AN EXPLORATORY EVALUATION OF THE SOCIOECONOMIC IMPACTS OF SELECTED NRF FUNDING INSTRUMENTS

FINAL REPORT

PART 3 OF 4

VALUING RESEARCH: THE CASE STUDIES

February 2015
Contents

1. Structure of the Report ............................................................................................................................................. 1

2. The Case Studies ......................................................................................................................................................... 1
   2.1. Approach and Methodology ................................................................................................................................. 1
   2.2. Strength of the Evidence ........................................................................................................................................ 1
   2.3. Selecting the Cases ............................................................................................................................................... 2
   2.4. Case Study Findings ............................................................................................................................................... 4
   2.5. More about the Cases .......................................................................................................................................... 6

3. Valuing Cases from SARCHI ....................................................................................................................................... 7
   3.1. Case Study 1: The Pomegranate Story – Supporting a Fledgling Industry ........................................................... 7
   3.2. Valuation for Case Study 1 .................................................................................................................................. 13
   3.3. Case Study 2: Building a World Class Initiative for the Pharmaceutical Industry ............................................. 16
   3.4. Valuation for Case Study 2 .................................................................................................................................. 23

4. Valuing Cases from the Centres of Excellence ............................................................................................................... 25
   4.1. Case Study 3: Excellence in Invasion Biology ........................................................................................................ 25
   4.2. Valuation for Case Study 3 .................................................................................................................................. 33
   4.3. Case Study 4: Preventing and Managing Forest Infestations ............................................................................... 39
   4.4. Valuation for Case Study 4 .................................................................................................................................. 46
   4.5. Case Study 5: From TB Research to Clinical Trials .............................................................................................. 50
   4.6. Valuation for Case Study 5 .................................................................................................................................. 53

5. Valuing Cases from NEp/NNEP and SARCHI .............................................................................................................. 56
   5.1. Case Study 6: Equipped to Lead – Cell Biology, Lipid Characterisation and Other Applications ......................... 56
   5.2. The Value Proposition for Case Study 6 .................................................................................................................. 60
   5.3. Case Study 7: African Firsts – NMR, Vaccines and Malaria Drugs for Africa ....................................................... 61
   5.4. The Value Proposition of the NMR Facility at UCT ............................................................................................... 66
   5.5. Case Study 7A: Synergies – The SARCHI Research Chair in Drug Discovery .................................................... 67
   5.6. Valuation for Case Study 7 .................................................................................................................................. 69

List of Figures

Figure 1: Value proposition of the pomegranate research programme ............................................................................ 7
Figure 2: Valuation steps .................................................................................................................................................... 14
Figure 3: Impact considerations ...................................................................................................................................... 15
Figure 4: The value proposition of the Research Chair in Pharmaceutical Drug Delivery Technologies ...................... 16
Figure 5: Estimated pathways to more effective pharmaceutical products ................................................................. 23
Figure 6: Summary of value proposition of CIB project used for valuation ................................................................. 25
Figure 7: Ecosystem services from an economic standpoint ............................................................................................ 34
Figure 8 Valuation steps .................................................................................................................................................... 34
Figure 9: The value proposition of the CTHB project used as case study ................................................................. 39
Figure 10: Funding trends for the CTHB for the period 2005-2013 ................................................................................. 44
Figure 11: Citations for peer reviewed journal publications by CTHB (2005-2013) 45
Figure 12: Valuation steps for Sirex woodwasp analysis 46
Figure 13: Pathways to economic impact, Sirex woodwasp analysis 47
Figure 14: Net benefits for levels of adherence to Sirex management protocols (R million) 49
Figure 15: Value proposition of the CBTBR project used as case study 50
Figure 16: Valuation steps for the TASK Applied Science Facility 53
Figure 17: Overview of Graduates using the XPS/ESCA, UFS (2010-2013) 59
Figure 18: Value proposition of the High Field NMR Facility at UCT 61
Figure 19: Potential pathway from research to policy and back 71

List of Tables

Table 1: Selected case studies, with the classification and monetisation approaches 3
Table 2: Net value created for the pomegranate industry by the Research Chair and his team 15
Table 3: Description of benefits considered in fynbos Code of Best practice analysis 35
Table 4: Values generated annually and Present Value of benefits under variety of discount rates – R2014 38
Table 5: Funding leveraged by the CTHB for the period 2005-2013 43
Table 6: Net benefit figures for levels of adherence to Sirex management protocols (R million) 48
Table 7: Areas of potential value of the TASK Applied Science facility 54
Table 8: Annual net value created by the TASK Applied Science facility 55
Table 9: Median cost per person per year for different anti-malaria strategies 69
1. STRUCTURE OF THE REPORT

The report is divided into four parts that can be read together or separately, although they cross-reference one another.

They provide different levels of detail and can be used for different planning and assessment purposes.

**Part 1 of 4:** This is the Summary Report. It describes the evaluation purpose and context, the approach and methodology followed, the main strategic findings and insights, and the resulting recommendations. It summarises the different value propositions of NRF supported research and research capacity strengthening efforts, the role that the NRF has played, and other factors that influence road to impact in each of the funding instruments.

**Part 2 of 4:** Understanding Impact in five NRF Funding Instrument Portfolios. This part of the report discusses the type and scope of the benefits, outcomes and impacts found as a result of the support of each of the five funding instruments. It highlights the factors influencing efforts to achieve impact, and how the NRF has contributed. It also describes the valuing and effort at monetisation done for the HCD Scholarship and Fellowship funding instrument. The frameworks and methodologies that were used for this part of the study are described in Part 1 of the report. For easy reference the list of findings in this part of the report is also provided in the list of annexes in Part 4.

**Part 3 of 4:** Valuing Research and Research Capacities - the Case Studies. This part of the report focuses on the economic valuing and efforts at monetisation that were done for the CoEs, SARChI and NEP/NEPP funding instruments. It gives a description of the eight case studies used for this purpose, the valuing methods and calculations. The level of detail in the case study descriptions also gives an opportunity to illustrate the role that the NRF has played on the road to impact.

**Part 4 of 4:** The Annexes provide details relevant to the evaluation questions that had to be answered; the documents read persons interviewed; the acronyms used, the findings that followed from the analyses in Part 2 of the report, and the biographies of the evaluation team members. The survey instruments are not provided due to the complex routings that were followed on-line, while the interviews, although semi-structured, were significantly adapted per stakeholder and purpose. These instruments are available from the evaluation team.
2. THE CASE STUDIES

2.1. APPROACH AND METHODOLOGY

A case-based design was developed for phase 2 of the evaluation. The researchers were guided to focus their data collection on specific areas of common interest. In all studies the researchers first familiarised themselves with the guidance and documentation provided. Information gaps and areas for analysis were identified, and questions prepared for data collection.

In most cases, one-on-one interviews or focus group discussions were held with key researchers and research team members (including postgraduate students and postdoctoral fellows) and, to the extent that time allowed, with external stakeholders – usually officials from the institution, research partners, the private sector or government. Face-to-face, Skype, telephonic and email interviews were conducted. In order to better understand and/or validate key claims, subsequent to the interviews additional data and information were requested from, or provided by the stakeholders. Triangulation was used wherever possible to strengthen the credibility of the case analysis, in particular in understanding the role that the NRF played – if any - in achieving the relevant benefit or impact.

The use of the Social Return on Investment (SROI) methodology was originally considered as valuation tool. Its principle of valuing what matters most to those impacted by an intervention may resonate with, and be viewed sympathetically by, the academic community whose goal is not the maximisation of economic returns. However, it was soon clear that its involved nature did not lend itself to interventions as wide ranging and at the scale of the NRF funding instruments.

It may in future likely still be used for specific research breakthroughs; the methodology offers the greatest potential for learning when employed to analyse a more focussed intervention, developing an understanding of valued change from the perspective of the impacted stakeholders, and establishing alternative indicators that can then be employed more widely in the future to provide evidence of value creation.

Instead, some of the numerous methodologies for calculating rates of return to research were used in order to provide illustrative examples of potential or realised value. At no time was an effort made to do a comprehensive valuing of the socioeconomic benefits and impacts resulting from a particular funding instrument. Instead, the focus was on identifying the value proposition presented by each funding instrument, highlighting those aspects which can be quantified and calculated in monetary terms.

2.2. STRENGTH OF THE EVIDENCE

The evidence presented in the case studies is a consolidation of the discussions, written explanations and information extracted from documentation, including from publication and patent lists, and various reports. The need for systematic triangulation using different sources and methods was emphasised. Although triangulation could not in all cases be equally rigorously applied, the evidence was strengthened among others by (sometimes confidential) assessments and evaluations submitted to the NRF by various university officials, or by external experts and stakeholders, including those involved in assessments of the Centres of Excellence and Research Chairs since their inception; by survey data obtained for different purposes; and in some cases, by written testimonials about the role of the grant-holder and his/her team from government and other external stakeholders with intimate knowledge of what was achieved. Where clear patterns arose across cases, this was also seen as adding credibility to key findings.

1 And in the case of the HCD and Thuthuka, also in some cases between analysts
2.3. SELECTING THE CASES

Studies of socioeconomic impact tend to cherry-pick the best examples of such impacts in a portfolio, frequently to advocate for science funding. In this evaluation the team sought to understand the type of impacts in the portfolio of each funding instrument, and then to provide illustrative examples of the strategic as well as direct and indirect socioeconomic benefits or impacts that have followed, or might still follow.

