of this infrastructure. In addition, the necessary sample preparation areas and equipment are in place, as identified at the time of the visit.

The equipment is, on the whole, well utilised and is considered to largely be “fit for purpose”, although there are some limitations due to fluorescence in certain samples (although a future upgrade to an alternative wavelength laser could overcome these). Furthermore, some analyses require certain skills which can take time to acquire and master.

In 2018 it was reported to have been used for 896 hours by 69 people from 23 departments, and was fully operational for the year apart from the December closing period, and 31 days that were lost due to breakdowns and maintenance. The Covid-19 pandemic coupled with a transition to a new director did, however, result in limited usage in 2020. The wide usage is reflected in the progress reports submitted by the grant holder: an extensive list of users is identified, along with a set of key impact projects that are directly linked to the equipment usage. Furthermore, a number of science engagements linked to the equipment are identified. Having said that, the value in structuring of equipment-specific facilities (rather than discipline-specific) such as this one as a nationally utilised centre, instead of one that is sustained solely by UCT was identified during the visit, given the importance and potential wide application of this equipment.

The unit has a well-established system for training users, booking usage, and maintaining logbooks, which were explored during the visit. Once a person has been trained to use a piece of equipment and are competent to use it themselves, they can book a slot through an online system. Some bookings need approval before they are confirmed. Log sheets are used to record actual usage, problems encountered by users, time of use, department, etc.; all information that is used to do billing. In terms of usage charges, there are some complaints that these are too high, although the charges are still below cost recovery.

In terms of maintenance, an onsite technician keeps a record of all issues, how frequently they arise, and solutions to the issues. At the time of the site visit it was largely operational, although the unit was waiting on a card which had broken, but this was considered part of normal operation/maintenance, and the waiting period for this card was not considered unacceptably long. It was identified that maintenance of the equipment is a challenge, given that the NEP grant did not include a maintenance budget. UCT does have certain mechanisms in place for emergency repair and maintenance, which has been accessed by the unit, but these funds are limited. The question was raised as to how smaller institutions which do not have UCT’s resources would be able to maintain such equipment if maintenance is not included in their grant. Maintenance also becomes more of a challenge as equipment ages, and in South Africa such equipment is often used for longer than in other parts of the world where it is replaced more frequently.

The visit indicated that there was a highly competent staff complement, including those skilled in sample preparation, analysis using the equipment, and maintenance. The head of the unit recently changed from Prof Sewell (the grant holder) to Prof Rob Knutsen who is well skilled in this area.

7.4 Concluding remarks

The case studies provided above highlight three cases where equipment purchased through the NEP has contributed to significant research achievements and human capacity development within the country. A summary of learnings are used to guide the formulation of recommendations for improving the NEP as follows:

- The Growsafe case study demonstrates how RI can be used for commercial opportunities, including the partnership with Vytelle.
- Both the High Vacuum Heat Treatment Furnace and the EMU equipment provide excellent examples of how RI funded through the NEP has been used to form collaborations. However, these opportunities do depend on the type of equipment funded (the GrowSafe Feed Intake and Beef System is particularly niche).
- Furthermore, the EMU's training, access, and booking systems appear to be well developed, and could provide learnings for others with similar set ups.
- Risk planning should form a critical component of equipment acquisition and installation. While the Covid-19 pandemic could not have been planned for, load shedding is a foreseeable risk, and power backups (including those for data records to prevent data loss) should be budgeted for and included in the installation.
- Additional funding should be made available for ongoing maintenance as well as equipment upgrades when equipment becomes obsolete.

8. EVALUATION FINDINGS

The presentation of the evaluation findings is structured according to the key evaluation questions (EQs) presented in Table 1 of this report. In answering the evaluation questions, the data collected during the evaluation has been triangulated across all of the different sources. Consideration is also given to the programme Theory of Change.

8.1 EQ1: To what extent has the design of the NEP enabled the achievement of its intended objectives?

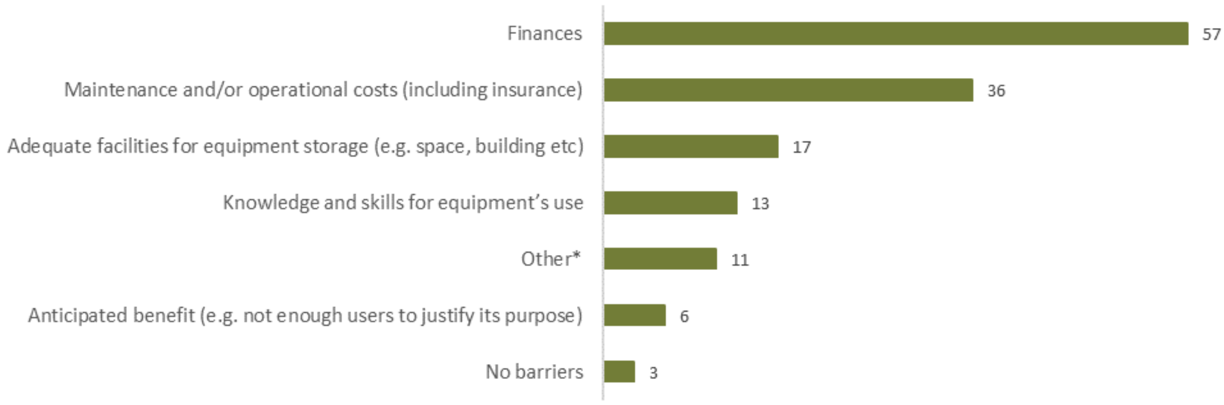
This section investigates and assesses how the NEP was conceptualised and intended for implementation.

Summary of finding: The evaluation finds that the NEP is well defined in its programme design and is aligned with the broader research infrastructure programme that is being driven by the DSI. The NEP fulfils an important and unique role in South Africa's R&D programme - it is clear from the results that in its absence, most institutions would not have access to state-of-the-art equipment. It does not duplicate the efforts of other government activities and was found to align with international programmes in the benchmark review. However, the programme's design could be strengthened with the provision of additional or supplementary funding to cover operational and maintenance costs, which were identified as a gap in ensuring optimal equipment usage (which is a key assumption underlying the programme's Theory of Change). It is highlighted that the design of the programme as it stands does not specifically focus on capacity building at HDIs or gender equality, which was included in the original conceptualisation of the NEP.

As demonstrated in the literature review (Section 3), the role of the national system of innovation (NSI) in the development of the country is clear. The vision for how science and technology can be used to drive progress towards a knowledge-based economy to ensure economic growth and socioeconomic reform is clearly outlined across several policy documents, including the DST's Ten-Year Innovation Plan, the NDP, as well as the White Paper on Science and Technology. Key to this effort is the provision of research infrastructure and the development of highly skilled human capital. For this reason, the DST allocated funds to the National Equipment Programme through the National Key Research and Technology Infrastructure Strategy, which aims to equip South African research institutions with state-of-the-art research infrastructure to advance the national R&D agenda.

The core objective of the NEP is thus to provide funding for state-of-the-art equipment to universities, science councils, national research facilities, and museums. Grant holders surveyed in the evaluation reported that the greatest barrier their institutions faced in acquiring state-of-the-art equipment was the lack of funds (**Error! Reference source not found.**). Almost all (94%) grant holders indicated that their institution would not have been able to attain the equipment in the absence of their NEP grant. It is also interesting to note the important role that the NEP plays in contributing to addressing the barrier of lack of maintenance and/or operational costs identified in Figure 9.

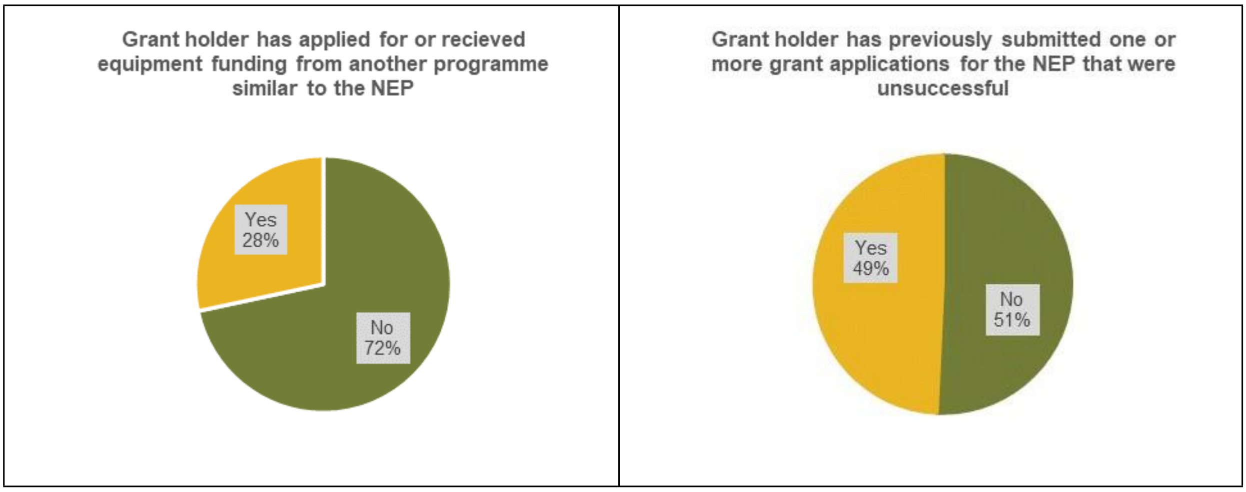
Figure 9: Main barriers to acquiring, upgrading, or developing equipment within grant holders' institutions



Source: Grant holder digital survey
n=67

Furthermore, over 70% of NEP grant holders had never applied for or received similar grants from other sources, despite about half of them having been unsuccessful in previous NEP grant applications (30% of previous applicants had been unsuccessful more than twice), signalling the important and unique role of the NEP in meeting their equipment needs.

Figure 10: Grant holders' access to equipment funding[80]



Source: Grant holder digital survey
n=67

Findings from the interviews conducted with university DVCs and Research Officers indicate that universities align their research equipment strategies with the NEP, particularly well-resourced universities. Universities plan their research equipment strategies starting at the faculty level, with faculty committees reviewing equipment plans before these are sent to the institutions' research committee. Faculty committees prioritise the equipment required for the specified period, and this priority list is then considered by the broader committee when funding applications to the NRF are made. One institutional representative said: *"It depends*

[80] *Grant mechanisms similar to the NEP included: Collaborative Program in Additive Manufacturing, DBSA Green Fund, DSI High-end infrastructure Grant, FWO (Belgium), Helmholtz Young Investigator Grant, IAEA TC grant, Institutional minor equipment and NLC-rental pool program, Netherlands Organization for Scientific Research (NWO), Newton, NNEP, NRF: e.g. rated researcher, Other NRF grants such as CSRR, The German DFG, UCT's Faculty of Science, Wellcome trust, Carnegie Corporation of New York, DST, MRC LMB(UK), Wits Faculty.*

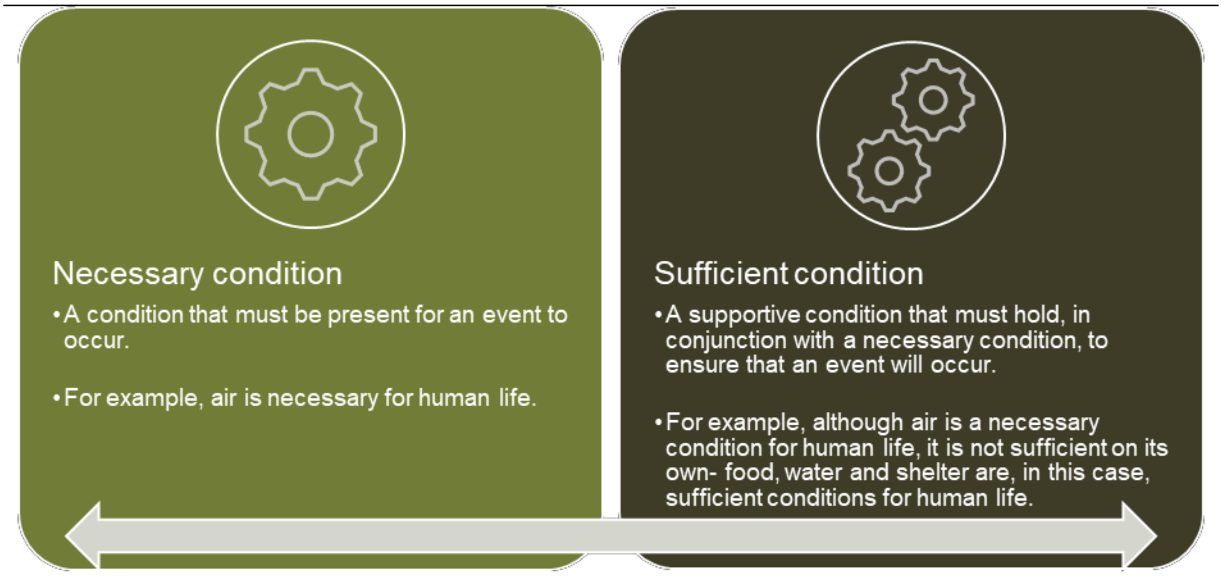
on the cost of the equipment we are looking for, the pricier the equipment the more the university has to look at the NEP".

The NEP is designed to ensure co-investment in the equipment. This is done through a condition that requires host institutions provide one-third of the cost of the acquisition of the equipment, while the NRF provides the remaining two-thirds, between R1 million and R10 million. The institutions confirmed that having to commit their own funds towards the acquisition and maintenance of the equipment ensures accountability, ownership, and a vested interest in the ongoing use and maintenance of such research infrastructure. Institutional contributions are paid using faculty or departmental budgets, from Research Councils, government subsidies, and funding received from industry.

Some of the gaps identified in the design of the funding model pertained to the funding ceilings and operational costs. The feedback received from the grant holder interviews indicates that while most grant holders found the R10 million funding cap to be sufficient to procure state-of-the-art equipment, the lower cap of R1 million was somewhat restrictive. For example, some state-of-the-art equipment costs just less than R1 million, or equipment pieces that either perform enabling functions for larger equipment or improves the efficiency or competitiveness of the research, is excluded from the grant but it still unaffordable for many researchers. This 'missing middle' equipment also includes software and desktop equipment that enables the larger equipment to function optimally. Further, smaller equipment pieces under R1 million were anecdotally reported to make up the lion's share of equipment needs in certain fields and the competition for this niche funding is high.

When assessing the design of the NEP model, it is important to reiterate the role of state-of-the-art equipment as one of several inputs that foster the development of a holistic research environment in South Africa. Two concepts are crucial in this regard:

Figure 11: Defining necessary and sufficient conditions



Source: (Swartz, 1997)

The presence of the equipment funded by the NEP is a necessary condition to sustainably create competitive research across the R&D space in South Africa. Put differently, without the NEP grant funding, there are virtually no alternative mechanisms for researchers to obtain larger pieces of technical equipment that contribute to cutting-edge research.

However, there are many supplementary conditions linked to the development of competitive research outputs using the funded equipment, including:

- Researchers must have funding to cover non-equipment related costs associated with research, including the cost of consumables, the salaries of technicians and operators, and other related research costs;
- The equipment must be maintained to be in working condition;
- Researchers must have the skills necessary to utilise the equipment optimally; and
- There must be sufficient interest in the field of research to which the equipment is applicable.

While both necessary and sufficient conditions must hold true to enable innovative research, the NEP addresses the necessary condition (providing state-of-the-art equipment) but there is seemingly little to no support offered for the establishment or development of the abovementioned sufficient conditions. During the interviews, grant holders reported difficulties in covering the following equipment and research related costs:

Medium-to-long-term maintenance costs – once the initial 3-year maintenance plans and policies expired, institutions were left with the ongoing cost of financing maintenance plans and policies. The failure to renew equipment maintenance plans would compromise the optimal usage of the equipment over time, which ultimately negatively impacts the achievement of intended programme impacts. The grant holders have yet to report any external channels for equipment maintenance support and there is a strong reliance of the institutions' ability to continue financing these equipment maintenance costs.

Operational costs – these include the costs associated with consumables (which vary by equipment piece), as well as the salaries associated with employing part-time or full-time technicians and operators. An inability to fund the costs of the consumables required to utilise the funded equipment could lead to the occurrence of "white elephant" equipment pieces. One such instance was found among the sample of grant holders, whereby the costs associated with running the NEP equipment were so great (in the ballpark of R50 000 per experiment) that it wasn't being used at the time of the evaluation due to lack of funds available. As indicated in Figure 9 above, finances, maintenance, and operational costs were the leading barriers identified by grant holders to acquiring, upgrading, or developing equipment. In the absence of alternative funding mechanisms, the employment of equipment technicians and operators is strongly dependant on the institutions' ability to finance the salaries of such experts. Funding for the operational costs ensures that the equipment can be optimally used.

General funding costs – general R&D funding was also identified as a gap in the research system in South Africa. Often, R&D efforts are costly and pose a high risk in the sense that there is no guarantee of generating new research developments. As a result of this, grant holders have reported a tendency for researchers to make use of existing tried and tested methods, that are reliable and pose few risks in the way of producing results, instead of engaging in efforts to develop new, cutting-edge methodologies. In this way the lack of general funding is stifling the willingness of South Africa researchers to push the boundaries of innovation.

On the basis of the above, three key ways in which the design of the NEP funding model can be improved to address these funding concerns include:

1. Providing matched maintenance and operational funding;
2. Providing funding to cover the salaries of the equipment operators and technicians;
3. Providing an additional 10% of the grant value for maintenance and further training, which can be accessed in the 4th or 5th year; once the initial maintenance contract has expired.

Expanding the scope of the NEP grant to include additional maintenance support is also in line with international best practice. Evidence from the benchmarking exercise indicated that programmes in Australia and Singapore, namely, the Linkage infrastructure, Equipment, and Facilities (LIEF), the National Collaborative Research Infrastructure Strategy (NCRIS), The

National and Medical Research Council (NHMRC) Infrastructure Support and Equipment Grants, and the National Research Infrastructure programme, all offer maintenance support as part of their equipment funding models.

As a final observation in terms of the design of the NEP, it is highlighted that the design of the programme as it stands does not specifically focus on capacity building at HDIs or gender equality, which was included in the original conceptualisation of the NEP. Having said that, the extent to which HDIs and gender equality are impacted by the programme are explored in the sections that follow.

In conclusion, the design of the NEP may be further enhanced with the provision of supplementary funds to maximise the usage of the funded equipment. While there is a trade-off between providing fewer high-value grants and more low-value grants, in the sense that larger grants allow for the acquisition of more sophisticated pieces of equipment, there is value in ensuring that supplementary funds are available to enable research efforts (and equipment usage) beyond the grant period. The NEP may wish to consider alternating (low and high value) grant offers between call periods.

8.2 EQ2: Has the NEP been implemented as envisaged?

This section assesses how the programme has been implemented in practice, highlights consistencies and deviations from the design that came about during implementation, and looks to identify, if any, implementation failures.