<table>
<thead>
<tr>
<th>Selection of the Case Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Spread across the funding instruments:</strong> Three cases were selected from each of the Centres of Excellence and SARChI, and two from the NEP/NNEP. Thuthuka and the HCD Scholarships were themselves each a case study as a result of the nature of the grants and their strong focus on capacity strengthening (described each in its own chapter in this report).</td>
</tr>
<tr>
<td>2. <strong>Demonstrating different types of value creating vectors:</strong> Cases emphasise different types of impacts resulting from basic (use-inspired) research, technology development, policy influence and strategic human capital development.</td>
</tr>
<tr>
<td>3. <strong>Highlighting a specific theme:</strong> For some coherence, one national strategic priority area, <em>i.e.</em> the bioeconomy, was selected as broad theme within which to explore the different cases, with several relating to health as a sub-theme.</td>
</tr>
<tr>
<td>4. <strong>Demonstrating specific attributes:</strong> Several cases were selected to highlight specific attributes particular to that case, such as a research focus on resolving South African or Africa-wide challenges, new research directions in areas of national strategic interest stimulated or built up, or public-private partnerships catalysed. In one case the synergy or interface between two NRF funding instruments, viz NEP and SARChI, was highlighted.</td>
</tr>
<tr>
<td>5. <strong>Balancing direct economic impacts with indirect impacts or wider ripples:</strong> The cases balance those with direct economic impacts – some already achieved, some still only potential - that avail themselves for monetisation (albeit some with significant assumptions) with those where the impacts were primarily strategic, often with a long-term view, and/or very difficult or impossible to monetise.</td>
</tr>
</tbody>
</table>

The team therefore tried – to the extent that a few case studies allow – to cover a range of benefits or impacts across three of the five funding instruments: the CoEs, SARChI and NEP/NNEP. This assisted in identifying the value proposition of the work highlighted in each case, which then helped to inform key findings about the possible value proposition of each funding instrument.

In future, the classification of impacts and pathways towards impact highlighted in the portfolio analyses in Phase 1 (described in each of the funding instrument chapters in Part 2 of this report), can be used to frame and focus more comprehensive evaluation. In addition to what has been done here, many different types of approaches and methodologies exist which can be considered for application, given the most state of the art understanding of the field.

One major omission in the triangulation has been insufficient voice of collaborators and partners; this will be crucial for full-fledged studies in future. There were also many funding streams enabling a particular set of impacts, making it difficult to determine the contribution of each. In spite of this, the evaluation team is confident that a plausible case can be made for the noted contributions by NRF.

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2 A case study approach would not have been suitable for the HCD Scholarships and Thuthuka

### Table 1: Selected case studies, with the classification and monetisation approaches

<table>
<thead>
<tr>
<th>Selected Case</th>
<th>FI</th>
<th>Key reasons for selection</th>
<th>Strategic priority &amp; field</th>
<th>Monetisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Excellence in Invasive Biology</td>
<td>CoE</td>
<td>Demonstration of multiple value creating vectors, with several directly monetisable impacts that illustrate scope of CoE contributions. Significant policy influence.</td>
<td>Bioeconomy Invasion biology</td>
<td>Yes – one component of several possibilities</td>
</tr>
<tr>
<td>2. Preventing and Managing Forest Infestations</td>
<td>CoE</td>
<td>Demonstration of multiple value creating vectors, with several directly monetisable impacts that illustrate scope of CoE contributions. Significant support to the private sector.</td>
<td>Bioeconomy Tree health biotechnology</td>
<td>Yes – one component of several possibilities</td>
</tr>
<tr>
<td>3. From TB Research to Full Clinical Trials</td>
<td>CoE</td>
<td>Demonstration of unexpected impact rippling out from a limited CoE contribution, following use-inspired basic science combined with entrepreneurship and window of opportunity.</td>
<td>Bioeconomy / Health Biomedical TB research - clinical trials</td>
<td>Yes</td>
</tr>
<tr>
<td>4. The Pomegranate Story: Assisting a Fledgling Industry</td>
<td>SARCHI</td>
<td>Demonstration of impact of a Research Chair attracted to South Africa, and responsive to the needs of the private sector.</td>
<td>Bioeconomy Postharvest technology</td>
<td>Yes – one of three Chair programmes</td>
</tr>
<tr>
<td>5. World Class Initiative for the Pharmaceutical Industry: Biomaterials &amp; Drug Delivery Technologies</td>
<td>SARCHI</td>
<td>Demonstration of significant strategic impacts by Research Chair, without readily monetisable component but essential for national interests. Strong contribution by NEP/NNEP.</td>
<td>Bioeconomy / Health Pharmaceutical biomaterials &amp; drug delivery</td>
<td>No – potential for application and impact, but not yet realised too complex</td>
</tr>
<tr>
<td>6./7. African Firsts: NMR, Vaccines and Malaria Drugs for Africa</td>
<td>NEP &amp; SARCHI</td>
<td>Demonstration of key role of instrument - frequently funded by NEP/NNEP in universities - in world-class scientific breakthroughs, with direct economic consequences. Demonstration of Research Chair achievement in addressing a serious African challenge with major international collaboration and direct economic and social impact.</td>
<td>Bioeconomy / Health NMR: Chemical analysis, vaccine development &amp; drug delivery</td>
<td>Yes - one component of several possibilities</td>
</tr>
<tr>
<td>8. Equipped to Lead: Cell Biology, Lipid Characterisation and other Applications</td>
<td>NEP/ NNEP</td>
<td>Demonstration of a cutting edge NRF funded departmental facility’s utilisation for multiple, diverse projects, and without which breakthrough work would have been impossible. Potential for national application emerging in at least one project.</td>
<td>XPS/ESCA: Chemistry – energy security, NANOSAM: Chemistry – energy security, laser research, RC 1 Reactor: Chemistry – energy security</td>
<td>No – potential for application and impact, but not yet realised</td>
</tr>
</tbody>
</table>
2.4. **CASE STUDY FINDINGS**

In this study, the value of research oriented funding instruments such as the CoE, SARChI and NEP/NNEP was modelled via a case study approach. The wide variety of economic, social (health) and environmental values created by the research outputs of the different institutions supported by NRF cannot be easily aggregated; it is essential to be able to work with a precise scientific output or set of outputs (research findings) with some cohesion between them.

The following details the key valuation findings from the case studies reviewed. They give only a snapshot of the many different types of impacts and mostly realised returns on investment, and the precise role of the NRF in the process. The cases are recorded in detail in each of the following five chapters, with a specific focus on tracing exactly what role the NRF contribution played in achieving the valued impact. The cases were selected purely to be illustrative of the spectrum of possible impacts in the various portfolios (their selection criteria are listed in the previous chapter); in several cases already-prominent examples of impact were used to determine what these might have yielded in terms of ‘monetisable’ value.

As noted above, in future a more systematic stratified case study approach can be used to identify estimates for sector specific values for those themes, sectors or fields prioritised by national interests or by the CoE, SARChI or NEP/NNEP Funding Instruments.

Sustainable research institutions require a critical mass of researchers – staff, students and partners - to create an enabling environment for academic and research activities, helping to maintain mutual support and allowing researchers to keep abreast of recent advancements and debates. Follow-up studies that explore the value of sustainability may provide further supporting evidence for the value to educational institutions and to national interests of increasing the throughput of post-graduate students across the human capital development pipeline.

A recurring caveat for all use-inspired research case studies is that without effective implementation, the estimated value of the research can be significantly undermined. For this reason, the evaluation team was hesitant to speculate about potential value that has not yet been realised through successful implementation.

**Case Study 1: Excellence in Invasive Biology**

*Centre of Excellence in Invasive Biology (CIB)*

This valuation analysis focused on one of the work components of the CIB, namely the creation of sustainability guidelines for the South African wildflower industry. The analysis suggested that the research contributed to benefits in the region of R11m to R76m per annum with a medium figure of R42m. This value is distributed across a range of stakeholders, including the wild flower and tourism industries as well as water users and is predominantly economic (use value) in nature. Likely additional beneficiaries not included in the analysis include marine based tourism, the fishing industry and wider South African society. That the benefits modelled in the analysis excluded non-use values of the preservation of the wild flowers of the Agulhas plain, the total economic value (inclusive of use and non-use values) of the research is likely to be significantly higher. The analysis suggests an effective intervention in the strategically important area of biodiversity.

**Case Study 2: Preventing and Managing Forest Infestations**

*Centre of Excellence in Tree Health Biotechnology (CTHB)*

This valuation analysis focused on the development by the CTHB of controls for the future management of the *Sirex* woodwasp. The research’s focus on non-native pine plantation forestry meant the identified value was predominantly economic in nature. The estimated economic value to the industry’s growers and processors of avoidance of another outbreak was estimated to be between R 1.0-1.2bn (though the full economic value is less than zero if full opportunity costs are included). The estimated value is heavily dependent on the implementation of the research findings (an issue due to the high opportunity cost of certain prevention approaches e.g. thinning). Since the research was undertaken, the *Sirex* woodwasp has become ubiquitous in South Africa. The value of the benefits is, therefore, likely to be an underestimation of the full current value of prevention.
Case Study 3: From TB Research to Full Clinical Trials

*Centre of Excellence for Biomedical Tuberculosis Research (CBTBR)*

The value analysed in the creation of the TB clinical trial facility is economic – direct and indirect; direct in terms of net employment, foreign exchange earnings and taxation – the latter two components constituting approximately R28m per annum; indirect in terms of demand for local services and products. The possible health (and associated socioeconomic) benefits are potentially significant due to the prevalence of TB in South Africa. The presence of a world class facility in South Africa may also have a potentially catalytic effect on other parts of the medical industry. Resource constraints prevented the full exploration of these potential wider values.