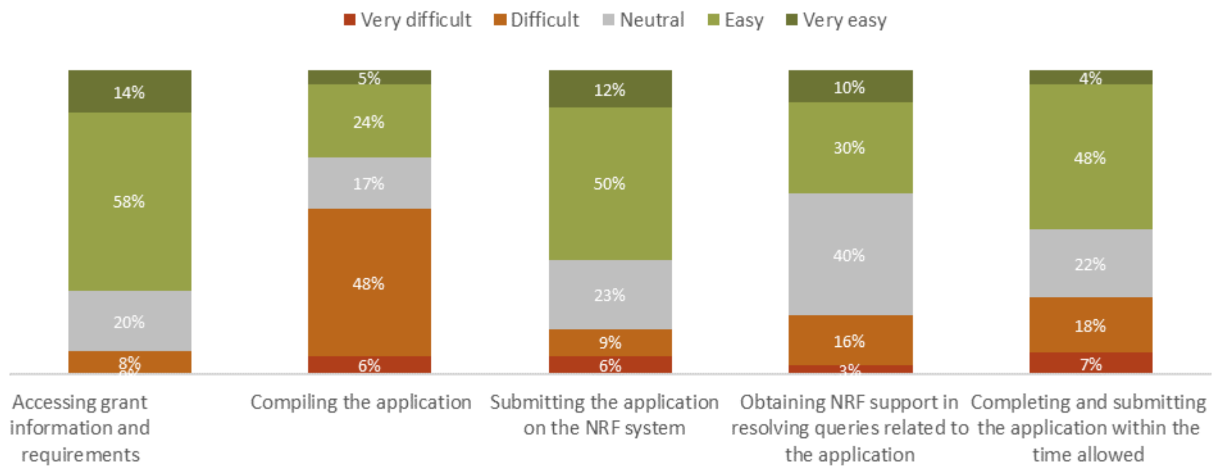
Summary of finding: The evaluation finds that the NEP has been implemented as planned overall. Several challenges were identified that have affected the roll-out of the funding, including the unpredictability of funding for grant calls and delays in the commissioning of the equipment, due mostly to external factors.

8.2.1 State of implementation

Application process

When a call for proposals is circulated, the NRF conducts a briefing meeting to take interested applicants and administrators through the call documents and application process. In recent years, the NRF has also hosted proposal development workshops for interested parties, particularly applicants from HDIs, that are planning to submit an application. The workshops are run by facilitators that either have experience in working with high-end research infrastructure, who had previously applied for a grant, or have served on the review panel. The requirements for the grant and information on how to compose the application are covered in detail during the workshop. Institutions requiring further or more in-depth support may also approach the NRF for such support, which is provided on a one-on-one, informal basis. In addition, institutions can invite the NRF to present a briefing on the NEP prior to the release of a funding call. Despite all of this support being available, during the grant holder survey, many respondents (54%) reported experiencing difficulties with compiling the NEP application (Figure 12).

Figure 12: Grant holder ratings of the NEP application process



Source: Grant holder digital survey
n=67

Grant information

Most survey respondents reported being able to access the grant information and requirements for the NEP. This was echoed during the grant holder interviews, where they noted that they had generally been made aware of the call from their institutions or by regularly checking the NRF's website. However, this was not always the case; some grant holders, particularly those from HDI's, indicated that they weren't prepared for the application as they were not aware of when to expect the release of the call, which impacted on their ability to plan for and compile the proposal. It is the duty of the institutional research office to share funding calls with relevant researchers, which points to communication issues within the institution in these instances.

Compiling the application

More than half of the survey respondents indicated that the application was difficult to compile. This was supported by the feedback provided by grant holders during their interviews, in which they identified several difficulties. Firstly, grant holders from HAIs and better resourced universities reported receiving more institutional support in preparing grant applications than those from HDI's. HAIs and better resourced institutions have skilled Research Officers and established researchers, some of whom have served on the NEP review panel or have attained NEP grants in prior years, and therefore have a good understanding of what is required. Grant holders at these institutions therefore benefit from the institutional support provided, which includes internal review committees that have input to the proposals to ensure quality before they are submitted to the NRF.

Some of the larger universities even release internal grant calls ahead of the NEP call in order to select the top five applications for submission to the NRF. Interestingly, the universities in the Western Cape were found to collaborate and strategically plan the equipment required within the province and then assign applications to the different institutions. Grant holders from HDIs and institutions with fewer resources felt disadvantaged in this regard since they did not have the same institutional support, and had to approach the NRF directly for queries as there was no institutional knowledge available to them.

This finding was supported in the interviews with programme managers from both the DSI and NRF, who noted that proposals from HAIs and research-intensive universities were generally of a better quality than those received from HDIs. It was noted that Research Officers at better resourced universities also review the proposals to ensure alignment with the university strategic plan, and to endorse the application (with regard to the co-funding and how the equipment will be deployed), which also carries weight in the review process.

The programme managers noted that researchers at HDI's and poorly resourced universities do not have access to this robust mechanism and are also generally less experienced. In this way, while the NEP is open to all universities, HAIs and research-intensive universities seem to have a competitive advantage.

The programme managers from DSI referenced the DHET review of HDIs, which identified several structural and capacity issues that impact on the ability of HDIs to attain grant funding. While DHET is in the process of addressing these issues, they are complex and will require significant time and effort. The NRF has attempted to address this issue by undertaking interventions, such as the pre-proposal workshops mentioned above, to assist HDIs or grant holders applying to the NEP for the first time to improve their proposals. However, they noted that they uptake of these workshops has not been as high as was hoped and that the workshops have not impacted on the quality of the applications in a significant way.

Furthermore, one of the key requirements for the NEP application is being able to demonstrate a strong publication record or work track record in the area of research for which the equipment is being applied. Grant holders from HDI's or smaller teaching (vs research intensive) universities generally don't have a publication track record specific to the research area or evidence of specific expertise in the area. For example, one grant holder from a HDI had been unsuccessful in four previous applications for the NEP as he did not have the required track record. This again speaks to the broader capacity issues at HDIs, who generally struggle to attract prestigious researchers with longstanding academic careers.

A few of the grant holders from smaller institutions thus felt that it was unfair for HDIs to be judged against the same metrics as more established and better resourced institutions. They noted that the demand for the equipment at poorly resourced institutions may be low in absolute terms but high in relation to the size of the faculty or division, making the receipt of a grant even more important for the HDI. However, the lower absolute demand may disadvantage these applications given the lower number of users anticipated to benefit from it, even though the greater benefit to the institution would be substantial. The introduction of a 'relative need' metric may help to address this issue. Alternatively, one suggestion made during the interviews with programme managers from the DSI was to ringfence targeted funding to capacitate HDIs specifically, in order to level out the competitive advantage held by HAIs, and to capacitate them to become more competitive both locally and internationally.

Another challenge that grant holders identified with regard to the NEP application during their interviews is the broad range of information required, which made the proposal onerous to develop. Some of the grant holders specifically struggled with trying to assess the potential demand for the equipment, noting that it requires some guesswork and also relies on prompt responses from potential users, which was not always possible. A few grant holders also felt that the request for information was vague or that the application framework is convoluted and that they did not always know how to respond. For example, one grant holder felt that the headings in the application form are ambiguous and that the request for information overlaps in different sections.

Some survey respondents also noted that the strategic priority areas required in the proposal were often decided in a vacuum. One of the requirements for the application is that the equipment should feed into a strategic priority in the science and innovation space. However, survey respondents indicated that there is very little space to question whether those strategic priority areas are appropriate given the country's context or not. These grant holders suggested that applications should allow applicants to provide reasoning for why they believe their piece of equipment is crucial to the science and innovation space in the country, even if that piece of equipment does not operate in the sectors seen as a strategic priority by the DSI.

Finally, some grant holders felt that applicants should have to declare any conflicts of interest when applying for the NEP, which is important for the review committee to assess.

Online system and NRF support

Most of the survey respondents indicated that the submission of the grant application on the NRF online system was easy enough, although a few noted that it could be improved to make it more user friendly and intuitive. The NRF also noted a challenge around applicants submitting their proposals close to the cut-off time, which overloads the system.

Timeline to compile application

While more than half of the survey respondents indicated that the timeline was sufficient to compile the application, many grant holders felt that it was too short, likely due to the timing of the grant call. While grant holders are given two to three months to compile their applications, some noted that compiling the application towards the start or end of the academic year was difficult, both because they had other academic responsibilities and because obtaining the required information for the application was difficult at this time. Others felt that the application time was too short given the vast amount of information required. Given the rigour required for the application, some grant holders suggested that the NRF extend the application deadline to allow sufficient time for the compilation of proposals. However, the NRF noted that the timelines are set in order to allow sufficient time for the review process and for awards to be made within the same financial year, and that it is therefore not flexible.

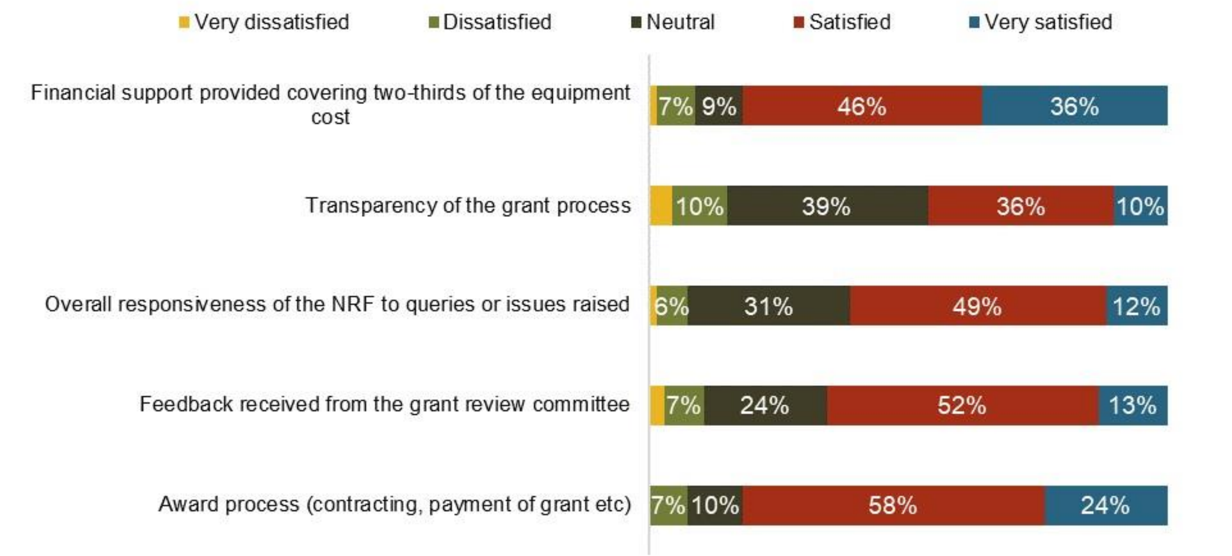
Review and award process

The NRF has amended the NEP review process based on learnings over the years. The initial approach included soliciting reviews from experts and then deliberating these in a panel setting. However, many reports were found to be inadequate using this method. The process was amended, as described in the overview section of the NEP (section 4.3), to include the appointment of two lead reviewers (based on the applications received) who compile and present a report for broader discussion within the panel. Two international reviewers are also invited to sit on the panel and review some of the applications. The programme managers at the NRF noted that this approach has worked well and has led to useful discussions in determining scores.

Over and above the scientific merit of the application, the panel also assess applications in line with the NEP's objectives, the number of grants awarded to an institution in prior years, the geographical spread of applicants, race and gender targets, the number of proposed users, and the amount requested, among other factors. The programme managers at the NRF noted that they had undertaken an analysis several years ago to understand why certain universities, particularly the HAIs, had received more awards than HDIs. They found that while HDIs generally had a good success rate, they had consistently submitted fewer applications than the HAIs or well-resourced universities over the years. That is, the HAIs had taken advantage of the allowance and submitted five applications for each call, which resulted in some of them receiving awards during every call. While the NRF try not to give grant awards to the same applicant in two successive years, this decision is determined by the funding available and the merit of the proposal, and has resulted in several grant holders being given more than one grant (in different funding cycles). This may again point to capacity issues among researchers at HDIs and poorly resourced universities, who may not be able to compile multiple applications at once given the absence of institutional support.

Grant holder survey respondents expressed mixed views about the application review process. In the digital survey, grant holders were generally satisfied with the feedback they had received from the grant review committee, although a quarter of respondents indicated neutrality on this item. During the interviews, some grant holders indicated that they had received little or no feedback about their application and some questioned whether the reviewers had sufficient expertise to review applications within very niche focus areas. The programme managers from the NRF noted that they have worked to improve the feedback process over the years and provide detailed feedback on the panel's decision to each grant holder. However, fewer than half (46%) of the survey respondents indicated that they were satisfied with the transparency of the grant process in the survey. Almost two-thirds (61%) of survey respondents expressed satisfaction with the responsiveness of the NRF to their queries or issues raised. Further, the majority of the respondents were satisfied with the award process and the structure of the financial support received.

Figure 13: Grant holder ratings of the NEP grant process

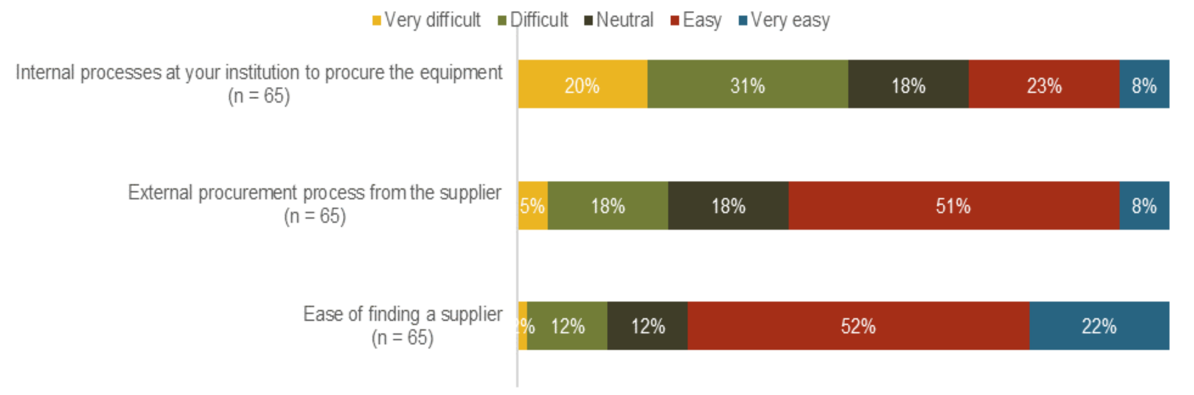


Source: Grant holder digital survey
n=67

More than half of the grant holder survey respondents (62%) indicated that they received the first grant payment within 6 to 12 months of submitting the application, while 20% had received it within 6 months, indicating an efficient grant award process. The majority of grant holders had used the grant to acquire new equipment (75%), with 18% using it to upgrade existing equipment, and a few using it to develop new equipment locally (7%). When asked to provide recommendations for programme improvement based on their experiences of the programme, one grant holder suggested that the NRF compile and circulate a guide regarding the post-award process, which would be especially useful for new grantees.

Equipment acquisition and commissioning
Most grant holders had commissioned their equipment within the specified two-year timeframe. During the grant holder survey, most respondents (74%) indicated that they were able to easily find a supplier for the equipment. They rated the procurement process as being generally manageable from the supplier's side, however, more than half of the grant holders (51%) experienced difficulties with the procurement processes at their institutions. This was confirmed during the grant holder interviews, where respondents indicated the large administrative burden of their institution's procurement procedures, including lengthy tender processes.

Figure 14: Ease of procuring the equipment once awarded the grant

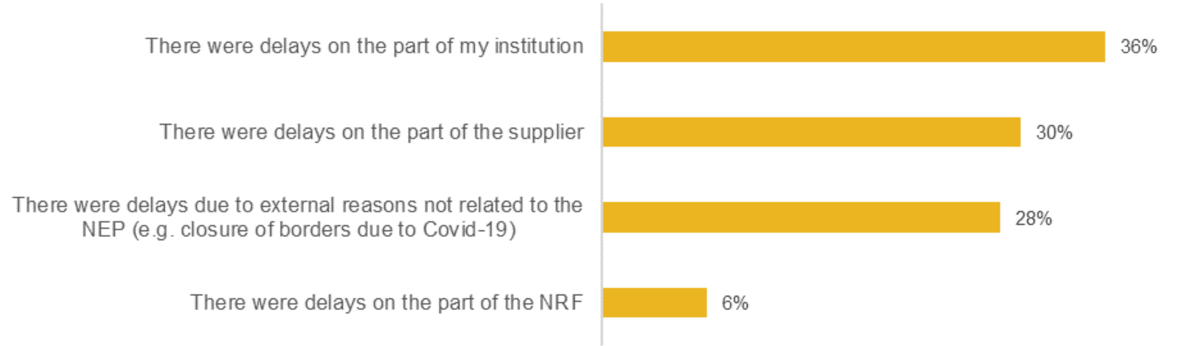


Source: Grant holder digital survey
n=67

Where grant holders had faced challenges in acquiring the equipment, it was mostly as a result of delays at their institution, on the part of the supplier, or for external reasons not related to the programme. Very few survey respondents reported delays on the part of the NRF, which again indicates the efficiency of the grant award process. During their interviews, some grant holders noted that the acquisition of the equipment was affected by global supply chain issues, which was compounded by the Covid-19 pandemic and delayed imports from international suppliers. Once received, almost all of the equipment was fully functional, except in a few cases where parts had been damaged or were missing, which had to be resolved with the supplier. In a few instances it was found that the equipment could only be used in certain seasons, which did not coincide with the anticipated delivery timeframe.

Exchange rate fluctuations also affected the acquisition of equipment; fluctuations in international currency values that occurred between the time of the award of the grant and the placement of the order often drove the cost of the equipment up and the institutions had to cover the shortfall. As a result, this left the institutions with unanticipated costs before the equipment could be purchased. Further, during their interviews some of the DVCs noted the creation of cashflow problems as a result of the structure of the grant. While 80% of the grant is paid upfront as the first tranche, some suppliers required payment in full before the equipment could be dispatched, which had to be paid by the institution or from the applicant's other grant funding alongside the one-third contribution, thereby creating cashflow issues. The final 20% tranche of the grant was only paid once the equipment was commissioned.

Figure 15: Reasons for delays in commissioning the equipment

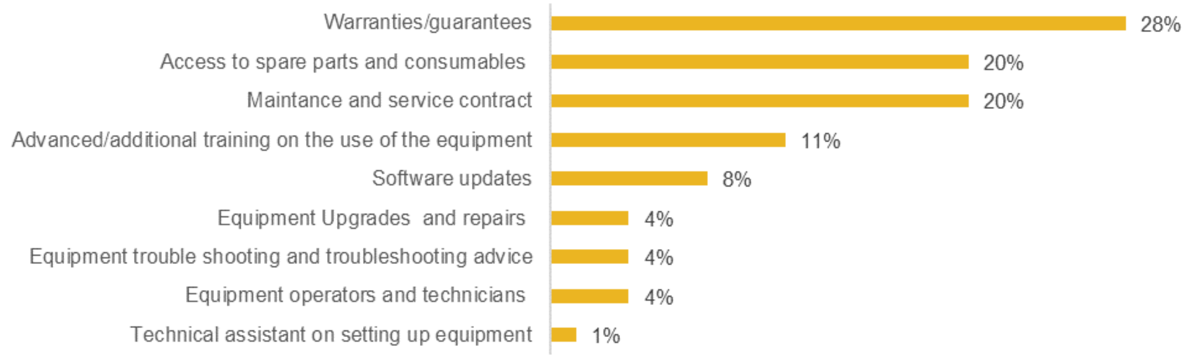


Source: Grant holder digital survey
n=67

During the grant holder interviews, almost all of the respondents noted that their institutions had the physical infrastructure in place to house the requested equipment, which is a requirement of the NEP funding. In a few instances the infrastructure had to be upgraded, and in one instance the equipment was too large to fit in the lab and had to be housed elsewhere, but the institutions were able to undertake this process independently. As a result, the housing for the equipment did not pose a barrier to its commissioning.

When asked what additional support they required from suppliers, the majority of grant holders indicated that they needed warranties or guarantees on the equipment (28%), access to spare parts and consumables (20%), as well as maintenance and service contracts (20%). Quite a few grant holders noted that it was difficult for them to get extended maintenance and service contracts from the suppliers to cover the 5-year period required by the NEP.

Figure 16: Additional support required from supplier



Source: Grant holder digital survey
n=67

Functionality of the equipment

Almost all of the funded equipment (96%) was operational and in use at the time of the survey. All respondents except for one (98%) indicated that the equipment acquired through the NEP was state-of-the-art. All of the grant holders that were interviewed during the evaluation were satisfied that the funded equipment met their needs. The operation of the equipment did incur costs, which is to be expected, including minor breakdowns or damage and ongoing maintenance. Breakdowns that require spare parts can take an extended period of time to address, given the need to import them or send them overseas for repair. The running costs of some pieces of equipment were very high, which impacted their use. The equipment maintenance costs were especially a concern at HDIs, where their limited capacity to cover these costs affects their ability to win NEP grants.

The grant holders noted how the Covid-19 pandemic had adversely affected their use of the equipment. Research activities, and therefore outputs, were delayed due to national lockdowns; some of the grant holders had to leave their equipment unmonitored during the hard lockdowns, which impacted their projects. The overall usage also dropped given restrictions imposed in accessing the facilities. Power outages as a result of loadshedding also affected some of the grant holders negatively; in one instance, the funded equipment is required to run 24 hours a day and required a generator and monitoring trips in the late hours of the night to ensure it was working. The impact of power outages was also noted in the case studies, where back-up systems for data recovery were required to prevent the loss of data collected using the equipment.

When asked about the challenges experienced with accessing the equipment, the RI users surveyed identified downtimes caused by technical issues, high maintenance costs, and loadshedding as key issues. In some cases, a high demand for access to the equipment among students caused delays with their research projects. Over-usage of the equipment also led to more frequent downtime and servicing.

Consumables used during the equipment's operation and maintenance, given potential exchange rate or inflationary pressure, might cost more than anticipated, driving up the equipment's cost. Considering the added pressure of power outages as a result of loadshedding and the need for some pieces of equipment to run continuously, this places a large cost and somewhat unanticipated burden on the research institution. In a couple of cases, these running costs proved too high to justify, with the equipment effectively becoming a "white elephant" and not producing the anticipated research outputs, even though the NEP grant had already been paid out in full.

Training of operators
The majority of grant holder survey respondents (69%) indicated that both them and the equipment operators had received training on the equipment from the supplier. During the interviews, the grant holders noted that they were satisfied with the training provided by the supplier, and that the suppliers had been responsive to further requests for support or queries.

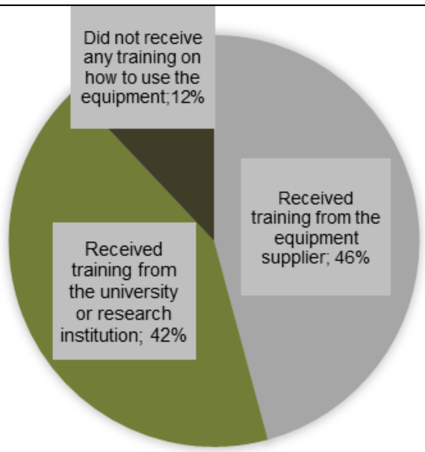
Figure 17: Grant holder feedback on provision of training from the supplier

Source: Grant holder digital survey
n=67

The operation and upkeep of the NEP-funded equipment requires dedicated operators and technicians, which depends on the availability of the specific skill sets within the country and the funding of personnel by the recipient institution. Some of the DVCs interviewed noted the challenges associated with recruiting full-time operators for the equipment, as the cost of doing so is high and they are difficult to find. In response to these challenges, some institutions had trained postgraduate students to operate the equipment. However, turnover is a concern, as upon graduating with their advanced degrees they tend to leave the institution for permanent jobs elsewhere. Where grant holders were the primary operators, their other responsibilities at the institution prevented them from fulfilling this role on a regular basis. Several challenges were also noted with regard to technicians, who are responsible for maintaining and repairing the equipment. As with operators, technicians are costly to employ. In addition, some of the suppliers require that their own technicians repair the equipment in order to ensure that the conditions of the warranty are met, without which it would be voided. Finally, given the specialised nature of some of the funded equipment, technicians may require highly specialised skills, which are scarce (as opposed to instances were one technician could service a broad variety of equipment pieces).

The RI users were also asked to indicate whether they had received training as part of their survey. Slightly fewer than half (46%) had received training from the supplier, while 42% had received training from their institution, and 12% had not received any training.

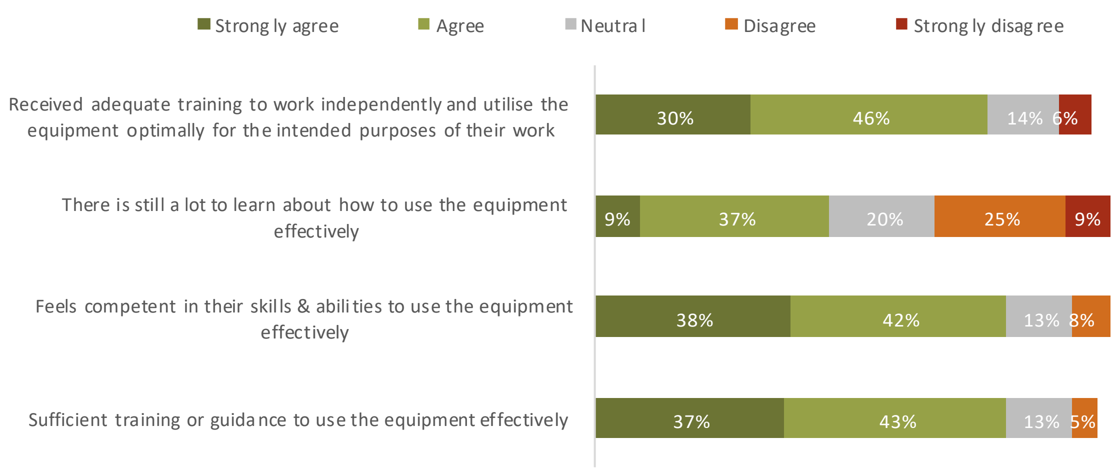
Figure 18: RI user feedback on training received to use the equipment



Source: RI user digital survey
n=99

RI users were also asked to report on their perceptions of the training. The majority of respondents (80%) were satisfied that they had received sufficient training and guidance to operate the equipment effectively and felt competent in their skills to use the equipment. Most respondents (76%) felt that they could operate the equipment independently and optimally for their work. However, some respondents (46%) noted that there was still a lot for them to learn in order to operate the equipment effectively.

Figure 19: RI user respondent perceptions of equipment

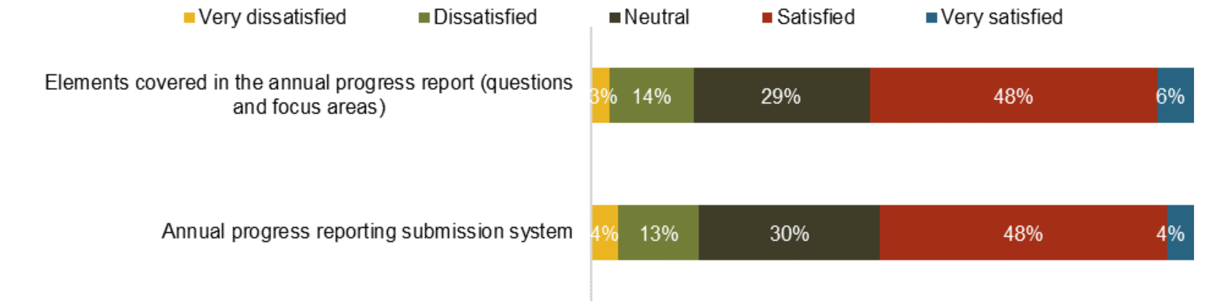


Source: Equipment user digital survey
n=99

Progress reporting

As part of their award, grant holders are expected to submit annual progress reports from the time of the award to five years post the commissioning of the equipment. A standard template is provided by the NRF for reporting and includes information on, among other categories, equipment installation, research highlights and impact, equipment users and outputs, and the leveraging of funds. All 120 grant holders had completed the APRs in the required format during the period under review. However, they expressed some dissatisfaction with the reporting process. Only around half of the survey respondents indicated that they were satisfied with the APR submission system and the elements covered in the APR.

Figure 20: Grant holder ratings of the APR



Source: Grant holder digital survey
n=67

Grant holders elaborated on this during their interviews. Firstly, they identified a lot of repetition of information required within the APR tool as well as between the grant proposal and APR. Grant holders are required to complete the 'grant details', such the reference number of the original application, grant UID(s), the year of award etc in each APR, which is cumbersome and results in an unnecessarily long document. This section of the report is most important when a grant holder holds two or more grants, otherwise the information is unlikely to change over the reporting period. Further, the 'evidence of alignment to national imperatives' section is provided in the application proposal yet has to be repeated in every annual report, which is repetitive and time consuming. Given that these are unlikely to change over the reporting period, the grant holders felt it may be useful to only report on any changes to alignment with national imperatives that may occurred over the reporting period.

Many grant holders also indicated that they were uncertain about what information was required within each section of the APR as it does not provide guidance. The evaluation team noted a lack of standardisation when reviewing the 'research highlights' and 'impact' sections; in some instances grant holders report on research efforts alone while in others they report on outputs and outcomes. The information provided is often repeated across both sections. Further, some grant holders provide long, detailed narratives, while others provide a short overview. This make it difficult to analyse what is being reported in terms of the outcomes achieved. The provision of sub-headings and additional guidance on what grant holders are required to report would help to standardise the information for analysis and reporting.

The grant holders were also concerned about the length of time allowed to report on outputs. Progress reporting is meant to conclude within five years of the grant holder commissioning the equipment. However, for some pieces of equipment, the collection of data only concludes after four or five years, which prevents grant holders from having outputs to report on due to the fact that data collection has been ongoing over several years. Or it can take several years for the equipment to be functional, for users to be trained in its use, and for research projects to be completed. This gap can be addressed by allowing for reporting on data generation where research outputs have not yet been completed. The reporting period can also be extended for a longer period to ensure the documentation of outputs stemming from the funded equipment.

Finally, the grant holders were concerned about reporting on users' personal details with the introduction of the Protection of Personal Information Act (POPIA), for which they don't have the required consent.

Given that the NRF relies upon the APRs to assess grant holder progress and the outcomes of the programme (institutions are not required to provide the equipment usage logbooks), it is critical that a standardised reporting system is instituted to enable an evaluation of the programme outcomes and impact over time.

Funding

Several challenges around funding were identified by both the grant holders and the programme managers during the evaluation. The programme managers noted that funding for the NEP had been significantly affected over the period of review due to economic challenges. National Treasury implemented budget cuts to the Medium Term Framework, which resulted in a reduction in budget for the infrastructure programme of approximately R360 million. The DSI also launched the Research Infrastructure Roadmap (SARIR) in 2016 which is funded from the same budget as the NEP, and which affected the funding available for grant calls. An initial decision was taken to fund the NEP in alternate years, instead of every year (with the SARIR funded in in-between years) to deal with the constraints. As a result, NEP grants were awarded annually up until 2016, while no grants were funded in 2017. The NRF hadn't planned to provide funding in 2018 either, however, there were unspent funds late in the financial year, which were directed to the NEP. Overall, the erratic nature of the programme funding impacted upon both the NRF's and grant holders abilities to plan for grant calls.

With regard to the institutions, some of the DVCs and grant holders reported that it was difficult for their institutions to source funding for the one-third cost required by the grant. This was of particular concern among grant holders from poorly resourced universities. Given the varying cost of equipment and the varying size of the balance sheets of research institutions, most respondents flagged the blanket co-payment rate (one third the equipment value) as being too high. Respondents suggested that the equipment cost and availability of co-payment funds be considered to adjust the co-payment size on a sliding scale. Grant holders also faced challenges in sourcing funds to cover the operational and staffing costs for the equipment (which is discussed in more detail in the relevance section above).

Relationship between DSI & NRF

The NRF is an implementing agency of the DSI. As highlighted in the literature review section above, the DSI develops R&D policy and strategies, while the NRF conceptualises, implements, and drives programmes that align with these. The DSI and NRF work closely together to ensure synergy in their efforts. The NRF is required to submit an annual performance plan for approval by Cabinet (as indicated in the PMF Act), as well as quarterly reports and annual reports for the NEP to the DSI. Regular management meetings are also held for the DSI to provide oversight on NRF programmes. During the interviews with programme managers, both the DSI and NRF noted having a cordial working relationship, in which problems could be discussed openly and resolved.

8.3 EQ3: Has the implementation of the NEP been efficient? How well were resources used in the programme?

This section assesses the efficiency of programme implementation and the use of resources in the programme.

Summary of finding: The financial data made available did not allow for sufficient analysis to fully answer this question.

Over the review period of 2014/15 to 2019/20, a total of R1.1 billion was allocated to the NEP to cover both grant disbursements, as well of the NRF's operational costs relating to the administration and management of the NEP. Table 9 below details the annual allocation to the NEP. Within this table, the annual allocation – which amounted to R912 million during this period, refers to the planned allocations, while the additional allocations – which amounted to R195 million during this period, refers to unplanned monies made available during the year in question.

Table 9: NEP funding by financial year

Financial year	Annual allocation	Additional allocation	Total
2014/15	R169 179 000	R68 557 000	R237 736 000
2015/16	R179 447 000	-	R179 447 000
2016/17	R188 959 000	-	R188 959 000
2017/18	R181 226 000	-	R181 226 000
2018/19	R43 875 000	R126 831 174	R170 706 174
2019/20	R150 000 000	-	R150 000 000
Total	**R912 686 000**	**R195 388 174**	**R1 108 074 174**
% of total	**82%**	**18%**	

Source: NEP Allocations from 2014-2019

Between 2014 and 2019, the NRF received a total of 241 applications for grant funding (Table 10). The total [81] quoted value of the equipment across these 241 applications amounted to R1.6 billion, with investments ranging from R0.5 million to R28 million. The 241 applications requested a combined R1.05 billion in funding from the NEP (66% of the total value above). The difference arises because funding requested was generally less that the quoted cost of the equipment. In terms of percentage, applicants requested between 35% to 96% of the quoted cost of the equipment. Only 4 applicants requested more than 100% of the quoted cost.

An analysis of NEP grant data presented in Table 10 reveals that the NEP awarded 126 grants during this period, 52%[82] of the total number of applications received during this period (126/241). The total value of grants awarded amounted to R 572 million. The largest amount awarded was R10 million, the smallest was R1 million, while the average grant size awarded was R 4.5 million. Assessing the total amount awarded against the total requested funding in this period shows that the NEP funded just over half (54%[83]) of what was requested from applicants, and only 36%[84] of the research infrastructure need identified. This indicates an improvement from the prior evaluation of the NEP in 2011 where only 38% of the funding requested was awarded to applicants.

[81] *Total investment in equipment/ research infrastructure irrespective of funding source*
[82] *Volume (number awarded/ number applied)*
[83] *Value (amount awarded/ amount requested)*
[84] *Value (amount awarded/ quoted value)*

Table 10: Application requests, value of equipment and grants made by the NEP between 2014-2019

Year	Number of applications	Total quoted value of equipment	Total amount requested from NRF***	Number of grants awarded	Total awarded****
2014/15	60	R 406 399 623	R 254 992 382 (63%)	32	R 143 371 000 (56%)
2015/16	51	R 287 990 400	R 205 041 971 (71%)	27	R 106 286 000 (52%)
2016/17	65	R 453 957 417	R 316 367 531 (70%)	28	R 156 153 881 (49%)
2017/18	*				
2018/19	53	R 387 307 014	R 240 059 635 (62%)	27	R 127 414 510 (53%)
2019/20	12	R 52 983 724	R 39 285 189** (66%)	12	R 39 285 189 (100%)
Total	**241**	**R 1 588 638 179**	**R 1 055 746 709 (66%)**	**126**	**R 572 510 581 (54%)**

Source: NEP Allocations from 2014-2019; NEP Data_2014-2019 (Grant holder information)_Original; and NEP NNEP_Applications dataset_2010-2020_October 2021_Updated_Original
** The database shared contained to data for applications made in the 2017 year*
*** Amount provided by DSI (does not align to contents of databases)*
**** () Percentage of total quote requested from the NEP*
***** () Percentage of the requested amount awarded by the NEP*

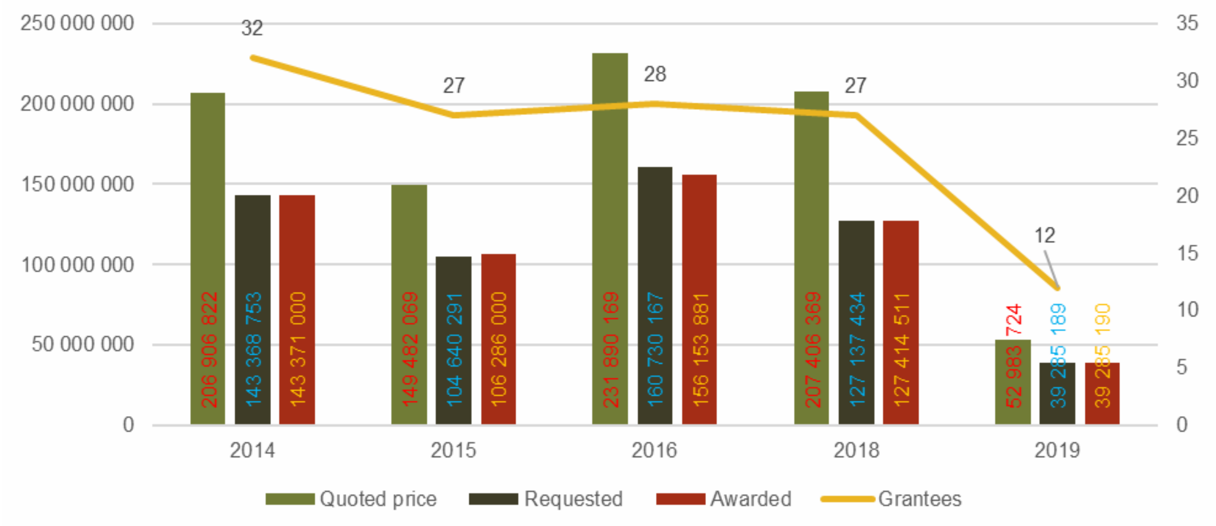
Limiting the analysis to just the 126 grants awarded shows that total investment in research expenditure was R849 million, of which the NEP funded 68% (Table 11). The NEP funded 100% of the *total value requested* by these grantees (total awarded/quoted value of equipment).

Table 11: Application requests, value of equipment and grants made by the NEP – Grantees only

Year	Number of grants awarded	Quoted value of equipment (n=126)	Total amount requested from NRF (n=126) *	Total awarded**
2014/15	32	R 206 906 822	R 143 368 753 (69%)	R 143 371 000 (100%)
2015/16	27	R 149 482 068	R 104 640 290 (70%)	R 106 286 000 (102%)
2016/17	28	R 231 890 168	R 160 730 167 (69%)	R 156 153 881 (97%)
2017/18				
2018/19	27	R 207 406 369	R 127 137 433 (61%)	R 127 414 510 (100%)
2019/20	12	R 52 983 724	R 39 285 189 (74%)	R 39 285 189 (100%)
Total	**126**	**R 848 669 153**	**R 575 161 833 (68%)**	**R 572 510 581 (100%)**

Source: NEP Allocations FROM 2014-2019; NEP Data_2014-2019 (Grant holder information)_Original; and NEP NNEP_Applications dataset_2010-2020_October 2021_Updated_Original
** () Percentage of total quote requested from the NEP*
*** () Percentage of the requested amount awarded by the NEP*

Figure 21: Application requests, value of equipment and grants made by the NEP – Grantees only



Source: NEP Allocations FROM 2014-2019; NEP Data_2014-2019 (Grant holder information)_Original; and NEP NNEP_Applications dataset_2010-2020_October 2021_Updated_Original

An analysis of spend against allocation for the period under review suggests that the NEP awarded just over 50% of total allocation to grantees. Part of the remaining 48% was used towards administrative costs for the NEP, while the rest remained unallocated.[85]

Table 12: Grant awards versus allocations

Year	Number of grants awarded	Total awarded	Total annual allocation	% awarded
2014/15	32	R 143 371 000	R237 736 000	60%
2015/16	27	R 106 286 000	R179 447 000	59%
2016/17	28	R 156 153 881	R188 959 000	83%
2017/18			R181 226 000	0%
2018/19	27	R 127 414 510	R170 706 174	75%
2019/20	12	R 39 285 189	R150 000 000	26%
Total	**126**	**R 572 510 581**	**R1 108 074 174**	**52%**

Source: NEP Allocations FROM 2014-2019; NEP Data_2014-2019 (Grant holder information)_Original; and NEP NNEP_Applications dataset_2010-2020_October 2021_Updated_Original

Given the parallel implementation of the Research Infrastructure Road Map and broader budget constraints, funding for the NEP had to be redirected in some years, which has affected the funds available for grants. This has also created some unpredictability in the planning for calls and awards. For example, in their interview, stakeholders from the NRF noted the funding of awards had not been planned for the 2018/19 financial year. However, towards the end of the financial year the DSI had unspent funds, which resulted in the NRF awarding funds in that year.