Case Study 4: The Pomegranate Story

*SARChI Research Chair: Prof Linus Opara*

Agricultural diversification is a sensible strategy for support of rural economies. Research into post-harvest technologies has helped drive the growth of the nascent Pomegranate industry and resulted in estimated direct and indirect benefits to the economy of approximately R65m to date with a further R90m projected through to 2018. We estimate this growth has also fuelled new job creation in the agriculture packing industry.

Case Study 5: Building a World Class Initiative for the Pharmaceutical Industry

*SARChI Research Chair: Prof Viness Pillay*

The potential value created by patented drug delivery technologies successfully taken to market is huge and varied. However, it is also likely to occur sometime in the future, and as such could not be valued here. However, the production of high grade graduates with leadership skills in cutting edge methods provides short to medium term value ranging from economic value in the form of reduced recruitment costs to cost savings / new revenue generation from a new cadre of leaders entering the sector. While the full value of a successful new drug delivery system may be a number of years off, the reputation for excellence can encourage foreign direct investment and have a brain gain effect.

Case Study 6: Equipped to Lead in Surface Characterisation

*NEP/NNEP grants: Proff Jannie Swarts, Hendrik Swart & colleagues, UFS – XPS/ECSA, NANOSAM, RC 1 Reactor*

As in the case of the other NEP/NNEP case study noted above, the surface characterisation facility at the Department of Chemistry at the University of the Free State, unique in Africa, has been crucial in supporting significant research breakthroughs. Here, they are further away from application and their potential much harder to estimate; their contributions have therefore not been valued here. At the moment the benefits from the use of this facility are thus primarily strategic, consisting among others of essential support to SASOL; a research breakthrough – very significant from a scholarly perspective - that could assist the brewing and baking industries, as well as local and international actors in the health field; and useful new insights with respect to the many advantages to the red meat industry of diet supplementation with conjugated linoleic acid. Implementation of these latter findings is hampered by practical and cost considerations; this might change in the near future if South Africa follows trends in Europe.

Case Studies 7 and 7A: African Firsts - NMR, Vaccines and Malaria Drugs for Africa

*NEP/NNEP grants: Prof Graham Jackson, with Prof Neil Ravenscroft, UCT - NMR*

*SARChI Research Chair: Prof Kelly Chibale*

This case study spanned contributions from both the NEP/NNEP as well as SARChI funding instruments. As with the drug delivery technologies case study, the potential value of a new, more effective drug created in South Africa are likely to be significant and many, but occurring in the future. It has therefore not been valued here; to do so realistically based on potential would require work beyond the scope of this study. However, the NRF SARChI contribution helped to catalyse R100m additional funding, expanded the research team from four to 26 in 2014 and an expected 50 in 2015, and supported a breakthrough that, if it comes to fruition after the on-going large-scale clinical trial, will help to address a disease that is estimated to cost Africa approximately US$12bn per year. While the socioeconomic benefits to Africa of a more effective anti-malaria drug are huge, so are the potential benefits of its creation in South Africa, including job creation, taxation, reduced health costs and the potential to more meaningfully
influence global research priorities in the area.

The high-field 400MHz Bruker NMR spectrometer is an expensive yet commonly available instrument in many Chemistry departments across South Africa. Its contribution at UCT represents many similar situations. It significantly increased the efficiency and saved costs for the work of Prof Chibale. In addition to supporting many others in research and training, it was also essential for the contribution of Prof Neil Ravenscroft to the development of a breakthrough vaccine that is currently being implemented to rid Africa of meningitis, a disease that has been causing at least 200,000 people per year to suffer, with mortality around 10-15%. It was a first for Africa in terms of its low cost, its ability to survive in high temperature enough days to enable vaccination campaigns in isolated areas, and its potential to wipe out the disease.

These two cases highlight the difficulties in estimating the precise contribution of such an instrument to eventual research breakthroughs followed by socioeconomic impact; they also highlight that this should be done in order to give due credit to the value proposition of a category of instrument in which the NRF has made a significant investment.

2.5. MORE ABOUT THE CASES

Three SARCHi case studies were used as examples for valuing the work of the Research Chairs. The first case, that of Professor Umezuruike Linus Opara, Research Chair in Postharvest Technology, describes the direct economic impact on the fresh fruit industry of one of three research programmes initiated by this Research Chair, who was attracted to South Africa from Oman by a SARCHi grant. The case study described in this report serves as an example of the situation where the arrival of the Chair holder sparked the development of a new research programme in response to technological needs of an emerging industrial sector, which hitherto, were not being addressed.

The second case focuses on the strategic benefits of the work of Prof Viness Pillay, Research Chair in Pharmaceutical Biomaterials & Drug Delivery Technologies. His work serves as an example of those Chairs where as a result of contextual factors or in some cases, personal choices, direct economic benefits are not achievable, yet strategic benefits are delivered that are of significant value. Prof Pillay balances pure basic, use-inspired basic and applied research in order to produce high quality basic and applied knowledge as well as market-ready students. This case also highlights the synergistic effect of the NEP/NNEP and SARCHi. Without the one, the achievements of the other would not have been possible.

The third case is captured in the NEP/NNEP funding instrument chapter; it should be read in conjunction with the other two SARCHi cases. Although this particular case emphasises the NEP/NNEP contributions, it also analyses and values the breakthrough work of Prof Kelly Chibale, the Research Chair in Drug Delivery.

The CoE case studies highlight some of the main impacts of the work of the Centre of Excellence for Invasion Biology (C I B) and CTHB. These two Centres have many aspects with direct or indirect economic value, in particular in terms of influence on policies, strategies, guidelines and management practices, as well as collaboration with the industry. However, after a broader description of the Centre programmes and achievements, the focus narrows down to a particular project for valuation. The case studies also include one initiative that spun off from CBTBR. This Centre has its own very impressive set of outcomes and impacts, similar to those highlighted in the other case studies; the case described here only serves to illustrate how a relatively small NRF contribution that builds on years of expertise can have a catalytic effect and lead to something much more substantive.

The NEP/NNEP case studies were selected to demonstrate (i) at the University of the Free State, the different services rendered by a state of the art facility that makes new areas of research possible as well as important capacity strengthening contributions. It provides many aspects of strategic value, although not yet any with direct financial impact in spite of strong capacity strengthening contributions, and (ii) at the University of Cape Town, the different types of contributions of a basic instrument to several world-class scientific breakthroughs with significant potential - and in at least one case already realised – for direct socioeconomic impact. It also demonstrates the synergy between funding programmes such as SARCHi and NEP/NNEP.
3. VALUING CASES FROM SARCHI

3.1. CASE STUDY 1: THE POMEGRANATE STORY – SUPPORTING A FLEDGLING INDUSTRY

Figure 1: Value proposition of the pomegranate research programme

The Chair in Postharvest Technology

A 2006 study by the DST underscored the considerable potential of cold chain technologies to make major contributions in South Africa’s national research and development strategy. The report also supported new initiatives to transform the SA fresh fruit industry through the development and application of postharvest technology and cold chain innovation. Following a detailed SWOT analysis of the fruit industry, the study identified key technology gaps as well as two broad-based interventions to address these gaps, namely (i) the development of an enabling framework for innovation for the fresh fruit industry, and (ii) a government-funded postharvest innovation programme. As a result the South African Postharvest Innovation (PHI) Programme was established as a public-private partnership between the DST and the Fresh Produce Exporters’ Forum (FPEF), which also served as the

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4 DST, 2006: Status Report on Postharvest and Cold Chain Innovation and Technology in the South African Fresh Fruit Industry
5 PHI is directed at developing innovative technology in the post-harvest leg of the fresh fruit value chain, to develop and maintain the global competitiveness of the South African fresh fruit industry
implementing partner. Since 2007, the Government has invested R30 million to support postharvest research and innovation in the fresh fruit industry. 6

Informed by this strategic focus, the DST-NRF South African Research Chair in Postharvest Technology was awarded to the University of Stellenbosch in 2007 as one of the first group of Tier 1 Chairs. The Chair was to provide an enabling environment in which the innovation challenges facing the fresh produce industry could be tackled through research and human capacity development. 7

In February 2009 Prof Umezuruike Linus Opara took up the position, setting up the research infrastructure, recruiting postgraduate students and postdoctoral fellows, and applying for additional funding to support an extensive research programme. Originally from Nigeria, Prof Opara, who is a renowned international leader in the field of postharvest technology, was recruited from Sultan Qaboos University (SQU) in Oman, where he held several senior positions after joining the university from the Institute of Technology and Engineering at Massey University, Palmerston North, New Zealand. In 2006 he received the Distinguished Research Award, SQU’s highest honour in recognition of research excellence and leadership. 8

The specific objectives of the Chair were to (I) develop high-level human capacity to support technological innovation in the South African fresh produce industry, and (II) to conduct leading edge research on cold chain technology to maintain quality, reduce incidence of losses and add value to fresh produce. In the vast majority of his projects – around 90% - Prof Opara focuses on use-inspired basic research9, complemented by some applied research.