8.4 EQ4: How effective has the NEP been in achieving its objectives?

In this section we assess the extent to which the NEP has made progress in achieving its intended outcomes, as well as factors that have contributed to or prevented this.

Summary of finding: The evaluation finds that the NEP has enabled the expansion of institutional

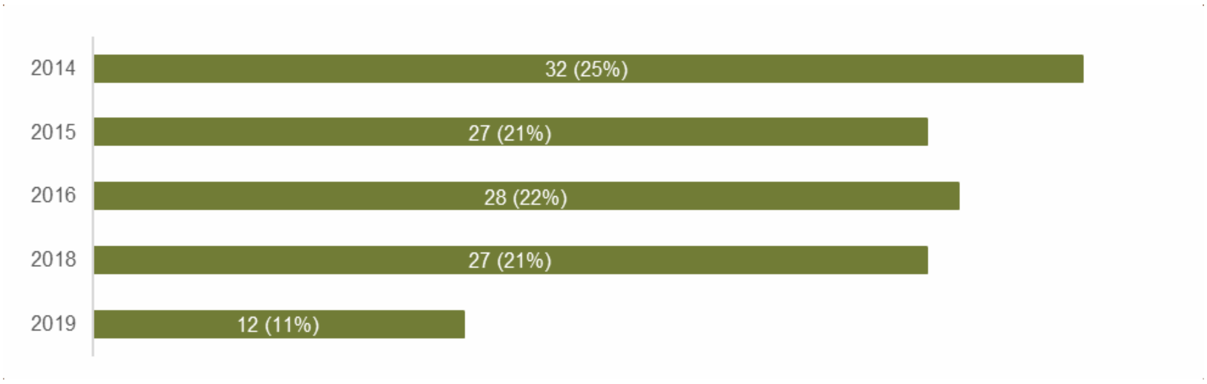
[85] *NRF operating costs are required to isolate administrative costs from unspent budget*

capacity for research, training, and innovation at public universities and recognised research institutions. The evidence demonstrates that human resource capacity has been developed at South African institutions through the programme, predominantly among postgraduate students. Grant holders were still predominantly White, although there has been positive growth in the number of Black grant holders over time. Despite a slower transformation rate among grant holders, almost half of all users capacitated using the equipment were Black, and almost half of all users were female, indicating progress towards objectives. However, despite the progress made, gaps still remain with regard to the transformation and capacitation of HDIs. Only five HDIs were awarded grants during the review period, which amounted to only 9% of the total value of funding awarded. The placement of the equipment was found to foster research collaborations and there are clear examples of how it enabled beneficiary institutions to undertake world class research, which has resulted in a range of research outputs for grant holders and student alike. Finally, many grant holders successfully leveraged the equipment to attain further funding for their own research and for their institutions.

8.4.1 Grant awards across institutions

During the period under review, a total of 126 grants were made to 120 grant awardees (four awardees held multiple grants), of which a quarter were awarded in 2014.

Figure 22: Number of NEP grants awarded by year between 2014-2019



Source: DNA analysis: NEP grant holder database

Of the R1 billion requested in funding over the six-year review period, a total of R572.5 million was awarded across 28 institutions (57%). The vast majority of funding (92%) was awarded to higher education institutions with the remainder awarded to other science institutions (8%). This indicates a sharp increase in funding from the prior evaluation report, which noted a total grant investment of R166.7 million over a four-year period, the majority of which went also to higher education institutions (84%).

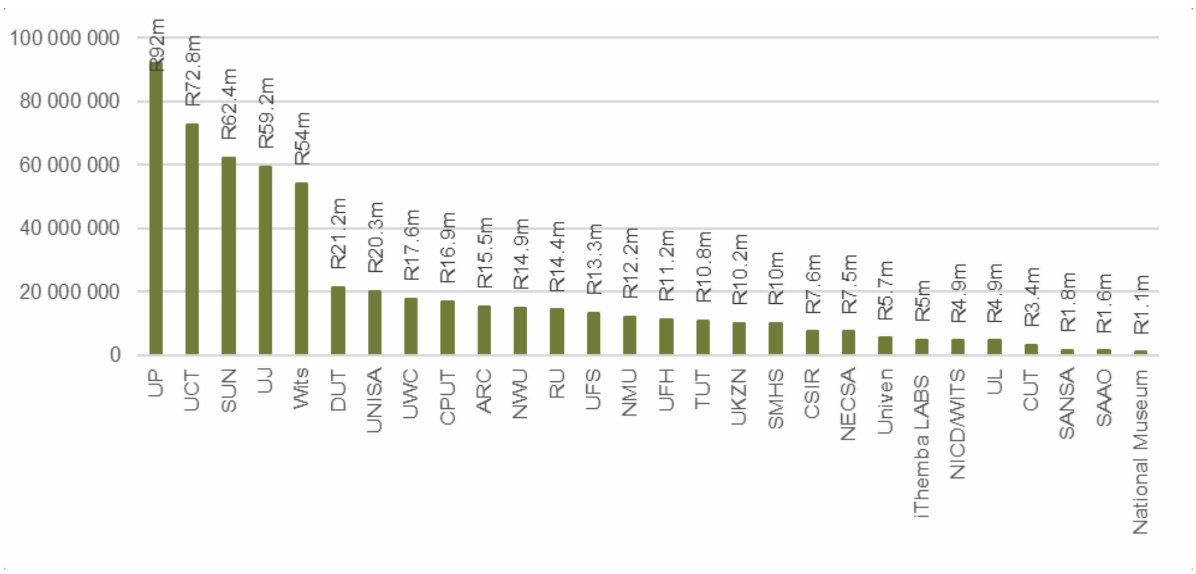
Table 13: Funding awarded by type of institution

Type of institution	Total funding awarded (R572.5 million)	Total funding requested (R1.05 billion)	Total number of applications awarded (N=126)	Total number of applications submitted (N=241)
University	R527.4 million	R906.7 million	113	204
Science institution	R45.1 million	R144.8 million	13	37

Source: DNA analysis: NEP application and grant holder databases

Five universities were awarded approximately two-thirds of the total grant funds (R340.4 million), each receiving more than ten percent of the total allocation. Three of them were HAIs (UCT, SUN, and Wits) and two were combined institutions (UP and UJ); the University of Pretoria held the largest amount of funding overall (17%). Historically disadvantaged institutions (HDIs) received 9% of the overall grant value (R49.4 million) spread across five institutions (UFH, UL, UNIVEN, UWC, and SMHS). These findings are similar to those from the previous evaluation of the NEP conducted in 2011, where four of the five institutions (UP, Wits, UCT, and UJ) had also received the largest grants, although UKZN had received the largest amount of funding during the prior assessment.

Figure 23: Total value of grants awarded by institution

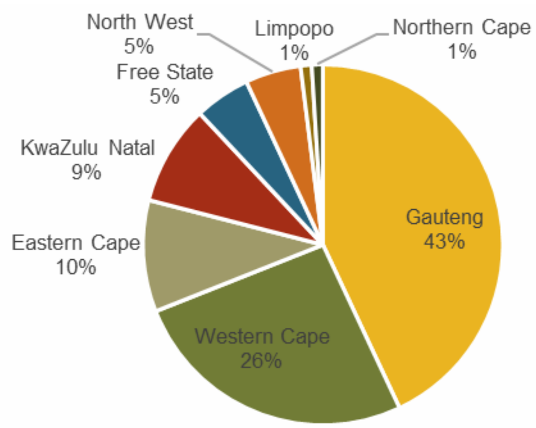


Source: DNA analysis: NEP grant holder database

The previous evaluation conducted in 2011 found that a total of 23 institutions had been awarded grants (17 universities and 6 science institutions), compared to the 28 institutions awarded grants during the current review period (19 universities and 9 science institutions).

Almost half of the grant value was allocated to institutions within the Gauteng province (43%), followed by the Western Cape (26%), and the Eastern Cape (10%) as seen in the figure below. This is likely due to the fact that more than a third (38%) of the country's public universities are situated in Gauteng and the Western Cape. A similar trend was seen in the previous evaluation where 62% of all grant funding was awarded to institutions in these two provinces.

Figure 24: Percentage of grant value awarded by province

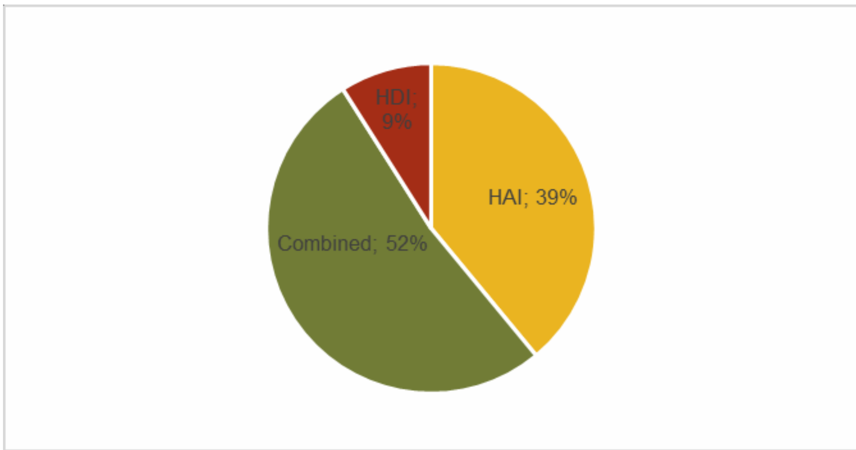


Source: DNA analysis: NEP grant holder database

Universities

In terms of the distribution of grant funding across the historical type of university, just over half of the funding was awarded to combined universities, with 39% awarded to HAIs and only 9% to HDIs. These findings mirror those reported in 2011 evaluation where 53% of grants were awarded to combined institutions, 37% to HAIs, and 10% to HDIs.

Figure 25: Percentage of grant value by type of university

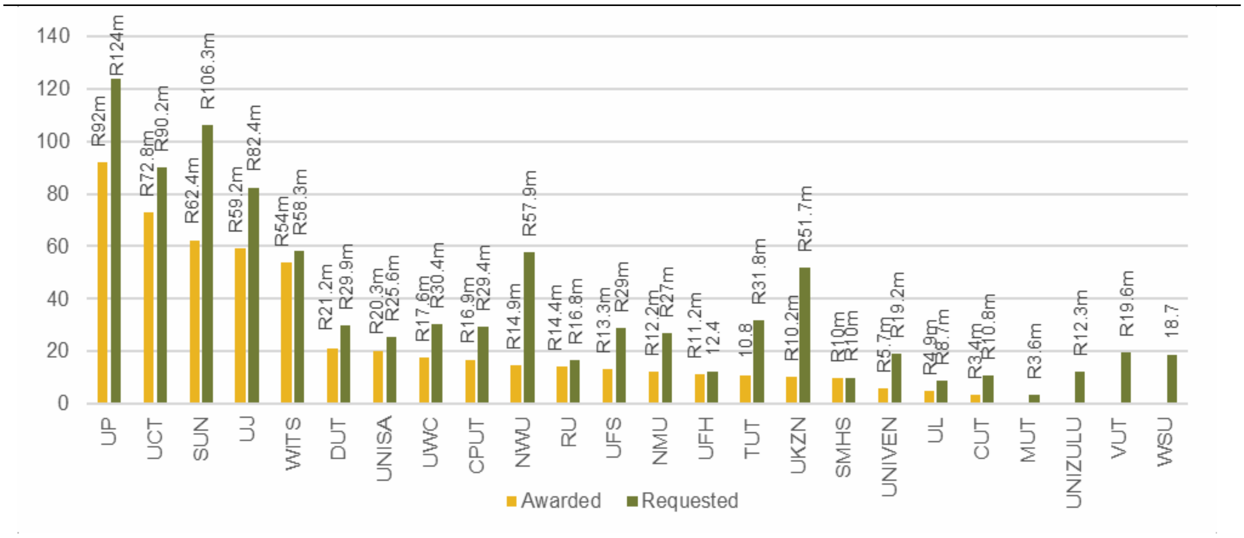


Source: DNA analysis: NEP application database

An analysis was undertaken of the grants awarded against the grant applications received. Of the R906.7 million requested by universities in the grant applications, the grants allocated provided for more than half (58% or R527.4 million) of the expressed need. The four HAIs (RU, SUN, UCT, WITS) were awarded 75% of the grant funding they applied for, while HDIs were awarded 43% of the grant funding they applied for, with only five of the nine HDIs being successful in their applications (MUT, UNIZULU, VUT, and WSU were not successful in any of their grant applications). The combined universities were awarded 53% of grants they applied for. No grant applications were received from the two newly established universities during the period under review (University of Mpumalanga and Sol Plaatjie University).

Further, two universities that were unsuccessful in their funding application during the previous evaluation in 2011 had been successful in the current evaluation period, namely CPUT and CUT, while VUT was unsuccessful in both assessments. This resulted in a substantial increase in funding for universities of technology from the previous evaluation (3% of total grants) to the current evaluation (9% of total grants).

Figure 26: Total value of grants awarded against funding requested: Universities



Source: DNA analysis: NEP application and grant holder databases

An overall success rate of 52% was achieved in terms of the number of grant applications submitted. HAIs again had the highest success rate (72%) with regard to the number of grant proposals submitted, followed by combined universities (51%) and then HDIs (32%). Further, academic universities had the highest success rate in terms of the number of grant applications submitted (61%), followed by universities of technology (45%) and then comprehensive universities (43%). With regard to the success rate by type of university, academic universities were awarded the most funding from their applications (63%), followed by comprehensive universities (55%) and then universities of technology (42%).

Table 14: Application success rates by type of university

Type of university	Total funding awarded	Total funding requested	Success rate (%)	Total number of applications awarded (N=113)	Total number of applications submitted (N=204)	Success rate (%)
By historical status						
HAI	R203.6 million	R271.6 million	75%	46	64	72%
HDI	R49.4 million	R115.3 million	43%	8	25	32%
Combined	R274.4 million	R519.8 million	53%	59	115	51%
By type of university						
Academic	R367.7 million	R586.2 million	63%	83	136	61%
Comprehensive	R107.4 million	R195.4 million	55%	16	37	43%
University of Technology	R52.3 million	R125.1 million	42%	14	31	45%

Source: DNA analysis: NEP application database

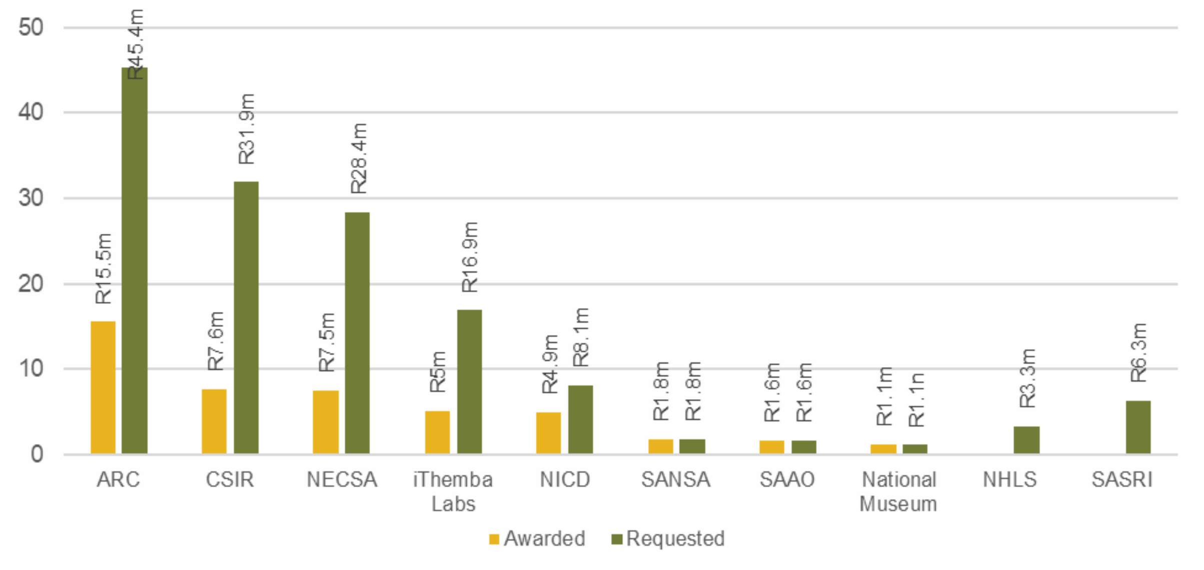
From the table above it is clear that HDIs submitted far fewer grant applications than HAIs. This aligns with the findings from the interviews with the DSI and NRF programme managers presented in the efficiency section above, which noted that the better resourced universities submit the maximum number of proposals which increases their rate of success. The lower success rate of HDIs (32%) also supports the feedback from the DSI and NRF regarding the poorer quality of applications as a result of capacity and support challenges.

Science institutions

Of the R144.8 million requested by science institutions in the grant applications, the grants awarded provided for just less than a third of the expressed need (31% or R45.1 million). Two-thirds of the total funds allocated to science institutes went to three science councils, namely ARC, the CSIR, and NECSA.[86] The NHLS and SASRI were not successful in any of their applications to the NEP during the period under review. Three science institutions that were unsuccessful in their funding application during the previous evaluation in 2011 had been successful in the current evaluation period, namely ARC, NICD, and SAAO.

[86] *Science institutions were defined as follows: Science councils (ARC, CSIR, and NECSA); national facilities (iThemba Labs, NHLS, SAAO, SANSA, and SASRI); and museums (National Museum)*

Figure 27: Total value of grants awarded of funding requested among science institutions



Source: DNA analysis: NEP application and grant holder databases

Since the National Museum was awarded a grant for its single application, it was the most successful science institution as measured by success rate, followed by National facilities (35%) and Science Councils (29%).

Table 15: Application success rates by type of science institution

Type of science institution	Total funding awarded	Total funding requested	Success rate (%)	Total number of applications awarded (N=13)	Total number of applications submitted (N=37)	Success rate (%)
Science council	R30.7 million	R105.7 million	29%	7	25	28%
National facility	R13.3 million	R38 million	35%	5	11	45%
Museum	R1.1 million	R1.1 million	100%	1	1	100%

Source: DNA analysis: NEP application and grant holder databases

8.4.2 Human capacity development

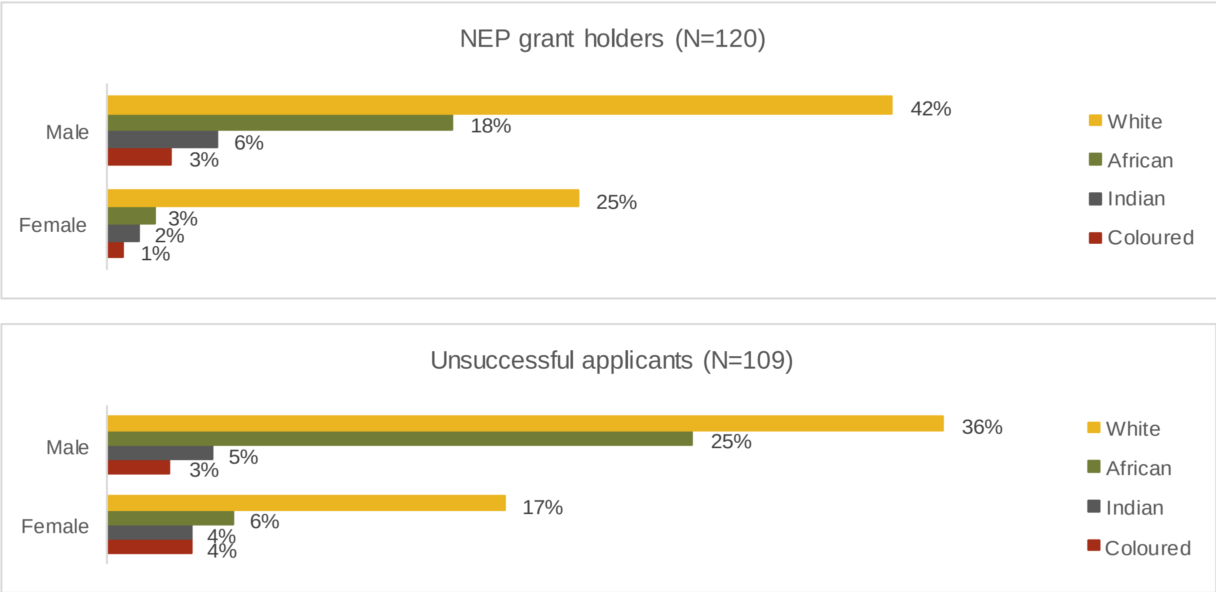
An analysis of the NRF grant holder database, APRs submitted by grant holders during the review period, and the stakeholder interviews was undertaken to understand the profile of beneficiaries and the impact that the equipment had on human capacity development.

Grant holders

An analysis of the grant holder database indicates that the majority of grants were awarded to White males (42%), followed by White females (25%), and then Black males (18%) (

Figure 28). More than two-thirds of grant awardees were male (69%), with only 6% of grants awarded to women of colour. Further, 72% of grant holders are South African citizens, with the remainder either being permanent residents in South Africa or of other nationalities. It is interesting to note that of the 25 Black grant holders, only 36% (9) were South African. The remaining Black grant holders were either permanent South African residents (40%) or from other African countries (24%).

Figure 28: Demographic profile of grant holders and unsuccessful applicants



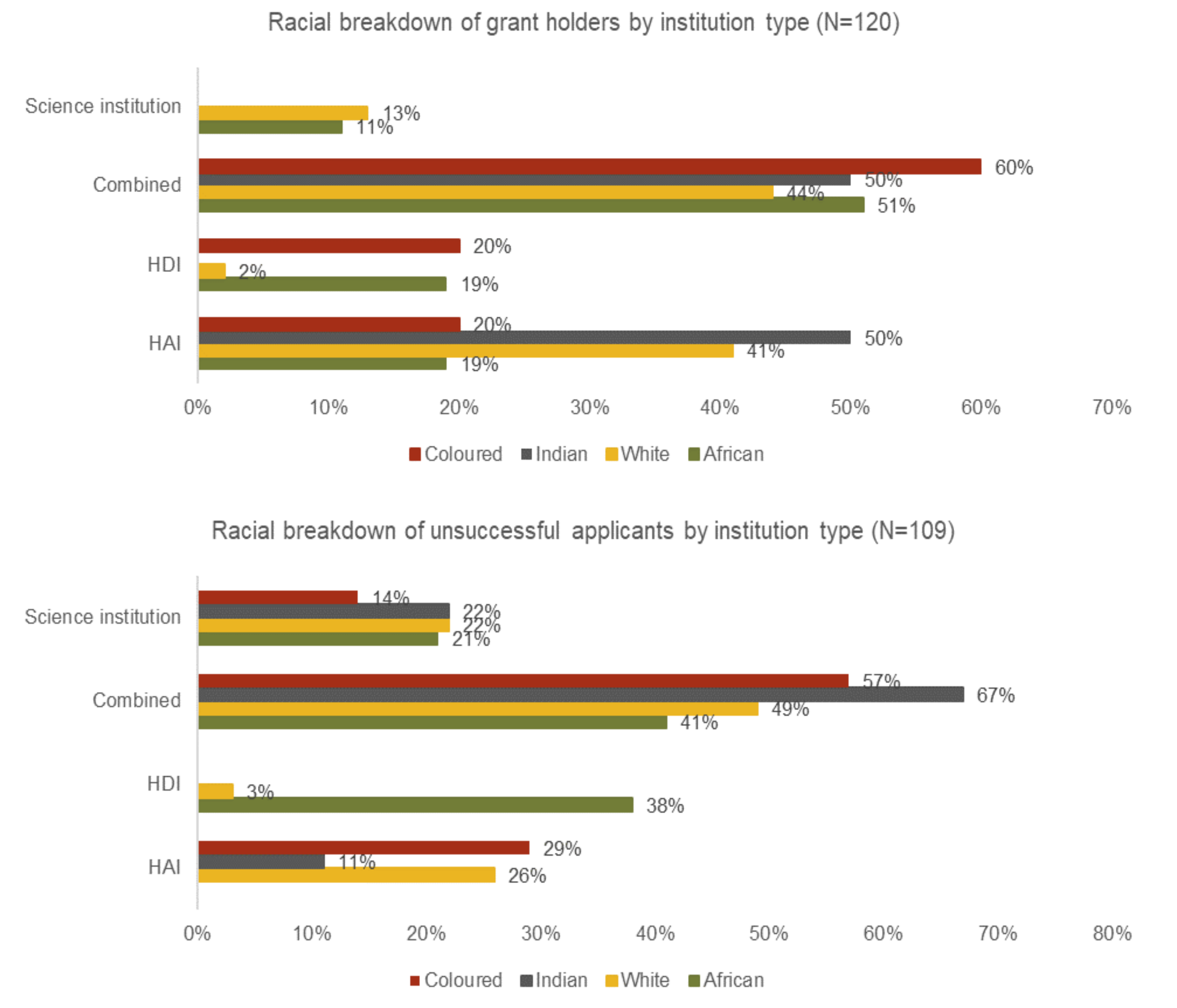
Source: DNA analysis: NEP grant holder database

The demographic profile of unsuccessful grant applicants indicates that the majority of unsuccessful applicants were White males (36%), followed by African males (25%) and then White females (17%). While the demographic pattern of unsuccessful applicants generally follows that of the grant holders, it indicates that African males were slightly less successful in attaining a NEP grant during the period under review.

While the majority of NEP grants were still awarded to White male (42%) and female (25%) researchers, there has been progress in terms of transformation; in the previous evaluation conducted in 2011, 56% of the grants were awarded to White male and 25% to White female researchers, with only 14% of grants awarded to male researchers of colour (versus 27% in the current study) and 5% to female researchers of colour (versus 6% in the current study).

In terms of the racial distribution of grant holders by type of institution, more than half of all the African grant holders were from combined universities (51%), followed by HDIs (19%) and HAIs (19%). A similar pattern was seen among Coloured grant holders. Indian grant holders were equally split between combined universities and HAIs, while White grant holders were predominantly from combined universities (44%) and HAIs (41%). When compared against the unsuccessful applicants, there were more African researchers from HDIs (38%) and science institutions (21%), no Coloured applicants from HDIs, and more Indian and White applicants from science institutions as compared to grant holders.

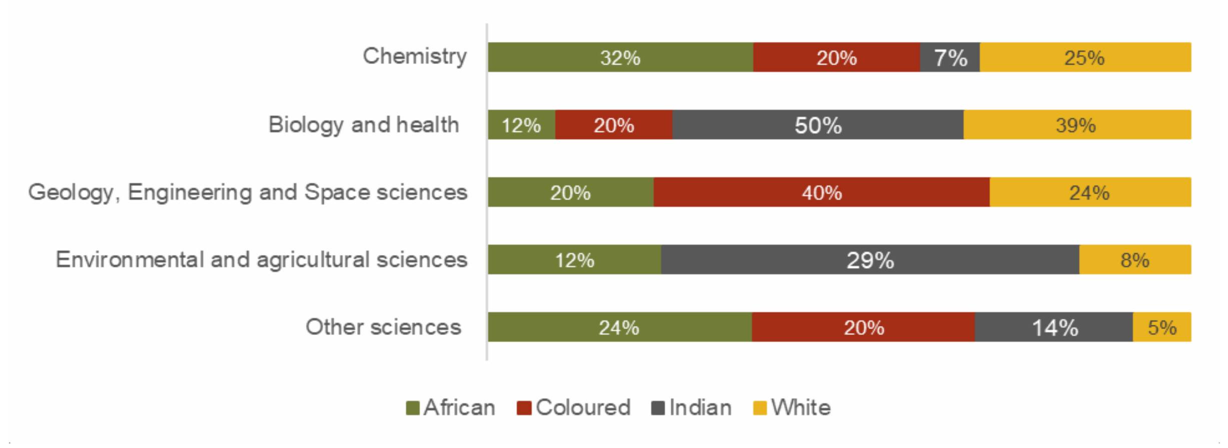
Figure 29: Racial distribution of grant holders and unsuccessful applicants by institution type



Source: DNA analysis: NEP grant holder and applicant databases

The majority of African grant holders were from chemistry or other scientific disciplines, while White and Indian grant holders were mostly from the biological sciences and health disciplines. Coloured grant holders were predominantly in the geology and engineering sciences.

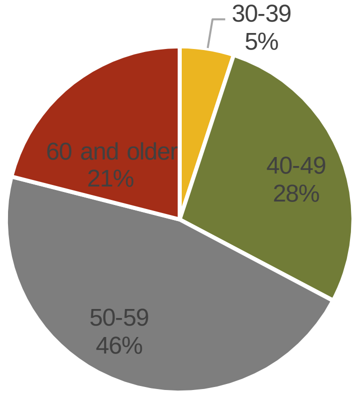
Figure 30: Race of grant holders by discipline



Source: DNA analysis: NRF grant applicant database

More than two-thirds (67%) of the grant holders were aged 50 years and older, of which 21% were over the age of 60 years. While all grant holders hold a doctoral degree, the age profile of awardees indicates a high success rate amongst senior academic staff. The age profile of grant holders also indicates that many are reaching the age of retirement, necessitating succession planning, which is discussed in more detail in the sustainability section. Grant holders in the current evaluation were older than the cohort from the previous evaluation of the NEP conducted in 2011 where 52% were aged 50 years and older. The proportion of grant holders aged 40-49 years decreased from 41% in 2011 to 28% in the current assessment.

Figure 31: Age distribution of grant holders



Source: DNA analysis: NEP grant holder database

An analysis of the NRF rating categories of grant holders compared to unsuccessful applicants indicates that most of the grant holders were rated as either established researchers or internationally acclaimed researchers, while unsuccessful researchers were either unrated or established researchers.

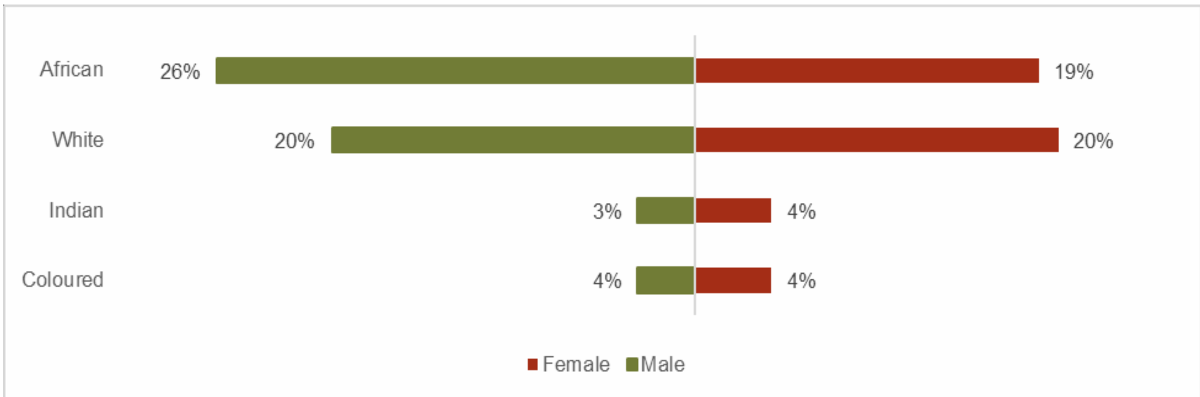
Table 16: NRF rating categories of grant holders and unsuccessful applicants

NRF rating level	Grant holders (N=120)	Unsuccessful applicants (N=109)
A - Leading international researcher	2 (2%)	1 (1%)
B – Internationally acclaimed researcher	39 (33%)	12 (11%)
C – Established researcher	43 (35%)	44 (40%)
P – Prestigious awards	1 (1%)	7 (6%)
Y – Promising young researchers	2 (2%)	-
Not rated	33 (27%)	45 (42%)

Source: NRF List of Current Rated Researchers (updated 12 May 2022)

Equipment users
A total of 2 422 equipment users were reported in the APRs, including the grant holders themselves.[87] Almost half of the users of the funded equipment were Black / African (45%), followed by White users (40%) with fewer Indian (7%) and Coloured (8%) users. A quarter (26%) of the users reported during the period under review were Black males. This represents an increase in the number of Black, Indian, and Coloured users from the previous evaluation report (55%) to the current report (60%).

Figure 32: Demographic profile of equipment users by gender and race

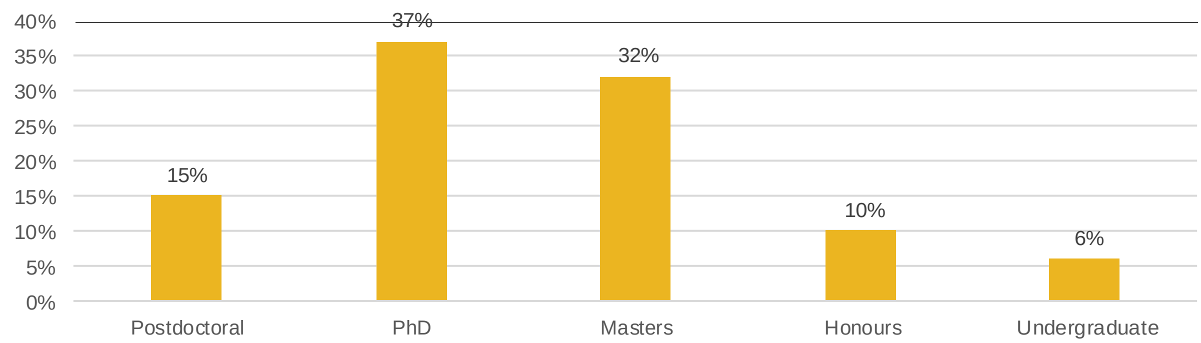


Source: DNA analysis: grant holder Annual Progress Reports
N=2 272

Thus, despite the majority of grant holders being White, almost half of the equipment users were Black (43%) indicating that research capacity is being developed among this target group and that they are benefitting from the placement of the equipment.

In terms of the students users of the equipment funded by the NEP, the majority were studying towards a PhD (27%) or Masters degree (32%). The remainder of students were in Postdoctoral positions (15%) or completing an Honours or undergraduate degree.

Figure 33: Level of student users of the equipment

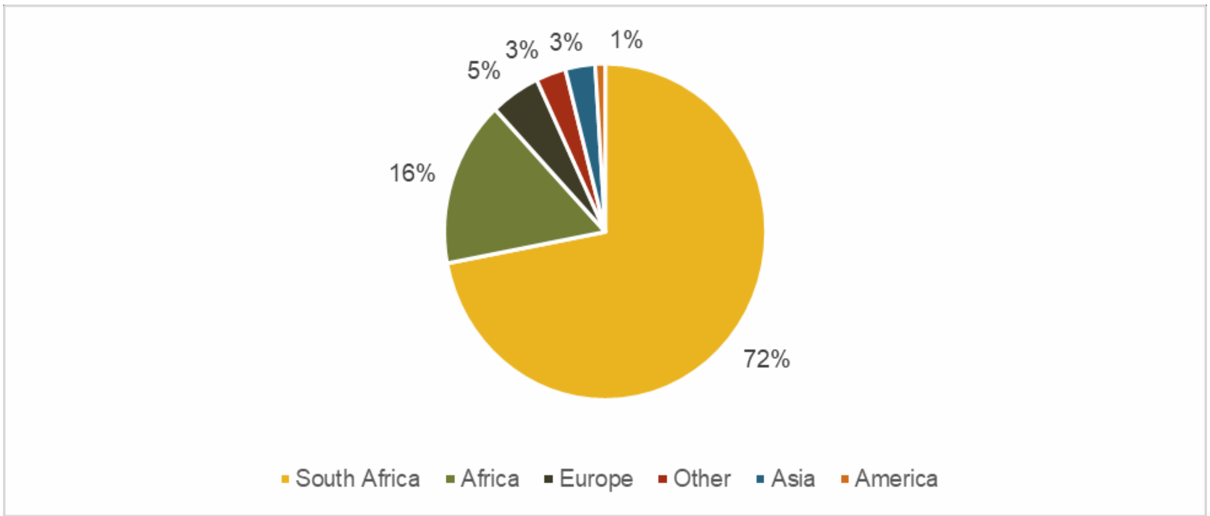


Source: DNA analysis: grant holder Annual Progress Reports
n=1 789

[87] *Analyses of the APRs rely on the data provided by grant holders, which may be subject to error and may not reflect all users in totality as some users could have been omitted during the reporting process. Further, there were some data missing regarding the race of users.*

More than three-quarters of the equipment users reported in the APRs were South African, while 16% were from other countries on the African continent, most commonly Nigeria and Zimbabwe.

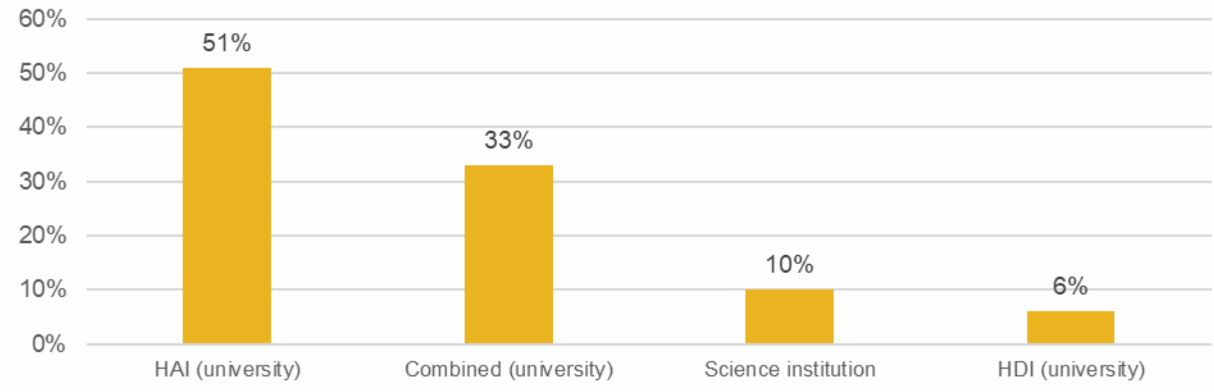
Figure 34: Citizenship of equipment users



Source: DNA analysis: grant holder Annual Progress Reports
n=1 907

An analysis of the number of users reported by type of institution indicated that half of all reported equipment users were from HAIs (51%), a third were from combined universities (33%), 10% were from science institutions, and 6% were from HDIs. Thus, while HAIs had an average of 310 users per university, combined universities had 73 users, science institutions had 32 users, and HDIs had 41 users each on average. This indicates a gap in capacity development among students at HDIs, which likely relates to the broader capacity issues already mentioned above. It could also potentially stem from issues related to tracking users at the institutions or reporting on users in the APRs.