Connecting with pomegranates – a new research direction

The SARChI Postharvest Technology Chair thus filled a clear strategic niche in South Africa, and quickly attracted the attention of key industry role players, among others from the rapidly emerging pomegranate fruit sector. Pomegranate production has surged in South Africa over the past five years. There are currently approximately 1,400 ha under cultivation; around 400,000 cartons were exported in 2011 and close to 500,000 cartons in the 2012 season. Global demand is rising for pomegranates as a ‘super fruit’ due to their high content of health-promoting compounds. South Africa also offers the opportunity to fill a niche marketing window in the Northern hemisphere when pomegranates are not locally available.

The pomegranate industry was searching for innovative technologies for assessing fruit readiness for harvest and packaging and storing arils to meet the demands of both local and export markets. As a young industry, pomegranates grown in South Africa are prone to attack by many pests, diseases and physiological disorders which result in a high incidence of postharvest losses. Fruit affected by internal disorders are often sold in the market, resulting in dissatisfaction which, if unattended, could result in loss of repurchase and loss of market share. This makes the marketing of whole fruit a particularly risky business.

Furthermore, the difficulty of peeling fruit to extract the arils may also result in consumers staining their clothes, which is difficult to remove with most household laundry stain removers. These challenges are further complicated by the fact that once extracted from whole fruit, arils have a very short shelf life of less than two days if the cold chain is not maintained. And unlike other well-established sectors such as pome fruit, stone fruit, citrus and table grapes, there is a lack of industry protocols and standards for postharvest handling and storage condition to maintain fruit quality and reduce losses, especially during export shipment.

After taking up the SARChI Postharvest Technology Chair, Prof Opara initiated two research programmes: (i) the development of cold chain technologies, i.e. packaging and refrigerated storage, and (ii) the development of measurement and prediction tools for fresh produce quality management.

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6 http://www.postharvestinnovation.org.za/
7 http://www.sun.ac.za/postharvest/
8 Prof Opara is a Chartered Engineer (UK) and, among others, founding Editor-in-Chief of the International Journal of Postharvest Technology and Innovation, Honorary Vice President of the International Commission of Agricultural and Biosystems Engineering (www.cigr.org) and Chair of Section VI (Postharvest Technology & Process Engineering), and Chair of the Non-Leafy Vegetables Section of the International Society for Horticultural Science (www.ishs.org).
9 Refer to Pasteur’s Quadrant elsewhere in this report.
Shortly after being approached by the representatives from the pomegranate industry, members of the Chair research team undertook a study of the pomegranate producing areas in South Africa in order to help develop a postharvest technology research road map based on inputs from growers, processors and government agencies responsible for regulating and inspecting fresh produce export quality.

Several key issues emerged from the study, among others (i) the lack of scientific methods to determine fruit maturity, which is essential for the effective management of harvesting and postharvest operations, and (ii) the high incidence of fruit spoilage and losses due to internal rots and external cracks, which resulted in the majority of harvested fruit being cut open, and the arils extracted and packed for both local and export markets.

The research road map identified three other critically urgent areas of research intervention in support of the pomegranate industry: (i) the development of science-based maturity indices to assess crop readiness for commercial harvest; (ii) postharvest protocols for the cold storage of fruit to reduce losses and maintain quality; and (iii) the development of modified atmosphere packaging technology to extend the postharvest life of arils.

This study therefore led to a new research direction for the Chair: a third research programme entitled Postharvest Innovation for the Emerging South African Pomegranate Fruit Sector. The work in this programme was the main focus of the case study for this evaluation.

**Towards impact**

The Chair has made significant strides towards findings of use to the industry. For the first research programme, Development of cold chain technologies, the research team showed that while ventilation is needed on fruit cartons to ensure the delivery of cold air to remove field from fruit during precooling and respiration heat during long term storage, exceeding seven % ventilation area does not offer additional benefits in faster fruit cooling rates, and thus may compromise the mechanical strength of the carton under compression loading during cold chain handling. The research also challenged the current practice of placing polyliner bags inside ventilated cartons containing fresh fruit. The bags slow down the cooling rate of fruit and increase the cost of refrigeration energy.

The research findings were widely disseminated through workshops and conferences. The work led to at least 22 publications in international peer reviewed journals.

Results obtained for the second research programme, Development of non-destructive measurement and prediction tools for fresh produce quality management, showed that near-infrared spectroscopy for monitoring and predicting citrus fruit quality, and optical coherence tomography for non-invasive detection and evaluation of rind breakdown, offer novel tools for the integrated management of citrus fruit quality. They help to minimise rejects and hence economic losses during export. This principle has also been applied to the accurate characterisation and quantification of the internal structure of pomegranates. This has considerable benefits for the rapid mapping and selecting of new cultivars to optimise the yield of edible fractions, including juice yield.

The research findings were widely disseminated through workshops, conferences and at least 10 publications in international peer reviewed journals.

The third programme encompassed the newest research direction and focus of the evaluation case study – Innovative postharvest technologies for maturity management, handling and processing pomegranates. The research has led to science-based indices for deciding on fruit readiness for harvest, in order to ensure optimum postharvest storage performance – i.e. minimum decay and weight loss – and sensory quality. Optimum cold storage conditions to maintain postharvest quality and shelf life were also determined for key pomegranate cultivars grown in South Africa. In addition, given the importance that consumers attach to good health outcomes from consuming pomegranates, the research has characterised and quantified the antioxidant compounds in South African pomegranates, as well as some elected functional properties. Together these results open the prospects for mining these phytonutrients for food, pharmaceutical and industrial applications.

The research findings were presented at various industry workshops and in numerous reports, and were discussed with the Technology Innovation Agency of South Africa during a preliminary meeting in February 2013. A total of 24 peer reviewed international articles have been published on the work to date, while three MSc and two PhD theses were completed.
The significant economic potential of the research has yet to be fully explored. The Chair was approached and invited to the headquarters of the South African Technological Innovation Agency (TIA) to explore how TIA could collaborate with the Chair to harness the economic potential of the pomegranate research. At a meeting in February 2013 it was in principle agreed that the Chair would be a principal technical partner and knowledge provider for a major agro-processing plant that TIA plans to set up, which would assist emerging and smallholder pomegranate producers to handle and pack their crop. No further actions have taken place because of the on-going changes in the senior TIA management.

**The contributions of the pomegranate programme**

The work of the Chair presents many strands of value creation for South Africa — some monetisable, while others are of non-quantifiable strategic value. The following aspects of the value proposition of the work of the Chair for the country are noted only with reference to one of the three research programmes — the work on pomegranates:

1. **New expertise attracted to the country**: The SARChI allocation brought significant high level expertise and connections to South Africa in an area of strategic importance at national and sector levels that could immediately contribute to existing and emerging sectors of the fresh fruit industry in South Africa. Based on the work conducted as Chair, Prof Opara received a C1 rating from the NRF in 2012, among others for the new knowledge being developed in support of the pomegranate industry.

2. **New research directions and infrastructure of value to a new industry**: As a result of engagement with industry stakeholders, the Chair’s research team supported the development of a postharvest technology research road map, which resulted in the establishment of a third area of research focusing on the emerging pomegranate industry in South Africa. The Chair also developed a new state-of-the-art research laboratory with NRF and external funding that includes fruit quality measuring equipment, cold storage, an experimental shipping container, potable wind tunnels, electronic sensors and packaging testing devices.

3. **Stronger linkages between academia and the fresh fruit industry**: Apart from the research initiated in collaboration with the industry, the Chair is regularly consulted by high-level stakeholders. At the launch of the Pomegranate Association of South Africa (POMASA), the Chair was consulted by industry stakeholders and invited to make a presentation on the state-of-the-art research results flowing from the work of the Chair’s research team. Consequently, the industry has continued to consult the Chair on their research priorities. He also represented POMASA at a recent workshop organised by the South African Postharvest Innovation (PHI) programme to establish future research priorities for the fresh horticultural produce industries. The Chair also served on the Programme Management Unit (PMU) of the second phase of the PHI, a public-private partnership between the DST and the Fresh Produce Exporters’ Forum (FPEF) aimed at developing and maintaining the global competitiveness of the South African fresh fruit industry. In this capacity he had the opportunity to represent the industrial stakeholders in discussion with, among others, the Minister of Science and Technology on research strategy and priorities in the sector.

4. **Stronger linkages between academia, public policy and practice**: The Chair is regularly consulted by public sector agencies on strategies for the development and beneficiation of postharvest technology for economic development, using the pomegranate fruit as case study. The Western Cape Department of Agriculture has invited the Chair to present keynotes during strategy planning sessions on the role agro-processing in economic development of the province. In 2012, the Chair was appointed as the African Scholar at the University of South Africa (UNISA) during which he delivered a lecture to staff and students on strategies for developing a new research programme. In 2013, the Chair was invited to a high-level meeting at TIA head office with senior management to share his experiences and expertise on pomegranates postharvest management and agro-processing and to explore the potential role of the Chair in supporting current and future agro-processing centres in South Africa.