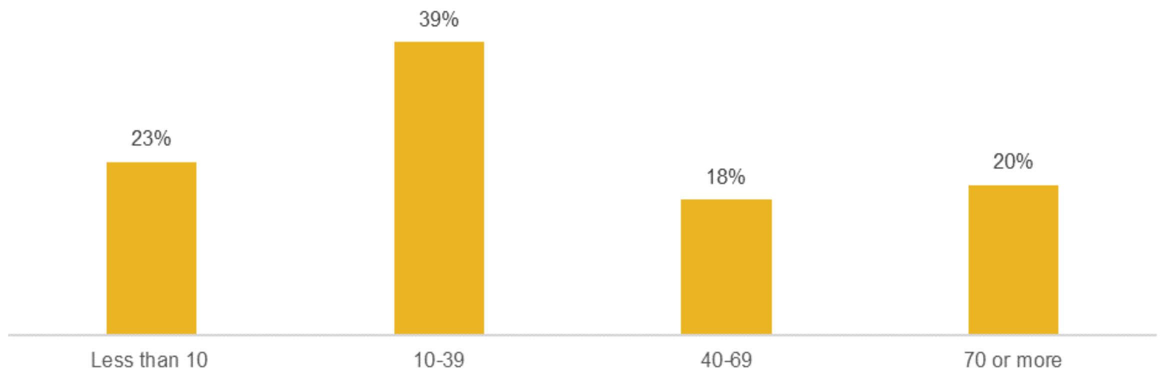
Figure 35: Proportion of users by institution type



Source: DNA analysis: grant holder Annual Progress Reports
N=2 422

In the grant holder survey, 39% of respondents reported that the equipment had been used by 10 or more users since its commission, while 20% indicated that the equipment had had 70 or more users.

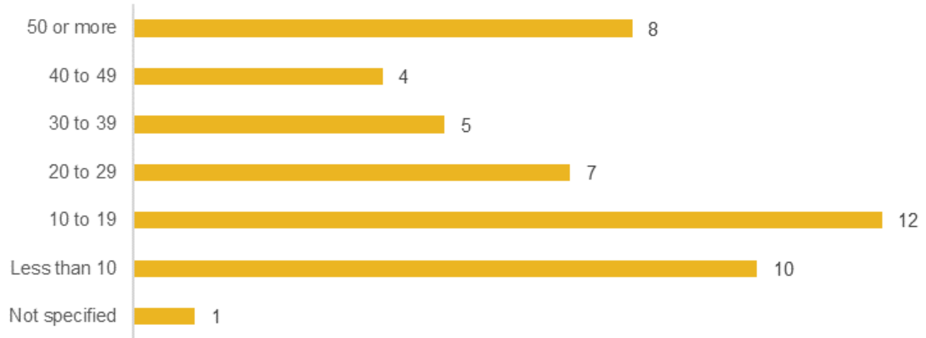
Figure 36: Number of users of the equipment to date



Source: Grant holder digital survey
n=66

External users[88]
In the digital survey 71% of grant holder respondent indicated that the equipment had been used by external users. When reporting on the annual hours spent using the equipment, a quarter of the respondents noted that external users had spent at least 30 or more hours using it.

Figure 37: Percentage of the annual hours spent using equipment that is by external users



Source: Grant holder digital survey
n=67

In terms of tracking who accessed the equipment, 67% of survey respondents indicated that their institution made use of registers to track equipment usage. Most external users were notified about the equipment via the institution's website, via word of mouth or conferences and workshops, or via collaborations between researchers (see Figure 38).

[88] External users refer to individuals outside of the funded institutions that make use of the equipment.

Figure 38: Means of notifying external users about the equipment

Source: Grant holder digital survey
n=67

Of the grant holders that reported external use of their equipment, 76% reported that a charge out system was in place at their institution and 88% indicated that the external users found the charge out rates to be reasonable. Fifteen percent of the grant holders surveyed indicated that the equipment had been used for classified work.

8.4.3 Research outputs and collaborations

Research outputs

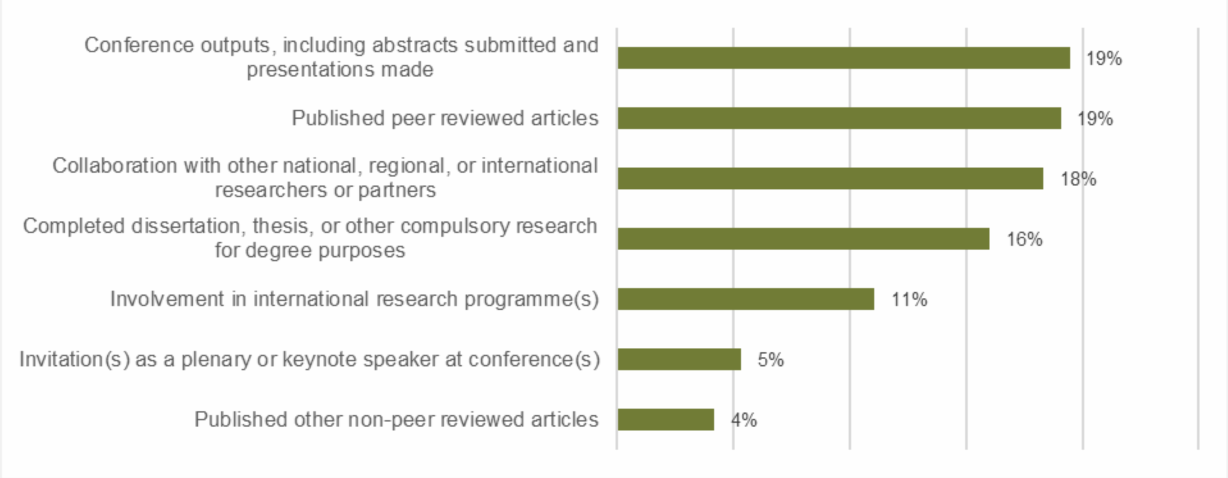
During the survey, grant holders reported that the majority of outputs produced as a result of the equipment's use included journal articles, conference outputs, collaborations with other researchers, and involvement in international research programmes.

Figure 39: Grant holder feedback on outputs stemming from the use of the equipment

Source: Grant holder digital survey
n=67

Similar findings were seen among RI users who had completed the survey; RI users were able to produce conference outputs (19%), peer-reviewed journal articles (19%), as well as opportunities to collaborate with other researchers (18%) as a result of the equipment. More than 80% of the respondents reporting research outputs indicated that they would not have been able to achieve these in the absence of the NEP-funded equipment.

Figure 40: RI user feedback on outputs stemming from the use of the equipment



Source: RI user digital survey
n=99

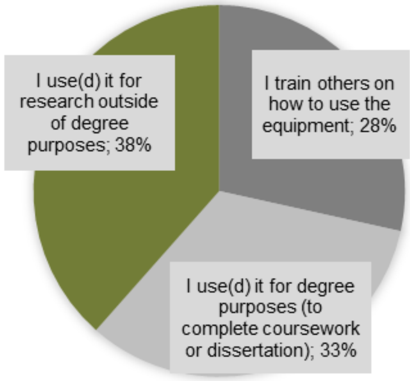
This is supported by the data provided in the APRs; a total of 2 422 users were reported over the period under review. Nineteen percent (471) of all users were reported to have produced at least one research output as a result of using the equipment, with most users having produced multiple outputs. Of the 120 grant holders, 66% (83) reported outputs for the users of their equipment. The table below indicates the number of users reported to have been involved with each type of output. It should be noted that there is duplication in the figures provided as multiple users were involved in the development of a single output.

Table 17: Number of users reported by output type

Publication type	Number of reported users
Peer reviewed journal articles	797
Books	6
Book chapters	13
Industry-specific reports	2
Conference-related outputs (peer reviewed and other)	297
Patents	1
Prototypes	13
Technical reports	14
Other recognised research outputs including student theses	10

Students have also used the equipment to complete their degrees as well as participate in research outside of the requirements of their degree. Most of the users (84%) were working with the NEP-funded equipment at the time of the survey.

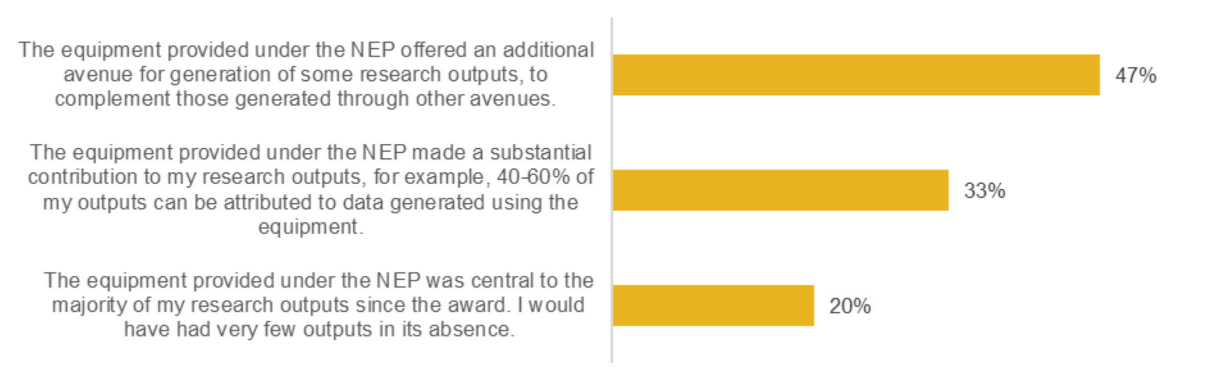
Figure 41: RI users' usage of the equipment



Source: RI user digital survey
n=99

More than half of the grant holders surveyed (53%) indicated that the equipment provided under the NEP made a substantial contribution to their research outputs.

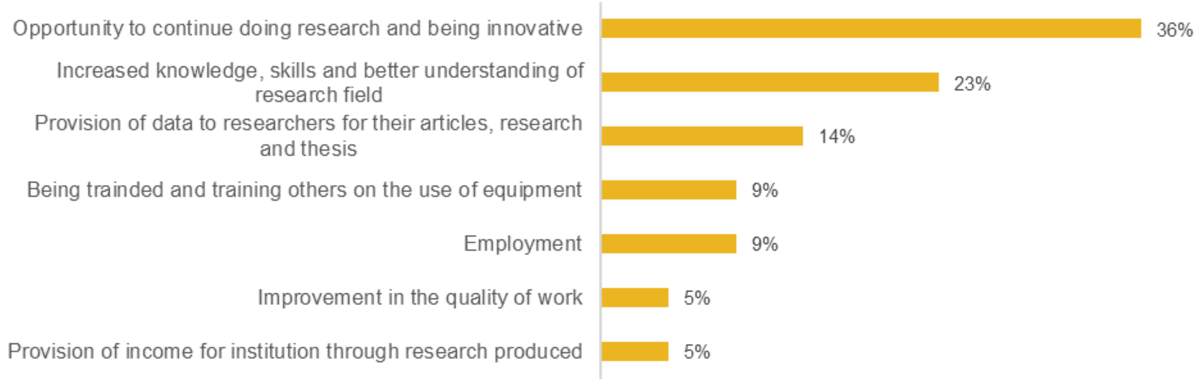
Figure 42: Contribution of funded equipment to grant holders' research outputs



Source: Grant holder digital survey
n=61

When asked to report on additional benefits received from utilising the NEP-funded equipment, almost a quarter of the RI users surveyed (23%) indicated that it had enabled them to increase their knowledge, skills and understanding of their research field. Other benefits included gaining employment and generating income for their institution through the research produced. One RI user noted that "t*he equipment also allows the research group to conduct commercial work of which the income is used for research and bursaries".* It should be noted that there is no 'one size fits all' approach to the equipment in that the number of users that can benefit from the equipment is quite specific to the equipment itself. Some equipment is too complicated, too fragile, or too dangerous to be operated by students and inexperienced researchers. In these instances, a qualified technician or equipment operator has to be appointed. Other pieces of equipment do not require operational efforts, but rather act to collect data "in the field", for example, sea-going equipment that is used to understand how the seabed is shaped. In these instances, learners and researchers benefit from the data or by-products produced by the equipment and human capital development manifests itself through the learnings around the analysis of data that would have otherwise not been possible without the equipment.

Figure 43: Additional benefits gained from equipment by RI users



Source: RI user digital survey
n=99

In their interviews, some of the grant holders noted that the equipment obtained through the NEP grant was the first of its kind in South Africa, which enabled novel research that would otherwise have required secondments overseas. One grant holder said *"Besides being able to publish this work in the future, we will be able to track an emerging fungal pathogen throughout the infection pathway and determine how it disseminates in the host. The pathogen Emergomyces africanus is a newly emerging disease found in South African AIDS patients and using this technology will help us develop tools at the forefront for this field of emerging fungal pathogens."* Further, a grant holder from CPUT reported on how having access to the NEP-funded equipment enabled both research and education activities that directly address issues of energy access and energy poverty. This is achieved through the promotion of renewable energy and energy storage methods that have been refined and tested using the equipment.

The case studies for specific pieces of equipment provided in section 7 highlight the success of the NEP grant in enabling cutting edge research to be conducted in South Africa. The grant holders and recipient institutions also expressed their gratitude for the funding and were pleased with the NEP grant as a whole.

While it was not possible to compare the outputs achieved as result of the NEP funding directly (due to the absence of a control group and data on grant holder outputs that had not been awarded grants), an additional analysis was undertaken among a random sample of peer-reviewed journal publications published by the equipment users between 2017 and 2019 to assess proxies for the quality of outputs achieved (namely, the journal impact factor and number of citations). A random sample of 5% of the peer-reviewed journal publications published during this period was drawn from different institutions and grant holders. A total of 40 articles were selected into the sample, for which the number of citations ranged between 0 to 46 per article (mean of 12.8 citations per article, with 514 citations in total). The impact factor for the journals within which the articles were published ranged from 0.3 to 14.9, with several prestigious journals noted, namely *Nature Communications, Chemical Engineering Journal, The Astrophysics Journal, and the International Journal of Hydrogen Energy.*

Collaborations

Many of the APRs reviewed highlighted the collaborative opportunities that have been enabled as a result of the placement of the NEP-funded equipment. Collaborations between HAIs and HDIs were reported; one grant holder from UCT reported on a research collaboration between the institution and four HDIs as a result of the funded equipment. A grant holder at UFH also reported establishing an existing and sustained research collaboration with UP, UJ, and WSU as a result of the NEP grant. Further, collaboration between institutions and industry were noted; a grant holder from CPUT collaborated with industry on a local manufacturing project involving the equipment. The grant holder at the National Museum noted that the NEP-funded equipment is being utilised for a multi-disciplinary project involving a collaboration between the University of California, the Field Museum in the USA, and Lincoln University in the UK. This was supported by the interviews, in which many grant holders noted how local and international collaborations had led to the development of new research ideas and an increase in the number of research outputs.

Science engagement
Many grant holders listed conferences and scientific engagements in their APRs. Many research outputs are regarded as having a direct impact on relevant scientific and community members. For example, research outputs produced by a grant holder at WITS has been reported to have had a direct impact on advising local farmers of medicinal plants (including traditional healers) on the properties of their products and how these may be impacted by climate change in the future. These research results have been shared with the Department of Environmental Affairs and integrated into their management plans. Further, a grant holder from UFH has reported on efforts to draft farmer training programmes. These programmes will be used to relay research findings that can be used to improve skills development among resource-poor farmers. In terms of the broader public, one institution reported using the equipment to demonstrate experiments on open days, for school tours, and for the general public.

8.4.4 Leveraging of funds

As reported above, 71% of the grant holders indicated that the funded equipment was used by external users. In three-quarters of these cases, a charge out rate was levied on the equipment, which was calculated based on the cost of the equipment's daily usage, maintenance fees, and consumable fees, with most external users believing that these fees were set fairly (88%). Therefore, while operational costs were still incurred in those cases, and while varying numbers of external users were interested in using NEP-funded equipment, the equipment was leveraged to offset some of the institutions' costs. This pay- to-use principle shifts the cost of running the equipment partially away from the research institution to external users, who sometimes use the equipment for more than 50% of its operational time. Simultaneously, a charge out system allows for collaboration, which ultimately yields improved research outputs, culminating in a net benefit for NEP grant holders, who purchased the equipment by improving the cost and research efficiency of the equipment. This pay-to-use principle would benefit those NEP grant holders who have not yet employed a charge out model and *may* assist in ensuring the sustainability of the equipment over time. During the interviews, the grant holders and DVCs noted a need for guidance in setting external charge out rates.

In some cases, the equipment was also used as leverage to apply for additional grant funding, replacement equipment[89], auxiliary equipment, and membership to national or international research consortia. Successes in this regard are evidenced in the APRs, which are required to include this information. The total value of the additional leverage across all grant holders is not readily calculated, due to there being potential for double counting (where applicants may have reported the 1/3 contribution by the institution as a leveraged fund, for example). Having said that, the leveraged amounts reported generally ranged from R50 000 to R4.6 million, with a few exceeding R10 million. A few examples are provided in Table 18 to demonstrate the range of aspects for which leveraged funds were received, and the range in amounts reported. Some of the HDIs had successfully leveraged their pieces of

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[89] Relatedly, a handful of respondents noted the omission of questions in the application process aimed at teasing out whether an applicant has prior experience in operating such equipment. On one hand, while this question might improve the effectiveness of equipment use, such a question also excludes many promising researchers who have theoretical knowledge and wish to move towards more practical application.

equipment for additional funding; the grant holder at UWC was able to attain additional grant funding worth R19 million for their role as PI on a research project, while UFH secured R560 000 in funding for research by postgraduate students from the DSI.

Table 18: Examples of leveraged funds

Purpose of leveraged funds	Examples
Additional grant and research funding (grant holders and postgraduate students)	SUN – 24.5 million UWC – R19 million NICD – R11.4 million NMU – R650 000 UFH – R560 000 UP – R450 000
Equipment maintenance	UCT – R4.6 million UWC – R350 000 DUT – R205 000
Running expenses and consumables for private sector projects	UP – R286 000 UKZN – R250 000 NMU – R200 000 NWU – R78 000
Additional equipment components	WITS – R1.5 million
Grant holder support	UIVEN – R25 000

During the Gauteng site visit, a grant holder at the CSIR reported that their NEP equipment had been used to leverage additional international funding, which enabled the institution to build a larger and more sophisticated equipment system than originally planned when applying for the NEP grant. Further, a grant holder from SUN was able to secure NIH funding to the value of R24.5 million as a result of having the equipment and with additional funding, several PhD students were able to secure post-doctoral fellowships.

The benefit of being able to leverage additional funding, along with the reduced cost of doing research elsewhere (locally or internationally) had the equipment not been available to the grant holder, makes the case for long-term cost savings, cost efficiencies, and potential monetary gains.

8.5 EQ5: What difference is the NEP making? What has the impact of the programme been?

This section assesses some of the impacts seen from the NEP funding to date.

Summary of finding: While the impact of the NEP could not be definitively assessed using the methodology applied in this evaluation, the findings point towards the positive impact of the NEP given the achievement of several long-term outcomes.

Impact assessments are used to measure the long-term benefits and ultimate effects of a programme. By measuring impact, one evaluates the totality of the effects of a development intervention, positive and negative, intended, and unintended. These are the results of achieving specific outcomes, such as reducing poverty and creating jobs. Impact evaluations seek to answer the question of “What do we aim to change?”[90]. Impact measurements focus on the difference between what happened with the programme and what would have happened without it. It answers the question, “How much (if any) of the change observed in the target population occurred because of the programme or intervention?”. Rigorous research designs are needed to measure impact. Measuring impact can also be complex

[90] *Department of Planning, Monitoring and Evaluation (DPME). (2019) Guidelines for the Implementation of the Framework for Strategic Plans and Annual Performance Plans. Pretoria, DPME.*

and intensive because it incorporates methods such as random selection to control and comparison groups. To measure impact properly, it also requires the collection of data following specific statistical methodology, over a period of time, from a range of control and intervention groups, which can be difficult and costly. Impact evaluations typically include a baseline and endline assessment of programmes. Measurements are also often collected from a control group that has similar characteristics to the target population but does not receive the intervention, allowing the two to be compared. To attribute changes in outcomes to a specific intervention, all other possible explanations must be ruled out, and all external or confounding factors must be controlled for. As a result, the impact of the NEP could not be measured fully in this evaluation.

However, there is evidence that the NEP has contributed to the development of a supportive research environment. Access to state-of-the-art equipment is regarded as a necessary condition for the development of competitive and novel research outputs. Several grant holders reported that the attainment and use of the NEP-funded equipment enabled them to make improvements to existing research methods, existing databases, and that these research outputs have contributed to the existing body of knowledge in their relevant fields.

While some gaps have been identified with regard to institutional transformation on the whole, there is evidence that the NEP has fostered institutional transformation in some respects. At UNIVEN, an HDI, one grant holder has used the equipment attained through the NEP to establish their unit as one of the leading laboratories in protein biochemistry on the continent. They were invited by the African Academy of Sciences (AAS) to submit a grant as part of their second Grant Challenges call on drug discovery in malaria and Tuberculosis. As reported in the grant holder's APR, the university's related research proposal has been shortlisted as one of fifteen projects, which speaks to their growing influence in this field. At UFH, the NEP-funded equipment has enabled the development of human capital and knowledge creation. The institution was able to increase the number of research publication outputs in DHET-accredited journals, as well as book chapters and conference presentations as a result of the equipment's placement.

Further, there is evidence that the NEP has enabled the establishment of new research areas. A grant holder at UKZN has reported on their ability to contribute to novel and important scientific research that will advance current knowledge in the field of epidemiology in terms of understanding the factors associated with the failure of anti-retroviral drug resistance in HIV strains in Africa as a result of the equipment funded by the NEP. The research endeavour involved a collaboration with an international team of researchers from the UK and USA. The results of this research were published in *Nature Communications* on World AIDS day. In addition, a grant holder from UP reported that NEP-funded equipment was used extensively to generate data for novel research applications, including space applications. The equipment was also used to develop prototype devices in support of the radio astronomy sector, both locally and internationally, which would not have been possible in its absence.

There is also evidence that the NEP has contributed to improving both the quantity and quality of research outputs at public South African institutions. A grant holder from UNIVEN noted that having access to the state-of-the-art research equipment enabled the institution to raise the average impact factor of their journal publications from approximately IF 3.0 to IF 4.0 in 2020. At UJ, access to the NEP-funded equipment enhanced the research capacity within their Engineering Faculty, as evidenced by the 77 peer-reviewed publications listed in ATLAS in 2020. Further, the university has reported the registration of a total of 9 patents in the final two years of the reporting period, which resulted in their researchers being invited to participate in several conferences.

Little is known about the research performance of these faculties prior to attaining the NEP-funded equipment. Furthermore, gathering data to set a meaningful quantitative baseline against which improvement can be measured is impossible given the multiple confounding factors that contribute to research performance, and the resulting challenges in attributing improved performance to particular interventions such as the NEP. Having said this, the overwhelming majority of grant holders reported that these research outputs would not have been possible had they not been awarded the grant. The placement of the equipment has helped researchers to overcome a range of challenges including delays in using other equipment due to long waiting lists, the contamination of study samples in transit, as well as user fees and transportation costs.

A total of R572 million has been invested in research equipment over the six-year period under review, which represents the most significant investment towards establishing research equipment in the country.

Stemming from the outcomes above, there is evidence towards the anticipated impact of the programme, namely the development of new and competitive products, technologies, and services which will ultimately contribute to socioeconomic development within the country.

8.6 EQ 6: Will the benefits of the NEP last or how can they be sustained?

This section assesses the extent to which the benefits of the NEP will be sustained over time and how this can be enhanced.

Summary of finding: The benefits from the outputs and outcomes achieved by the NEP to date are likely to be sustained going forward, however, there are several important considerations in terms of sustaining the programme in future.

A good return on investment has generally been seen for the NEP over the review period. The provision of the equipment has advanced research efforts at research institutions, enabled the development of human capacity, while enabling collaboration and innovation. The NEP is well-known among the science community and is a popular programme, as evidenced by the number of applications that have been received over the years. It has also grown from investments of a few million Rand at the start of the programme to half a billion Rand invested over the review period. The continuation of the programme is therefore important to further advance R&D in South Africa. Considerations in this regard, unpacked further here, include ensuring ongoing funding from National Treasury; ensuring that investments and focus areas are strategic; human capital needs; succession planning; life cycle planning for equipment end-of-life; and financial succession planning.

One of the main threats to the programme’s sustainability is the funding made available by National Treasury for the research infrastructure programme. A key consideration for attaining this funding is the demonstration of tangible outputs that translate into socioeconomic development and the improvement of citizen’s lives. A key aspect of this lies in the commercialisation of processes and products stemming from the use of the equipment, around which there is room for improvement. Another key consideration is that of transformation, both at the researcher and institutional level, for which several gaps have also been found during this evaluation.

Going forward, more strategic investments will need to be considered, particularly due to broader budgetary limitations, to ensure alignment with the country’s research agenda and to address gaps in the RI landscape. In addition, human capital needs to be nurtured. Given that many grant holders that were awarded grants during the review period are close to retirement, there is a risk with regard to the continued operation of the equipment in the absence of these specialist skills. Succession planning and the development of human capacity for the future is critical; one way in which this can be achieved is through mentorship. Pairing senior grant holders with younger researchers can help to ensure skills transfer, both in terms of using the equipment and in developing their capacity to secure future grant funding and in developing a track record through publication. It would also ensure that there is a second person with in-depth knowledge about the equipment, which mitigates the risk of having all knowledge sit with one person, while also easing the workload of grant holders who have other academic responsibilities. However, appointing a 'second person in command' would require funding. The same principle applies in nurturing a cohort of future operators and engineers to operate and maintain the equipment. The development of a pipeline of specialist researchers (at Honours, Masters, and PhD levels) who are able to use the equipment will also assist in ensuring sustainability going forward.

There is also a need for lifecycle planning for RI. The useful lifespan of most equipment procured through the NEP is between 5 and 15 years. Once that time period has passed, technological advancement will most likely have made the equipment less relevant, or the passing of time will have made the equipment itself obsolete. Either way, the decommissioning of the equipment poses serious risks to the sustainability of research. The fact that the NEP exists as a mechanism for researchers to potentially replace such equipment aids in sustaining research, recognising that due to fiscal constraints, it is impossible to finance every replacement piece of equipment that grant holders apply for.

One suggestion made by respondents referred to an 'award cycle' model. In phase 1 of the award cycle, the NEP grant can be targeted at smaller pieces of equipment (valued below R5 million, for example). All funds available for the NRF to allocate to the NEP can then be run down as usual up to a certain point. Thereafter, all funds could move into a contingency reserve. This contingency reserve can be built up over years and aid in offering NEP grants in phase 2 of the proposed cycle to larger pieces of equipment (above R5 million), with the cycle repeating every few years. However, the lack of availability of similar initiatives or programmes in South Africa is equally important to stress. The NEP acts almost as a sole provider of grant funding to finance equipment purchases. As one respondent indicated, having industry buy-in is critical:

[…] it is difficult to get industry in the RSA to invest in research infrastructure at universities. Many companies do no R&D, unlike overseas. Perhaps the NEP needs to craft a model whereby companies can co-sponsor equipment at universities in unison with the NEP and reap the benefit of having samples analysed with the equipment "off-site" and on a shared cost-basis with universities. This could include co-paying or fully paying the operator's salary, paying towards running costs but not paying a premium fee for analytical services, etc. There would need to be regulation of the instrument use as well (e.g., 50% industry, 50% academic). In effect, this can reduce the total spend needed for companies to get some R&D going and it could benefit universities with infrastructure. Down the line, skilled people (graduates) could filter into such companies as they have created a work link with the universities. This is just one idea on how one might get more money into the system. Indeed a "think tank" might want to look at this type of idea and devise strategies to grow the pot of money available in the NEP.

Even with the NEP in place, and researchers available to use the purchased equipment, there is also a need for financial succession planning. In some cases, the maintenance of equipment is costly. However, without maintenance, the useful life of the equipment might be cut. In other cases, respondents suggest that consumable costs are prohibitively high. Cutting into the useful lifespan or the potential up-time of the equipment inevitably jeopardises the number of research outputs produced and opportunities for collaboration. Again, respondents suggest that a portion of the contingency fund previously mentioned can be earmarked for a top-up grant application. This application can assist in covering maintenance costs or subsidising the cost of consumables to ensure that the equipment is used.

Beyond these steps to ensure continued equipment operation, the equipment has and can continue to be used to secure further funding. Using the equipment obtained through NEP grant funding as the basis of advertising for one's research capabilities ensures that the equipment can be used outside of NEP-backed research, allowing researchers to diversify away from the grant funding, and hopefully commercialising some of their research. Such indirect advertising is not wholly effective on its own. As a result, grant holders also need to advertise the use of their equipment to potential collaborators, as well as use the NRF Research Equipment Database for promotion of equipment availability, as appropriate. Those collaborators (either internal or external to their research institution) can pay a user fee (covering maintenance, consumables, and a slight profit mark-up) to produce their research with the help of those trained to use the equipment[91]. If usage uptake is sufficient, some of these user-fees can be put away to replace components and even entire items of equipment.

9. CONCLUSION AND RECOMMENDATIONS

The findings of the study have conclusively demonstrated that the NEP plays a vital role in supporting research and development in South Africa, providing researchers with critical research infrastructure which they may otherwise not have access to. This is reflected in the research outputs, capacity development, and collaborations which have been generated as a direct outcome of equipment installed under the NEP. Overall the programme is considered to be effectively implemented, with a number of challenges related to the funding applications and, subsequently, the sustainability of the purchased equipment being highlighted through the study.

Several recommendations are made based on the findings of the evaluation, in an effort to maximise the value gained from the programme. Recommendations include those that relate to the programme design or are strategic in nature, and those that relate to operational considerations. Within each of these broad categories, recommendations are further grouped thematically.

9.1 Strategic recommendations

9.1.1 Funding gaps

R1: Address concerns related to funding for extended maintenance contracts, running costs, training, and salaries of operators and technicians to maximise the use of funded equipment through engagement with the institutions and grant holders.

Some of the grant holders reported limitations in covering other equipment and research related costs, which in some cases they felt impacted negatively on the extent to which the benefits of the equipment could be maximised. These included the costs for medium-to-long-term maintenance of the RI once the initial 3-year maintenance plans and policies expired, as well as operational costs associated with using the equipment, including consumables and salaries for part- or full-time operators and technicians, particularly at poorly resourced institutions.

Whilst not denying these challenges faced by grant holders, given that the programme budget is already constrained, it is understood that it is not an option for the DSI or NRF to allocate additional funding to the NEP for supplementary funding (as is done in some of the other countries considered in the international benchmarking review). In addressing this concern, it needs to be reiterated that the NEP is a partnership between the DSI, NRF, and the institution that receives the equipment. Institutions thus need to take greater ownership in helping fulfil the funding needs of their researchers. As such, it is recommended that institutions assess the options to fill these funding gaps using other funding sources, such as directly using subsidies received from publications and student graduations towards equipment-related needs. HDIs and poorly resourced institutions are able to negotiate with

[91] As one grant holder pointed out, this is also useful from a reputational perspective. As a primary user of the equipment, such individuals have the right to request that their name appear on any research output that uses the equipment.

the NRF to waive the one-third contribution to the equipment costs. Where the one-third contribution is waived, funding that would've been used for this purpose should be put towards equipment running costs or operator costs. The NRF should engage with Research Officers at the individual institutions to assist them in planning to fill the funding gaps.

One way of tracking whether there will be issues with funding individual pieces of equipment in future is to introduce a requirement that grant holders include any updates to the original funding plan submitted with their grant application, during each reporting cycle.

R2: Introduce flexibility in terms of the minimum NEP funding cap (R1 million) to cover smaller pieces of equipment.
Feedback received from the grant holder interviews indicates that while most grant holders found the R10 million funding cap to be sufficient to procure state-of-the-art equipment, the lower cap of R1 million was in some cases restrictive. For example, some state-of-the-art equipment costs just less than R1 million, or equipment pieces that either perform enabling functions for larger equipment or improve the efficiency or competitiveness of the research, is excluded from the grant, but it still unaffordable for many researchers. Smaller equipment pieces under R1 million were anecdotally reported to make up the lion's share of equipment needs in certain fields and the competition for this niche funding is high.

It is recommended that a provision be introduced into the design of the NEP to allow for grant holders to apply for funding for certain pieces of equipment costing between R500 000 and R1 million to be considered on a case-by-case basis. Grant holders will need to demonstrate that this equipment is critical for their research, either on its own or as a complement to another larger piece of equipment funded by the NEP, and that they are unable to source other funds for it. Different lower threshold levels could also be considered for "plug and play" equipment versus custom-built equipment.

9.1.2 Transformation

R3: Capacitate HDIs to be better positioned to access NEP funding and equipment.
One of the core objectives of the NEP is to drive transformation by 'developing human resource capacity that is focused on historically disadvantaged institutions, women, and people with disabilities.' Despite this objective, the data shows that HDIs submit far fewer grant proposals than HAIs or combined universities, and had a lower success rate in securing funding. Only 9% of the overall grant value allocated during the period under review went to HDIs (spread across five institutions), and HDIs received 43% of the grant funding they applied for (as compared to HAIs who received 75% of the funding requested).

Discussions with DSI and NRF suggest that this observation is largely not due to a lack of funding, and as noted above there is an opportunity for HDIs to negotiate the one-third contribution to the equipment cost if they are constrained by funding. The issue instead lies with the fact that HDIs lack the institutional capacity and support that is available at better resourced universities, including that offered through research offices, which impacts on the number and quality of proposals submitted. Researchers at these institutions also lacked the required track record needed to secure grants, and in some cases did not have the long-term research programmes in place to warrant large strategic equipment investments, with them rather focusing on shorter term and contract research.

As such, it is recommended that the NRF helps to build the capacity of HDIs in two ways. The first of these is training to provide research offices with the skills to provide improved support to their academics in building research portfolios and preparing successful grant applications. The roles of these offices could include communicating grant information to researchers (including closure dates and requirements for grant preparation), providing support in identifying equipment needs, offering internal review of grant applications prior to submission to the NRF, and assisting the institution to strategically plan for equipment that will be required over the medium term. The second is providing academic support directly to researchers to help them write stronger proposals. It is noted that the DHET has provided substantial investment into programmes that are aimed at capacitating and supporting HDIs, and the assistance to research offices could form part of this investment.

A further recommendation here is that the NRF could facilitate partnerships between HAIs and HDIs, where the HAIs can provide mentorship to HDI researchers on developing grant proposals and through reviewing the proposals in an effort to improve proposal quality and to transfer grant writing skills. Alternatively, a small review committee could be appointed by NRF, made up of individuals considered by them to be best suited for the task, that provides mentorship, guidance, and review or quality assurance support to researchers from HDIs to improve their proposal development skills and chance of success – this panel would serve the function of internal review panels at HAIs. This panel could also provide in-depth feedback to unsuccessful applicants from HDIs to assist them in strengthening future applications.

The final suggestion here is to introduce a mechanism to increase the access of HDIs to NEP-funded equipment via mobility and support grants (as opposed to purchasing the equipment). A competitive grant funding mechanism could be introduced to cover, for example, user fees and travel costs for researchers and students to access equipment at other institutions. This will allow them to develop their track records and enhance capacity over the short-term, which would in turn strengthen the grant applications from HDIs over time.

9.1.3 Strategic planning

R4: Institutions need to strategically plan for the equipment they require.

As mentioned above, the NEP is a partnership between the DSI, NRF, and the funded institutions. To this end, institutions need to take a leading role in strategically planning for the equipment they will need over the short and medium term (over two to five years). Planning institutional priorities for RI ahead of time will allow institutions to be better prepared to submit grant proposals when grant calls are released as they can begin to collate some of the information required and can divide requests for multiple pieces of equipment over different years. Institutional planning and commitment are important for both HDIs and other universities to maximise the benefit to be derived from the NEP. Such planning can be led by a steering committee appointed by the institution and should include the DVC. The NRF could facilitate the establishment of these steering committees, particularly at poorly resourced institutions.

R5: The NRF could facilitate the establishment of research consortia to help institutions collaborate and strategically plan for the equipment required in their province.

As noted in the findings of the study, the Western Cape has an interesting approach to applications for NEP funding. All of the institutions in the province meet to discuss and prioritise the pieces of equipment they require in the province, after which individual institutions are assigned the responsibility of leading the grant application for individual equipment pieces. This model could be applied in other provinces through support from the NRF, to improve success rates of applications, strategic placement of equipment, and allow for mentorship and shared learnings between HAIs and HDIs – although at the same time should be designed in such a way as to not hinder transformation through exclusion of certain individuals or institutions.

9.1.4 Sustainability

R6: The NRF should support institutions and grant holders in establishing charge-out models and expanding external equipment usage.

The DVCs and grant holders indicated uncertainty around how to set charge out rates (for both internal and external usage) for the funded equipment. To ensure the efficient recovery of costs, it is recommended that the NRF host workshops to explore cost recovery models, which should in turn inform the provision of guidance to institutions on how to set charge out rates.

Furthermore, to assist with ensuring financial sustainability and to increase collaborations, it is recommended that during this workshop institutions and grant holders be informed of the benefits and importance of proactively advertising the use of their equipment to potential collaborators, who will pay a user fee (covering maintenance, consumables, and a slight profit mark-up). The NRF Research Equipment Database is one channel that could be leveraged in this regard. If external usage is sufficient, some of the user fees can be used to replace components and even entire pieces of equipment. Whilst provision for external usage of equipment is included in the grant application, this is not always maximised in practice, signalling the need for ongoing guidance on this matter.

A further suggestion offered here for consideration is to link the additional maintenance provision commitment required from the institution to be linked to the expected life of the equipment, rather than making it a fixed two years. This could help ensure that funding is available to maintain equipment for the full duration of its' useful life.

R7: Institutions and grant holders should prioritise succession planning for the equipment.

The development and nurturing of human capital is critical in sustaining the benefits of the funded equipment beyond the life of the grant, especially since a large portion of grant holders in the study were nearing retirement. This need is provided for in the grant application, which requires applicants within 5 years of retirement to submit a succession plan as part of the application. Consideration could be given to requiring updates to succession planning to be included in the APRs. Succession planning should also be a key responsibility for funded institutions going forward rather than relying solely on grant holders to ensure it occurs. Institutions, in collaboration with grant holders, should be required to conduct strategic succession planning for each piece of equipment that they acquire through the NEP. Institutions should appoint at least one secondary or co-grant holder whom the main grant holder can mentor and train to ensure the transfer of skills, in terms of using the equipment, in developing their capacity to secure future grant funding, and in developing a track record through publication. This pairing of researchers will also ensure that there is a 'second in command' should the grant holder become incapacitated in any way and could also help to support transformation in the institutions. The same principle can be used to ensure a future pipeline of skilled equipment operators and technicians. Further, retired grant holders and researchers can also be contracted where appropriate to develop the capacity of younger researchers by providing advanced training on specialised equipment or research methodologies.