5. **New knowledge generated towards South Africa’s knowledge economy and global reputation**: The work of the Chair has led to at least 56 publications in peer reviewed international journals over the last five years, with 25 published on the pomegranate work alone. Just in terms of the pomegranate research, the team has:

- developed science-based tools (indices) for assessing pomegranate fruit readiness for harvest to meet the long distance export cold chain requirements and maintenance of fruit quality
° determined the optimum cold storage requirements to reduce losses and maintain the quality of pomegranate fruit during storage
° developed mathematical models of fruit water loss to assist in selecting suitable modified atmosphere packaging to extend the postharvest life of pomegranate arils
° identified and characterised the health-promoting components and pharmacological properties of pomegranate cultivars grown in South Africa
° identified potential volatile biochemical markers related to the postharvest life of pomegranate arils that may in future support intelligent packaging that provides information to consumers on the postharvest life (‘use by date’) of arils on the market shelf.

6. **Contributing to South Africa’s global reputation:** The Chair’s research group is now nationally regarded as a leader in the field of postharvest technology, and increasingly also internationally. In South Africa they are the only researchers working on the postharvest technology and minimal processing of pomegranates. Internationally, the group has the largest number of researchers and postgraduate students focusing on postharvest technology of pomegranates. The international standing of the Chair is confirmed by invitations from around the world, among others to present a keynote address on recent advances in postharvest technology and agro-processing of pomegranates at an international postharvest conference held in Guangzhou, China, in November 2013.

7. **Expanded research through funding mobilisation:** The reputation of being a “SARChI Chair” facilitated access to a variety of funding sources nationally and internationally, which in turn enabled more extensive research activities. The Chair has in total for all three research programmes leveraged an additional R13 million from other funders and collaborators. With material and technical support from a major pomegranate processing storage and packing facility in Porterville and additional fruit supply by Colours Fruit (estimated at more than R100,000 in value), the Chair leveraged industry funding from the Perishable Products’ Export Control Board (PPECB; R300,000) and Citrogold (SA) Ltd (R300,000) to establish a research programme on refrigerated storage of whole fruit, and modified atmosphere packaging (MAP) and minimal processing of pomegranate arils. Support continues to be provided by key industrial role players through the supply of fruit, and access to orchard and storage and packing facilities. Other funding sources not targeting pomegranates enabled the procurement and access of equipment in other laboratories for pomegranate research. These include the South African Postharvest Innovation (PHI) Programme, HortgroScience, and the West African Agricultural Productivity Programme (WAAPP).

8. **Building research strength and quality through collaboration:** The Chair has established extensive interdisciplinary research collaborations, within Stellenbosch University, across institutions and countries. He currently supervises students enrolled in different departments across the faculties of AgriSciences, Science and Engineering. The programme on pomegranates is being implemented with collaborations across different departments within Stellenbosch University – horticultural science, plant pathology, botany, food science and polymer science, and the Central Analytical Facilities network. Collaboration with overseas universities focus on bilateral research projects, staff and students exchanges, joint supervision of postgraduate students and joint research papers, with the most productive collaborations to date with universities in Belgium, the United Kingdom and China. Knowledge and experience gained from these collaborations are now applied to the pomegranate work. For instance, the first research demonstrating the potential of using X-ray computed tomography to predict the internal structure of pomegranate fruit built on the success of joint research with Belgium, the UK and Stellenbosch University on the non-destructive measurement of citrus quality.

9. **High level human capital in a national priority area:** Since inception the Chair has focused on attracting postgraduate students from South Africa and the rest of Africa, with special efforts made to proactively recruit and retain graduate students from previously disadvantaged groups. Over the first five years until 2013, the pomegranate work has delivered four Master’s and two doctoral students, including four from the special designated groups. One of the Master’s’ graduates has joined the fresh produce sector, while one of the doctoral graduates has joined the University of KwaZulu-Natal and started a new initiative on the non-
invasive monitoring of pomegranate quality. This work has already led to a first publication. The pomegranate work is currently engaging two postdoctoral fellows, five doctoral and five Master’s students.

10. **Potential for direct and indirect economic value:** Commercial pomegranate production in South Africa started only around 2000, but is growing rapidly, with over 1,400 ha planted mostly in the last three years in the Western Cape and Northern Cape provinces. Globally, a total of 2.5 million tonnes of pomegranates are produced per year. Production in the southern hemisphere is less than 50,000 tonnes. Commercial pomegranate production in South Africa offers considerable economic opportunity for job creation, income generation and economic development. Although still limited, there is emerging evidence that the work on pomegranates has the potential to contribute to socioeconomic and environmental development goals in South Africa:

- There are many farmers growing 2-5 ha plots and looking for market opportunities through value addition. The process of transforming raw whole fruit into arils packed in modified atmospheres (MAP) contributes to this value addition. It involves the use of additional labour which creates jobs and other economic opportunities. However, there has as yet not been any attempt to set up a large-scale processing plant. It is expensive to airfreight processed pomegranates – more so than the whole fruit. It is also expensive to set up a processing plant; the processing needs to be accurate and hygienic, and the domestic market does not (as yet) justify such a venture.

- The reduction of postharvest losses can also potentially reduce the amount of wasted fruit taken to dumps. The use of non-invasive technologies to monitor quality would also eliminate the use of hazardous chemicals currently used in wet chemistry to characterise fruit quality. The research thus also has the potential for environmental impact.

All the research findings have potential for value addition in the pomegranate sector through industrial processing of the edible and non-edible fractions of the fruit in the food, cosmetic, pharmaceutical and medical industries. Although most of the research findings have yet to be taken up by the industry, there is some evidence of current application:

- The Chair has developed a set of industry guidelines\(^\text{(10)}\) for improving the cold chain management of pomegranates, ranging from techniques for assessing crop maturity and readiness for harvest, to recommended optimal cold storage requirements to maintain fruit quality during long export supply chains. Information provided in the report based on residence evidence from work carried by SARChI will form the industry ‘Blue Book’, a practice guide on pomegranates to be published by the PPECB.

- MAP requirements for handling pomegranates arils have been obtained on best film and storage conditions for optimum shelf life of arils. These are now applied in industry to maintain aril quality and extend shelf life, for example by the Houdconstant storage and packing facility in Porterville.

11. **Mainstreaming pomegranate research into the SA fresh fruit innovation system:** During the review of Phase II of the South African Postharvest Innovation (PHI) Programme in 2013, members of the Programme Management Unit (PMU) recognised the considerable research outputs on postharvest technology of pomegranates emanating from SARChI Postharvest Technology. Although previous PHI programmes focused on the well-established fruit sectors such as apples and pears, citrus, table grape and citrus, pomegranate industry role players acknowledged the importance and impacts of SARChI research on pomegranates and, in collaboration with the Chair, successfully made a strong case to PHI PMU for pomegranates to be included as one of the fruit sectors in the PHI portfolio. This success has led to the Chair working closely to develop a new project proposal worth over R 1 million which will be submitted in 2014 to PHI for funding under Phase 3 programme.

**The role of the SARChI funding instrument**

The benefits and impacts listed in the previous section clearly spell out the value proposition of the SARChI Chair in Postharvest Technology, with specific reference to one of its three research programmes, the work done for the

\(^{10}\) Report provided to the PPECB through Dr Mduduzi Ngcobo, Research and Innovation Manager
fledgling pomegranate industry sector in South Africa. The case study and related information confirmed several direct links between SARChI funding and branding, and the benefits and impacts noted earlier. In other words, these benefits and impacts would not have been achieved without SARChI support.

In the first place, without the attraction of being a DST-NRF SARChI Chair holder it is unlikely that Prof Opara would have embedded his expertise in the South African academic and industry sectors. He had a senior position in Oman and before this opportunity arose, did not consider South Africa as a potential home for his academic work.

Secondly, he directed his work to respond to the needs of the South African fresh fruit industry. The SARChI Funding Instrument objectives stipulate that Chairs are required not only to produce high level human capital and new knowledge, but to do so to the extent possible in areas of strategic importance. In order to contribute to this objective, the Chair in Postharvest Technology has focused his efforts on use-inspired basic research (estimated at 80% of his work) and some applied research (estimated at 15%) in an area of critical importance to the country’s fresh fruit industry.

Thirdly, the SARChI funding released significant time for research instead of other academic activities, leading to more and better research results and outputs, and the capacity to supervise and mentor many more postgraduate students and postdoctoral fellows. It enabled the chair to manage three substantive research programmes, to focus on research questions relevant to the industry, and to be highly productive within a relatively short period. It allowed the research team to grow from a four Master’s students only before taking up the Chair, to 11 Master’s students and 10 doctoral students in 2013. This led among others to a growth in publication output from only a few peer reviewed articles in international journals in the first few years of his tenure, to 16 in 2012 and 31 in 2013. The total of 64 outputs between 2009 and 2013 is nearly three times greater than the 23 publications during a similar period before becoming a Chair (2004-2008). The articles are also increasingly published in journals with higher impact factors.

Fourthly, before taking up the position as Chair, Prof Opara’s research funding came exclusively from the academic sector. SARChI funding enabled him to set up essential laboratory infrastructure, initiate three research programmes, and enable the initial research on pomegranates which gave the industry partners the confidence to allocate their own resources. In total, for the three research programmes an additional amount of R13.07 million was leveraged for an investment by SARChI of R12.2 million. The funding sources were varied: The University of Stellenbosch, the Perishable Products Export Control Board of South Africa, Citrogold Ltd., the South Africa-Flanders Bilateral Research Programme, the NRF (as rated researcher), the South African Postharvest Innovation Programme, Hortgro® Science, ACIAR in conjunction with the Australian Government and the University of Sydney, the EU with the Malawi Government, the West Africa Agricultural Productivity Programme (WAAPP) with the Nigerian Government, the Regional Universities’ Forum for Capacity Building in Agriculture (RUFORUM) and the PepsiCo Foundation.