R8: Align the NEP to DHET policy.

The DHET has classified universities in terms of their focus areas, resulting in some institutions being primarily focused on undergraduate training rather than research or postgraduate development. The DHET has also set institutional targets for the number of postgraduate student graduations expected. The NRF should align the NEP accordingly to ensure that grants are prioritised for research-intensive universities and those focused on postgraduate training. The NEP should also be aligned to DHET policy, particularly with regard to their capacity development objectives and well-founded labs.

R9: TIA, NIPMO, NRF, and TTOs should develop synergies towards increased research commercialisation.

The evaluation has highlighted that one of the main threats to the programme's sustainability is the funding made available by National Treasury for the research infrastructure programme. Key to attaining this funding is the demonstration of tangible outputs that translate into socioeconomic development and the improvement of the lives of South Africans. This is dependent, in part, on the commercialisation of processes and products linked to the use of the equipment.

Some evidence of the commercialisation of research outputs was identified during the evaluation, such as the case study of the partnership between GrowSafe Pty Ltd and Vytelle to create a “Leader in Bovine Biotechnology”. However, it is suggested that more can be done in the area of commercialisation, which will further contribute to the sustainability of the equipment and the NEP more broadly. It is recommended that seeking out opportunities for the commercialisation of research products and systems be more clearly communicated as a requirement of the grant application process. Furthermore, closer collaboration should be pursued between the Technology Innovation Agency (TIA), the National Intellectual Property Management Office (NIPMO), the NRF and the Technology Transfer Offices (TTOs) at the individual institutions to drive the commercialisation of research undertaken using NEP-funded infrastructure.

R10: The DSI and NRF, in partnership with institutions, could explore opportunities to secure private investment from industry to co-fund the provision of RI.
Given the uncertainty around available funding for the NEP from Treasury, the DSI, NRF, and institutions could explore opportunities to secure investment from the private sector to fund the NEP. This could be done via co-funding of particular pieces of equipment at universities or science councils by the private sector, who in turn would gain access to the equipment and researchers to undertake research and development projects for their products or offerings. For example, industry could make an upfront investment in return for a set amount of hours of access to the equipment for the year, or a set amount of hours of researcher or operator time.

9.2 Operational recommendations

9.2.1 Application process

R11: Ensure that the timing and communication of grant calls is streamlined and communicated clearly, to allow for applicants to plan effectively.
A number of interviewees suggested that there was a lack of clarity and predictability in terms of when and how much funding would be made available under the NEP. It is understood, for example, that this issue arose one year due to the NRF receiving additional funding very close to the end of the financial year which they had to spend immediately, impacting on the awards that were made in two years’ funding cycles. To overcome the uncertainty for grant applicants, it is recommended that the NRF engages with the DSI to highlight the importance of ensuring regular funding cycles for the NEP, including communicating the magnitude of funding that will be available each year. The frequency of funding and the amounts available should be clearly communicated through internet channels and direct engagements with potential grant applicants to enable effective planning by applicants.

A further confusion was identified in that grant holders suggested that the timing of grant proposals overlapped with particularly busy periods during the academic year (start or end of the academic year). This finding did not, however, overlap with the information received from NRF, which suggested that grant calls were announced each April. Once again, this appears to point to a communication issue, which suggests a need for the NRF to further engage with research offices at the universities to communicate the information appropriately, and ensure that websites are up to date with the correct information.

R12: The NRF should provide guidance and training for grant applicants to help them write their proposals and understand the post-award process.
The NRF could compile a guidance document detailing best practice and common pitfalls in applications, and a post-award guidance document for new grantees to ensure full understanding of the process. Grant proposal writing workshops could be offered to assist in proposal development, well in advance of the grant closing dates.

9.2.2 Annual reporting

R13: The NRF should streamline and enhance the annual progress report (APR) process.

Given that the NRF relies upon the APRs to assess grant holder progress and the outcomes of the programme, it is critical that a standardised reporting system is instituted to enable an evaluation of the programme outcomes and impact over time. The evaluation results suggest that the APR process can be improved, given that only around half of the survey respondents indicated that they were satisfied with the APR submission system and the elements covered in the APR.

Many grant holders indicated that they were uncertain about what information was required within each section of the APR as it does not provide guidance, and indeed a lack of standardisation in responses was observed when reviewing the 'research highlights' and 'impact' sections of APRs. The provision of sub-headings and additional guidance on what grant holders are required to report would help to standardise the information for analysis and reporting and for the evaluation of outputs and outcomes. This should be done in line with the Monitoring and Evaluation Framework that was developed as part of this evaluation, drawing on key reporting indicators and the Theory of Change. Grant holders should also be asked to provide photos and other evidence of their usage of and outputs stemming from the equipment as part of the APR. Further, a condition should be added to the funding contract making it compulsory for grant holders to participate in evaluations and other NEP-related research commissioned by the DSI or NRF to ensure good response rates.

In order to track the impact of the NEP more closely, the NRF should require grant applicants to align their proposals to the NRF Impact Framework, describing how their research using the funded equipment will address either knowledge or societal impact, or both.[92] This should also form part of the proposal evaluation scorecard. In addition, impact indicators should be set and measured during the reporting cycles to inform any impact evaluations undertaken in the future.

A further recommendation with respect to the online APR system is that it should be linked to grant holder profiles to remove the repetition required in the forms (such as grant holder details, award details etc). Finally, the NRF should hold grant holders accountable with regard to what they had committed to do in their grant proposals to ensure that they continue work towards these outcomes. This could be achieved by comparing the actual outputs achieved in the APRs against those provided in the proposal.

Some grant holders were concerned about the length of time required to report on outputs, as progress reporting is meant to conclude within five years of the grant holder commissioning the equipment. However, for certain pieces of equipment, the collection of data only concludes after four or five years, which prevents grant holders from having outputs to report on since data collection has been ongoing over several years. A related issue is that it can take several years for certain pieces of equipment to be functional, for users to be trained in its use, and thus for research projects to be completed. This gap can be addressed by allowing, where relevant and appropriate, for an extended timeframe for annual reporting to ensure sufficient time for the completion of outputs and outcomes stemming from the funded equipment.

[92] National Research Foundation. (2021). NRF Framework to Advance the Societal and Knowledge Impact of Research. Pretoria, NRF.

Annexure 1: Evaluation Matrix

Evaluation objective	Evaluation questions	Methods
1. To understand the design and purpose of the programme, how it compares to similar programmes, and the link between RI and human capital development. To design the underlying theory of the National Equipment programme.	• To what extent is the NEP aligned to the research infrastructure/ equipment needs and priorities in South Africa? What are the design strengths and weaknesses of the NEP? • How does the programme compare to similar local and international programmes? • What is known about how research infrastructure (or a lack thereof) impacts on human capital development and training? • How does access to research infrastructure affect research outputs? • What is the Theory of Change that underpins the programme? Does the underlying programme logic apply across all institutions (historically disadvantaged, universities of technology etc)?	Literature review Document review Benchmarking review Key informant interviews with funders and programme managers Development of Theory of Change
2. To assess whether the National Equipment Programme has been implemented as envisaged	• How were beneficiaries and grant recipients selected? How transparent and appropriate was this process? • What has been the level of interest or participation from research institutions? What were the reasons behind their participation/ non-participation? • How were the implementation agents chosen? How transparent and appropriate was this process? • Were the grant values allocated in line with what was envisaged in the NEP founding documents? • Is the equipment provided through the programme currently functional? • What tools have been used to measure, authenticate, and report programme benefits? Who drives delivery, who monitors and reports on it, and what is the frequency of such? • What are the main strengths and weaknesses of the NEP's implementation? What are the main enablers and bottlenecks/constraints/barriers to effective implementation? With whom do these bottlenecks/constraints/barriers lie (across all stakeholders)?	Analysis of programme documents and data Interviews with funder, programme managers, grant holders, and DVCs/Research Officers Site visits/virtual observations

Evaluation objective	Evaluation questions	Methods
3. To assess the effectiveness and impact of the National Equipment Programme	• In which scientific disciplines is the research equipment used? For what is it used? Are there any disciplines that were prioritised for funding? • How equitable is the spread of NEP grants across the 26 universities, the science councils, and national facilities, and across provinces? If not equitably spread, why is this the case? And what can be done to improve participation and success in the NEP? • How effective has the programme been in equipping South African research institutions with state-of-the-art research equipment? And in which disciplines? Which institutional contextual factors facilitate or impede progress? • Is there evidence that the NEP has increased research output quantity and quality? • Is there evidence that the NEP has increased research collaboration? • Has the programme achieved its objectives? What are the key successes produced by the programme? • Are turnaround times suitable for the research enterprise? If not, how can these be streamlined to improve effectiveness and enhance impact in terms of outputs? • What challenges did the programme face? At what level did these challenges lie (funder, implementer, beneficiary, or user)? • Is there evidence that South African research is more globally competitive as a result of the programme? To what extent has the NEP contributed towards closing the 'innovation chasm'? Is there evidence that the NEP has facilitated innovations in the scientific disciplines funded? • What factors have influenced the achievement or non-achievement of objectives? • Were there any unintended consequences or outcomes as a result of the programme? • What can be done to improve the effectiveness of the programme?	Analysis of programme documents and data (including research outputs reported in Annual Progress Reports) Interviews with funder, programme managers, grant holders, and DVCs/Research Officers RI user surveys RI user focus groups Case studies
4. To assess the efficiency of the National Equipment Programme	• Were adequate resources allocated to the implementation of the programme? • Were the outcomes achieved in the most efficient way with the resources available? Does the programme demonstrate value for money? • What is the proportion of funds allocated to operational overheads linked to the management of the grants vs the budget earmarked for grants? • To what degree were the programmes managed in line with good governance principles and management practices? • What is the cost of implementing the NEP in terms of the research outputs, including patents, produced (cost benefit analysis)? • What can be done to improve the efficiency of the NEP?	Analysis of programme documents and data Financial analysis

Evaluation objective	Evaluation questions	Methods
5. To assess programme sustainability	• What plans have been put in place for research equipment utilisation, maintenance, and replacement? • Is DSI the sole funder of the NEP? What additional sources can be tapped into to expand the pool of funds to support additional grants? How can funds be raised to support historically disadvantaged institutions to get on par with research equipment backlogs? • Was the NEP designed to be sustainable beyond the funding cycle? If so, how? What specific sustainability measures were built into the NEP? • How will the gains made be sustained (at the institutional level, in terms of beneficiary skills, and in terms of regional collaborations) • How would the discontinuation of the NEP impact the broader science system? • What are the recommendations going forward? • Should the NEP be continued? If so, with what changes, if any? • What factors hinder or promote sustainability?	All of the above

Annexure 2: Proposed Revised Logframe

Indicator no.	Description	Indicator	Target	Verification source
Output indicators				
Output 1	Institutions are awarded grants	% of successful applicants that have signed grant award contracts	100% of successful applicants have signed grant award contracts	Grant contracts
Output 2	Funded equipment is commissioned at recipient institutions and is functional	- % of awarded institutions that have commissioned the equipment - % of institutions that have functional equipment among those that have commissioned the equipment	-	Annual Progress Reports Site visit observations
Output 3	Human capacity is developed	- No. of users trained in the usage of the equipment, disaggregated by user type (postgraduate student, researcher, collaborator, external user at public or private institution)	- Min. 10 postgraduate students trained in equipment's use per year	Annual Progress Reports Training registers User surveys
		No. of operators trained to operate the equipment	-	Training registers Interviews with Research Officers and grant holders
		No. of technicians trained to maintain or repair the equipment	-	
Output 4	Increase in research outputs from equipment usage (indicating equipment productivity and innovative capacity)	No. of publications compiled from equipment's usage (local and international journal articles, book chapters, books, reports, conference proceedings etc), disaggregated by publication type and authorship (sole vs. co-authorship)	- Min. 4 publications in in international refereed journals per year	Annual progress reports Publications Registered patents
		No. of patents developed and registered	-	
Output 5	Research collaborations fostered	No. of research collaborations formed as a result of the equipment's usage, disaggregated by user type, collaboration type (institutional, private sector, national, regional, international collaboration), and collaboration activity (joint research project or publication, conference participation, research programme participation)	-	Annual Progress Reports User surveys
Output 6	Income leveraged by institutions to generate further income	% change in institutional income as a result of the placement of the equipment	-	Institutional financial records Interviews with DVCs/Research Officers

Output 7	Science / community engagement and communication	No. of science communication and engagement programmes the institution has hosted or participated in related to the equipment	-	Annual Progress Reports Interviews with grant holders and DVCs/Research Officers
		No. of community science outreach and awareness programmes the institution has hosted or participated in related to the equipment		
Output 8	Performance and financial reporting	% of grant holders that submit Annual Progress Reports	100% of grant holders submit Annual Progress Reports	Annual Progress Reports
		% of total sites visited by NRF	-	NRF site reports
		% of institutions that have received grant funding	-	Institutional financial reports

ANNEXURE 3: STAKEHOLDERS INTERVIEWED FOR THE EVALUATION

Table A1. Interviews with internal programme stakeholders

Organisation	No. interviewees	Position of interviewees
National Research Foundation	5	Deputy Chief Executive Officer: National Research Infrastructure Platforms
		Director: Human Infrastructure Capacity Development
		Executive Director: Human & Infrastructure Capacity Development
		Professional Officer: Human & Infrastructure Capacity Development
		Professional Officer: Human & Infrastructure Capacity Development
Department of Science & Innovation	4	Chief Director: Indigenous Knowledge Systems
		Chief Director: Basic Sciences & Infrastructure
		Director: Research Infrastructure
		Project Administrator: Basic Sciences and Infrastructure
Total	9	

Sampling of grant holders

The size of the grant holder sample selected for the semi-structured interviews was determined using a scientific sample size calculation. This calculation made use of three key variables, namely, (a) the population size; (b) the confidence level; and (c) the margin of error. The sample is calculated using the following formula:

$$\text{Sample size} = \frac{\dfrac{z^2 \times p(1-p)}{e^2}}{1 + \left(\dfrac{z^2 \times p(1-p)}{e^2 N}\right)}$$

Where:

- N = Population size[93]
- Z = Z-score[94]
- e = Margin of error[95]
- P = Standard deviation[96]

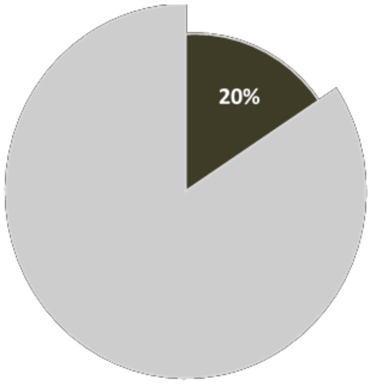
The NEP grant holder sample was calculated using the following values.

- Population size = 126
- Confidence level[97] (%) = 90%

[93] The population size refers to the total number of people within your demographic.
[94] The z-score included in this calculation is the number of standard deviations a given proportion is away from the mean and is determined by the confidence level.
[95] The margin of error, also referred to as "confidence interval," refers to the amount of error you wish to allow in your results.
[96] The standard of deviation indicates how much variation you expect among your responses.
[97] The confidence level is closely related to confidence interval (margin of error). This value measures your degree of certainty regarding how well a sample represents the overall population within your chosen margin of error.

- Margin of error (%) = 15%

Sample size relative to population size



The sample represents 20% of the population. Initially, 25 grant holders were selected from the population database (126) for the sample, however, it was later noted that 4 grant holders held multiple grants, such that there were only 122 unique grant holders, and the ultimate sample size was reduced to 24.

Once the sample size was determined, there was a need to ensure that the sample is representative across various population characteristics. These population characteristics are referred to as stratification categories.

Stratification Categories

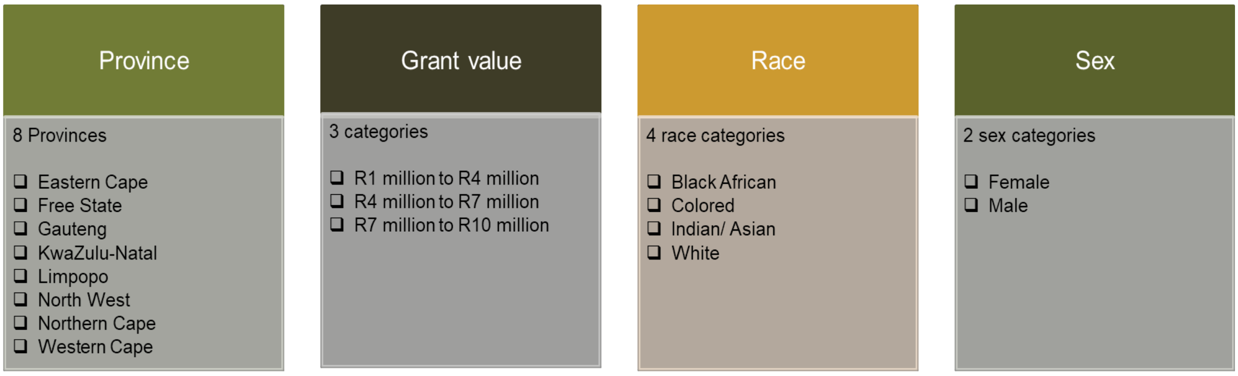


Table A2: Interviews with grant holders

Province	Institution	No. interviewees	Discipline / department of grant holder
Eastern Cape	RU	1	Geology, Engineering & Space Sciences
		1	Earth & Marine Sciences
Free State	CUT	1	Physical Sciences
Gauteng	ARC	1	Chemistry
		1	Environmental & Agricultural Sciences
	CSIR	1	Geology, Engineering & Space Sciences
	SMHS	1	Science Research & Applications
	NICD	1	Chemical, Metallurgical & Materials Engineering (Polymer Division)
	UJ	1	Chemistry
		1	Physics And Chemistry
	UP	1	Physical Sciences
	WITS	2	Biological & Health Sciences
		1	Physical Sciences
KwaZulu Natal	DUT	1	Physical Sciences
	UKZN	1	Earth Sciences
Limpopo	UL	1	Geology, Engineering & Space Sciences
North West	NWU	1	Chemistry
Northern Cape	SANSA	1	Institute For Water Research
Western Cape	CPUT	1	Biological& Health Sciences
	SAAO	1	Geology, Engineering & Space Sciences
	SUN	1	Chemistry
	UCT	1	Biotechnology
	UWC	1	Physics & Chemistry
Total		**24**	

The final sample list was compiled by including a list of individuals that satisfy all the stratification categories proportionately to that of the population database. This was an iterative process, which means that 24 grant holders were selected, and the list was then checked against the provincial, grant value, sex, and race sample target numbers. If there was an imbalance, grant holders were swapped out from the population group until the correct population-sample proportions were established.

Table A3: Interviews with university management

Province	Institution	No. interviewees	Position of interviewees
Gauteng	WITS	1	Assistant Director: Research Development
Limpopo	UL	1	Vice Chancellor
North West	NWU	2	Deputy Vice Chancellor: Research and Innovation
			Director: Research Support
Free State	CUT	2	Acting Senior Director: Research Development and Postgraduate Studies
			Acting Deputy Vice Chancellor
KwaZulu Natal	DUT	1	Deputy Vice Chancellor: Research Innovation Engagement
Eastern Cape	RU	2	Deputy Vice Chancellor: Research and Innovation
			Director: Research Office
Western Cape	UCT	2	Deputy Vice Chancellor
			Director: Research Development
	Total	**11**	

Table A4: Interviews with operators and technicians

Province	Institution	No. interviewees reached	Position of interviewees
Limpopo	UL	1	Equipment Operator
Western Cape	UCT	2	Equipment Operator & Technician