Finally, the SARChI support - which helped to leverage so much additional funding - also enabled new, and more, collaborative initiatives, both nationally and internationally. This increased productivity and exposure. The Chair has hosted research colleagues and postgraduate students on exchange programmes that have resulted in joint research papers. Collaboration with RUFORUM, for example, has brought fully funded students from other regions in Africa. The Chair has also been able to send graduate students to laboratories in other countries in order to enhance their research skills.

3.2. VALUATION FOR CASE STUDY 1

The approach employed to value the pomegranate research strands listed above is presented in Figure 2.
**Beneficiary identification**

The first step in estimating the value created by the research efforts of the Research Chair and his team required identification of the key stakeholders impacted by the research. The strong focus of the research on aiding the prospects of a particular economic sector naturally led to the selection of the industry as the key stakeholder. Within the umbrella term ‘the pomegranate industry’, we look not only at the added value going to farmers, but also additional workers as well as (indirectly) other related industries.

**Impact description**

The key impact considered in the analysis, stemming from the three research streams listed above, is the potential to increase the volume and value of pomegranates reaching the market. Industry opinion felt it was not possible to separate the individual contributions of the different research streams to this overall impact. They were therefore considered collectively in the calculations.

**Data**

As an emerging industry with limited infrastructure support, data for the pomegranate industry is limited to estimates of production and export levels dating back to its beginnings around 2009/2010. Only recently has data started to be collected on hectares of pomegranate trees under cultivation and the different stages of maturity of those trees. Pomegranate trees only begin producing fruit after three years and do not reach full maturity until seven years. This has implications for the calculation of labour requirements as a rise in pomegranate production does not automatically equate to an increase in cultivated area, but could simply reflect the maturation of existing trees.

Many pomegranate farmers are also farmers of other fruit. This means that new land under pomegranate cultivation may not significantly increase requirements for farm labourers, as the harvesting period for pomegranates does not interfere with farmers’ other crops and existing farm labourers are able to care for and harvest the trees. Hence, farmers may be able to produce additional pomegranates without requiring significant numbers of additional labour. Where additional labour is projected to increase (in line with increased pomegranate production) is in pack houses. It is this part of the production chain that our labour analysis has focused.

The pomegranate industry body POMASA’s projections of future production were used in the analysis plus current prices for the different qualities of fruit as well as the proportion of total production accounted for by each quality of fruit. POMESA and Professor Opara estimated the uptake of the research results by farmers took place from 2011. We have therefore only considered the research to have contributed to the growth of the industry from this year forward.

**Impact considerations**

A number of factors drive the growth of the pomegranate industry. Notable factors include market access issues (phytosanitary and sanitary), research and development, marketing and industry capacity building associations.
(Figure 3). The relative value that each contributes will vary across time depending on a range of factors from changing weather patterns to outbreak of new pests to new trade rules.

To understand the importance of the postharvest research in contributing to increasing production, it is necessary to consider how significant postharvest losses can be in the pomegranate industry. Postharvest losses are the most significant area of losses in pomegranate production. They can account for between 20-30% of total production. Combining this figure with (1) industry data on current pack house wastage levels plus (2) the effect of the Research Chair in catalysing farmers to experiment with pomegranate production from 2009, the overall contribution of the Research Chair and his team is estimated\(^\text{14}\) to be between 25-35% of total additional production witnessed and forecast for the industry\(^\text{15}\).

**Net value creation**

Based on the above assumptions and data and taking a mid-point estimate of 30% attribution, Table 7 presents the estimated value created through the work of the research team in terms of direct industry revenue, additional jobs (full-time equivalent) created plus indirect (multiplier) revenue for the periods 2011-2014 and projections through to 2018.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Value</th>
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<tbody>
<tr>
<td></td>
<td>2011-2014</td>
</tr>
<tr>
<td>Direct industry income (R m – 2014 prices)</td>
<td>45</td>
</tr>
<tr>
<td>Additional jobs (no. – FTE)</td>
<td>13</td>
</tr>
<tr>
<td>Indirect (multiplier) income (R m – 2014 prices)</td>
<td>20</td>
</tr>
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</table>

A combined income effect of R65 million (direct and indirect revenue) for the period 2011-2014 compares very favourably with the NRF funding to date of R12.2 million. While the numbers of additional jobs attributable to the work of the Research Chair and his team might at first appear low, it must be remembered that pack house work is often seasonal in its nature and not necessarily full-time. Based on a 3-month season, approximately 84 additional pack house opportunities become available over the period 2011-2018. This equates to more than R3 million in additional wages entering local communities over the same period. It should also be noted that the Chair has leveraged an additional R700,000 from the industry for his research.

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\(^{14}\) Attribution estimate informed by industry opinion

\(^{15}\) While the catalytic effect will be stronger in the earlier years and fall away in the future, greater reductions in post-harvest losses will compensate as more growers successfully employ it in future years.
3.3. CASE STUDY 2: BUILDING A WORLD CLASS INITIATIVE FOR THE PHARMACEUTICAL INDUSTRY

The Research Chair

Viness Pillay is Professor of Pharmaceutics and Executive Director of the University of the Witwatersrand (Wits) Advanced Drug Delivery Platform (WADDP), and holds the SARChI Chair in Pharmaceutical Biomaterials and Polymer-Engineered Drug Delivery Technologies. WADDP is an official research unit of Wits headed by Prof Pillay, supported by a research manager, 5-6 senior researchers, postgraduate students and an advisory committee that includes representatives from Novartis Switzerland, UKZN, and Florida University. The Research Chair falls under WADDP, and thus operates within the same structure.

Prof Pillay is widely recognised for his innovative work on designing commercialisable drug delivery technologies. He set out to become a global player and develop the required expertise for the country in this niche area. He started his academic career at the University of Durban-Westville in 1994 where he completed his Master’s degree in drug delivery. It was while he was reading for his PhD at Temple University in the School of Pharmacy in Philadelphia as a Fulbright Scholar in 1996 that he realised the importance of drug delivery in the pharmaceutical sector as well as the opportunities for research in this area. He was influenced by his supervisor, Prof Reza Fassihi, who was previously at Rhodes University and the University of the Witwatersrand before moving to the United States, where he had access to world class infrastructure and multinational pharmaceutical companies. It was in this dynamic environment that Prof Pillay was exposed to writing up patents for commercialisation, including a patent associated with his own PhD thesis.

Figure 4: The value proposition of the Research Chair in Pharmaceutical Drug Delivery Technologies

- **SARChI influence**
  - Prestige
  - Time release
  - Research staff

- **Research Programmes with Wits Advanced Drug Delivery Platform (WADDP)**
  - Leveraged R34m
  - Infrastructure
  - 18 new collaborations

- **Strategic benefits / impacts**
  - 15 patents, 35 primarily PCT under prosecution
  - 124 publications
  - 15 books, chapters, editorials
  - 317 conferences
  - 76 students, 90% from designated groups

- **Direct and indirect benefits / impacts**
  - SA reputation in priority area
  - New knowledge for competitive knowledge economy
  - Strong multi-disciplinary research group in strategic priority area
  - Strong international collaborations
  - Strong industry relationships
  - World class infrastructure
  - Large group of market-ready, market-attractive human capital, esp. from designated groups

- **Potential wider impacts**
  - Jobs created & other economic benefits
  - Population health improved
  - Lives saved

- **Potential**
  - Technical & specialist leadership
  - Rapid uptake of graduates
  - Drug delivery patents licensed, sold
  - FDI from positioning as expert in global pharmaceutical industry

"Figure 4: The value proposition of the Research Chair in Pharmaceutical Drug Delivery Technologies"
Developing a world-class laboratory connected to real market needs

Prof Pillay started his research career at the University of KwaZulu-Natal in 2000 and later moved to Wits. During this period he realised that there was a major shortage of qualified people in this field in South Africa, and assessed that this was largely due to the lack of capacity of the local pharmaceutical industry to absorb the graduates. Two years later, in 2003, he took up a full tenured post at Florida A&M University as Associate Professor in Pharmaceutics. He returned to South Africa after approximately 18 months, largely because of the access to newer research infrastructure afforded by the South African universities.

His early experience of the South African pharmaceutical industry inspired him to focus on developing local expertise that could satisfy market needs both locally and internationally. Despite most of the research funding in South Africa supporting HIV/AIDS, TB and malaria, his goal was to become a player in the global pharmaceutical industry by developing skills in the niche area of drug delivery technologies. He was determined to develop a world-class laboratory in this field in South Africa.

Since the establishment of WADDP in 2007, Prof Pillay has thus focussed on excellent research outputs, i.e. students, papers and patents, in order to produce good academic research with real potential for application. This meant understanding the relevant industry well by ‘landscaping’ to better understand what companies are researching in drug delivery, where they are going, and their human resource needs. This involves direct contact with companies. Leads are often generated from attending the annual Bio International Convention, as well as the Bio and Control Release Society mini-bio conferences. Such conferences provide an opportunity to understand the research needs of the multinationals. In one instance he was approached by Merck as a result of their interest in a certain technology highlighted in one of his international journal articles.16

Prof Pillay is also actively engaged in trying to influence the policy environment and to this end has contributed a ‘pharmaceutical’ perspective in several workshops arranged by the DST on i.a. nanotechnology, safety and the environment. A bilateral proposal, jointly prepared by Prof Pillay’s group and Prof Ismael Bianco based at CEPROCOR-CONICET, Cordoba, Argentina, is said to have resulted from these workshops. Prof Pillay is also regularly in discussion with the Director Strategic Health and Innovation Partnerships of the Medical Research Council, regarding developing a high level consortium in the area of drug delivery and drug discovery to work towards the development of a national policy in this area.

Prof Pillay’s team regularly reaches out to schools under the NRF SAASTA programme. They are beginning to work more and more with high school students considering a career in pharmaceutics.

The role of the SARChI support

Positioning the Chair as an international expert resource in drug delivery technologies is a critical and practical strategy, given the constraints in the local pharmaceutical industry, which does not have a strong focus on R&D. The SARChI support has been crucial to such positioning of the Chair globally by setting in motion a series of developments towards this goal. Having more people, more equipment, and greater recognition, has been the drivers for increased performance.

The SARChI funding and conditions have helped to move the work in this field towards a critical mass in terms of research publications in international journals, global collaborations with strategic partners, graduates with global

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16 Unfortunately the discussions stopped when the particular individual left the company.
leadership qualities, and numbers of patents. Crucial for these achievements has been the fact that the Chair could now focus 95% of his time on research. This nearly full-time engagement has been instrumental in driving the research agenda and extending the collaborative linkages. SARChI funding provided for a critical mass of researchers (staff and students), which resulted in more inputs (collaborations, projects and equipment), which led to substantially more outputs (research findings, patents and graduates).

“Infrastructure development via the SARChI Chair awarded to Prof Pillay has been outstanding. World class research cannot be undertaken in a research environment that lacks cutting-edge equipment and laboratories. During my visits ... I have witnessed that over the past five years the drug delivery laboratories at Wits have expanded from two laboratories to a current total of six fully-fledged and globally competitive laboratories for undertaking advanced drug delivery research. This is a highly impressive achievement.

The SARChI programme has directly supported and allowed Prof Pillay to leverage a large amount of funding to purchase a host of instruments that are the first in South Africa. For example, the MARAN-iP In Vitro Bench-Top MRI Imager is one of only four instruments in the world. Many instruments that have been purchased are for multi-disciplinary use and this therefore allows South African researchers in the fields of materials science, polymer science, chemistry, physics, engineering and nanotechnology to also have access to state-of-the-art research equipment.”

External expert engaged in institutional assessments, from NRF assessment report

According to Prof Pillay, the importance of the prestige associated with SARChI resulting from the recognition by peers of the high standards for qualification as a Research Chair cannot be overstated. It helps to attract high quality collaborators, postdoctoral fellows and research programmes, which in turn attract high quality students, as evidenced by the high percentage of students graduating cum laude from the work of the research team (details below).

It also opens new doors, nationally and globally. Prof Pillay's vision for a world-class laboratory was initially supported by Biopad and later by the TIA – support that was critical at an early stage. With the allocation of the SARChI Chair and the resulting increase in profile and output, the recognition by international funding agencies enabled Prof Pillay to tap into much larger, international grants, such as those of the US National Institutes of Health (NIH) (see details below). Although being a team member of an NIH project is not uncommon for South African researchers, qualifying as an NIH grant-holder – a recent achievement of Prof Pillay – is both prestigious and game-changing for funding.

The flexibility of the SARChI funding is also seen as a real benefit. Funds can be moved within categories so that different needs can be addressed in a timely manner – for example in obtaining equipment or funding student capacities – thus supporting strategies towards his vision.

The contribution of NEP and NNEP grants

WADDP, in which the Research Chair is housed, started in March 2007 with a grant of R11.6 million from Biopad, which was i.a. used to help establish important scientific infrastructure. Over time the unit accessed funding from the NRF NEP and NNEP; in one year receiving R111 million from these sources. SARChI funding enabled the addition of another approximately R3 million for equipment. Over time the unit has built up equipment worth a value of approximately R150 million, adding to the R50 million made available in laboratory infrastructure.

Students and postdoctoral fellows interviewed confirmed the importance of having access to world class infrastructure and equipment, all housed in the same centre, and operated by highly capable people. This is seen as greatly speeding up the research process.

17 The conditions of the Chair at the time made provision for only 5% of time to be spent on “other” activities.
The difference made by the Chair

The case study highlights a range of benefits flowing from this Research Chair. They help demonstrate intermediate impacts (or ‘outcomes’) towards ultimate impacts, and emphasise that there is a trajectory towards such impacts that need to be respected when assessing the value proposition of a national funding instrument such as those managed by the NRF:

1. Enhanced institutional and national standing in a field of strategic importance to Africa and developing countries: Prof Pillay has made significant progress towards positioning the research group as expert in drug delivery technology for the global pharmaceutical industry, attracting international funding and expertise to deliver into national strategic priority areas (e.g. HIV/Aids). As Research Chair, Prof Pillay focuses on designing more effective pharmaceutical products that directly impact communities for superior treatment of communicable, non-communicable, hereditary and lifestyle diseases - in particular, infectious and lifestyle diseases that disproportionately affect Africa and the rest of the developing world. The vast majority of his research is use-inspired basic or applied research; it is thus academically focussed yet IP driven. This approach ensures relevance and potential for commercialisation.

2. Delivering market-ready, market-attractive young scientists in a strategic niche area: The research group under leadership of the SARChI Chair provides the following value in terms of human capital development:
   - Technical and specialist leadership for local pharmaceutical manufacturing companies in the form of graduates proven to be of very high quality
   - Rapid uptake by graduates in the workforce, thus contributing to the employment statistics
   - Delivery of both graduates and experts on drug delivery systems to the NSI in the strategic priority area of HIV/AIDS.

“...The Chair provides a unique platform for postgraduate students at the Master’s and PhD levels to be trained for attainment of very successful careers... The research environment within the Chair program comprises distinguished guidance, instructional offerings, research facilities, library resources and a stimulating group of capable fellow postgraduate students. This is rather unique since upon the completion of their respective postgraduate degrees, students trained within the Chair program possess knowledge of a broad area integrating the in-depth working knowledge of a diverse scientific discipline and phenomenon pertaining to subjects such as physical chemistry, physical organic chemistry, mathematics, bioengineering, nanotechnology and the life sciences. In addition, the postgraduate students demonstrate the necessary intellectual ability, motivation and drive to take optimal advantage of the environment in the development of their skills as creative scholars and independent research investigators.”

Collaborator, Wits University

Since becoming a SARChI Chair, Prof Pillay’s students have grown in number from 12 to 76. Of these, 90% are from designated groups. Nearly all the Master’s graduates have qualified cum laude. SARChI provides bursary support for fewer than half of the students, yet there is a demand for student places, particularly from students from the rest of Africa and from other foreign countries.18

Students confirmed Prof Pillay’s reputation for training graduates who are close to the market, who will be exposed to interesting and applicable research, and who will undertake cutting-edge research in a niche area. The following list of reasons provided by the students and postdoctoral fellows for studying under the supervision of the SARChI team provides useful insights into student preferences and reasons for satisfaction:
   - Unique research, which means they get to work on interesting and relevant projects
   - Opportunities to be part of international projects
   - Prof Pillay’s reputation as a leading scientist doing cutting edge research in a niche area

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18 Prof Pillay confirmed that he receives on a daily basis requests from on average five foreigners applying to do a PhD at his unit - many with their own funding.
- A supportive team of supervisors who have an open door policy
- Good infrastructure, with modern and well-equipped laboratories
- Sufficient funding support, and hence no need to worry about operational costs
- An “expectant culture”, which pushes them to achieve the best which leads to high research output, awards and international recognition.

In most cases students have found employment even before graduating, typically in manufacturing, in regulatory affairs and in clinical trial testing, and frequently in local employment with multinationals. The students confirmed that graduates appear to be snapped up and rapidly absorbed by the academic sector and the industry, and specifically the manufacturing sector. They are also beginning to play a meaningful role in both the local and global pharmaceutical industry. For example, Prof Pillay’s most recent PhD student was recruited by Octoplus in the Netherlands prior to graduation, while one of his previous Master’s students was promoted to Head of R&D at Adcock Ingram within a mere 18 months after joining the company. Given the global nature of the pharmaceutical industry, approximately 10% of the students find employment overseas.

The senior industry managers confirmed that there was a high demand for good pharmaceutical students, with one estimating that the local industry (mainly retail) could absorb at least 25% more graduates than were currently entering the system. The SARChI supported graduate appointments were also seen as performing very well. For example, although Pfizer has a preference for pharmacists with work experience, one of the Master’s graduates had been promoted within two years to the level of senior regulatory pharmacist and hub liaison pharmacist – an exceptional achievement for a young graduate. The graduates were also seen as “market ready”, although opinions differed somewhat about some of the desirable characteristics. The recruits were seen as having a very good work ethic and coping well with pressure. Exposure to working in a diverse research group also meant that they had excellent interpersonal skills and could manage high level international interfaces very well - although in some cases graduates from elsewhere are somewhat more “streetwise in working with corporates”.

3. **Collaborations:** Since the establishment of the Research Chair, eighteen new collaborations were added to those that already existed at WADDP. This has resulted in greatly increased research outputs.

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19 Pradeep Kumar, a past SARChI grant-holder linked bursary holder and now lecturer in Pharmaceutics at Wits, is an example. He received the Scientific Committee Student Scholarship for his presentation at the 2012 conference of the World Federation for NeuroRehabilitation (WCNR 2012); Elsevier’s International Society for Development Neuroscience 2012 Student Award at the Society’s 19th Biennial Meeting held in 2012 in Mumbai; Two Elsevier’s Nano Today PhD Student Awards for two different presentations at the 2nd Nano Today Conference in Hawaii in 2011; a Wits Postgraduate Merit Award and the PG Merit Scholarship for academic excellence in 2011 and 2012; and an international travel grant to Lyon to present at the 2nd International Symposium Frontiers in Polymer Science, 2011.

20 The manufacturing industry has changed requirements, moving from relying on factory managers with technical training to requiring qualified pharmacists to run their production lines.
i. **Interdisciplinary collaboration** was greatly enhanced, in particular with intra-institutional clinicians: while the clinicians get to understand the pharmaceutical approach, Prof Pillay’s team is exposed to the hands-on approach of the clinicians and understanding the practical issues at the “coal face”. This has influenced his research efforts to arrive at tangible and patentable drug delivery systems. The purchase of instrumentation for multi-disciplinary research has also encouraged multidisciplinary collaboration, inter alia with researchers in the fields of materials science, polymer science, chemistry, engineering and nanotechnology.

ii. **International collaboration** was greatly widened to include international academic experts in The Netherlands, the USA, Tanzania, India, Argentina, Germany and Japan, as well as industry experts in at least five major companies in South Africa, Switzerland and the USA. As a result of SARCHi support, a new collaboration was also established with the MESA+ Institute of Nanotechnology in Twente, Netherlands, providing access to the use of equipment based there.

"Prof Pillay and his vast team of researchers, postgraduate students, postdoctoral fellows and collaborators have also benefited significantly from the state-of-the-art infrastructure created by him. The SARCHi grant funding has allowed Prof Pillay to acquire the most modern equipment and establish research infrastructure within the Faculty that ensures all research that is undertaken is globally competitive and at the cutting-edge of pharmaceutics and drug delivery technology research. The infrastructure instituted by Prof Pillay was created off quite a low base and the technology in place now pursuant to his SARCHi Chair far supersedes anything that has been in place historically. Astute and incisive purchases by Prof Pillay, supported by the University, the NRF and the Technology Innovation Agency (TIA) to a cumulative value of over R50 million have developed his facilities to a standard that is beyond what is available anywhere else in the country and most likely internationally as well."

4. **World-class infrastructure and research through leveraged funding**: SARCHi funding significantly boosted fundraising efforts. Over a period of seven years the Chair has received R17.5 million from the NRF. This has leveraged almost double this amount - an additional R34.3 million - from other NRF programmes,21 the MRC, TIA, CANSA SA and the African Network for Drugs and Diagnostics Innovation (ANDI). More recently the Chair has positioned itself to attract international funding, notably from the NIH. The prestige that was afforded by SARCHi, especially as a result of the rigor of the relevant peer review process, weighed heavily in favour of leveraging additional funding and support. It was this prestige that encouraged other funders to invest in the research underway at SARCHi. Funding from the private sector comprises a small part of the budget (approximately 10%) and results from contractual arrangements, e.g. the testing of products. Prof Pillay does not specifically target private companies for funding, preferring rather to focus on their IP needs.

"The NRF Research Chair that was awarded to Prof Viness Pillay has certainly benefited the South African research landscape with respect to the advancement of the knowledge frontiers in the Pharmaceutical Sciences. Prof Pillay and his large team of researchers, postgraduate students and postdoctoral fellows have significantly changed the research landscape in drug delivery systems design."

*Collaborator, South African University, NRF Assessment report*

5. **Contribution to the competitiveness of the SA knowledge sector**: Although difficult to link SARCHi to specific outputs independently from the WADDP, the amount and quantity of outputs from the research since the Chair has been awarded have considerably increased. The SARCHi support has therefore supported a critical mass of researchers and accelerated the scientific performance of the team. Before the allocation, the research team comprised of four researchers; it now constitutes 19 researchers, including 13 from designated groups. The number of conference presentations has increased from 131 to 317, and the number of books, editorials and chapters in books has risen to 15. A total of 124 papers have been published in ISI-accredited international

21** Blue Skies, Thuthuka, NEP, NNEP and SRIP
journals (2007-2014) versus 33 ISI-papers published before the SARChI era (from 1998-2006). Many more papers have been published in top-ranking ISI-accredited journals with high impact factors in the field.

6. **Potential for direct and indirect benefits through commercial products:** The route from drug development to commercialisation is long and difficult. Three components are required in order to register a new pharmaceutical product: (an) active ingredient(s), a drug delivery mechanism and a period of clinical testing via clinical trials. Only after successful clinical trials can the product be registered and commercialised. The drug delivery technology is therefore only one of three components required prior to commercialisation, and is dependent on the other two components. And of a hundred technologies, only one or two may succeed.

7. **The South African environment is not conducive to drug discovery and development.** The current focus on the manufacturing of generic formulations is a low mark-up industry that does not warrant huge investment in clinical trials that would be required for the introduction of a new drug delivery mechanism that could, for example, use less of the active ingredient or result in fewer side effects. Drug development is therefore typically pursued by international companies.

The commercial focus of the work of the Chair is on developing novel licensable drug delivery technologies that can be offered to the pharmaceutical industry to advance their existing or new drugs that are difficult or impossible to deliver. Over recent years, since the Research Chair was awarded, the number of patents has risen dramatically from two to 50, with 15 patents awarded and 35 (primarily PCT applications) undergoing prosecution. Three to five patents are being registered per year. Assuming that one to two per 100 patents are successful, for the reasons given earlier SARChI has had a huge impact on increasing the numbers of patents, and hence the odds of the successful commercialisation of one of these patents.

The following are notable examples from the patent portfolio:

**RapiDiss Wafer:** A novel pharmaceutical formulation known as the RapiDiss Wafer can effectively treat paediatric HIV/AIDS using a more patient-friendly formulation that delivers ARVs through the buccal cavity. The technology is a highly stable oral formulation that is placed inside the child’s cheek and releases the ARV medication directly into the systemic circulation. There is no need to swallow the wafer with water; neither does it require refrigeration to remain stable. More importantly, it also significantly improves the taste and pharmacokinetics of current liquid ARV formulations.

**A Polymer-Engineered Neural Device Patent for Spinal Cord Injury:** The neuro-nanopharmaceutical technology demonstrates the possibility of implanting a neuro-gadget into the injured spinal cord that will allow for effective treatment of individuals suffering from debilitating Spinal Cord Injury (SCI). The technology has shown promising results in terms of actively intervening with biochemical pathways to regenerate and restore neural activity at a SCI lesion. This is still at a prototype stage.

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22 However, commercial success may be hampered by the limited resources that can be dedicated by the Wits Technology Transfer Office to this process. The TTO has a portfolio of approximately 150 patents with a team of only 2.5 persons to deal with new disclosures, compliance with regulatory requirements, and NIPMO rebates on the patents. There is therefore very little capacity to focus on the commercialisation pathway of these patents.

23 Interest in the product was expressed by two international companies respectively, but for various reasons peculiar to the two companies, there has been no advance in commercialising the product.
Vaginal Microbiocide: The main challenge to be overcome is ensuring effective release of a biocide. A drug delivery mechanism for a microbiocide specifically for HIV was developed in collaboration with the University of Virginia. An agreement has been entered into with Conrad, a US based NGO associated with the University of Virginia, which focuses on diagnostics and therapeutics for orphan diseases. Conrad typically secures donor funding to develop the product and then facilitates the relationship between the drug delivery researcher and the active ingredient manufacturer.

3.4. VALUATION FOR CASE STUDY 2

The Research Chair’s focus on students, papers and patents presents particular difficulties to development of the type of high level valuation analyses common to this evaluation. The evaluation’s focus on impact requires the demonstration of a clear pathway to value. While the foci of the Research Chair clearly have the potential to create valuable impacts in the longer-term, it is beyond the scope of this evaluation to provide sufficient rigour to such a valuation analysis as to include one here.

Figure 5 presents key high-level inter-related pathways and contributory factors for the eventual creation of more effective pharmaceutical products (and ultimately improved health and economic returns), and highlights the distance (and thus complexity of valuing the contribution) of some value vectors from the final goals. The value vectors (listed above) represent different components within the diagram.

What we instead propose, is to illustrate pathways by which future valuation exercises might bring to light the potential value of the Chair’s work. The possible value vectors described in the above case study are considered in turn below.

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24 This is likely the closest to commercialisation in this patent portfolio, but still requires a long lead time including a 2-3 year period for the clinical trials.

25 Dashed arrows indicate estimated pathways.
Technical and specialist leadership

One pathway to understanding the value created through highly qualified graduates with leadership potential is the following:

To conduct further research with companies that have absorbed the Chair’s graduates in the past. Common impacts experienced by these companies (stemming from former graduates’ technical and specialist leadership) need to be identified before values can be understood. Without an understanding of common impacts, no aggregation of overall impact and valuation will be feasible.

To understand the reach of those impacts requires understanding how many of the available employment positions available in the sector match the aspirations of the students. For example, are students able to create significant value add in the retail sector, the sector this case study suggests could absorb at least 25% more graduates than are currently entering the system.

Rapid uptake of graduates

The economic value to students of gaining employment due to their post-graduate qualifications is captured in the human capital valuation section of the HCD chapter. While the data underpinning that calculation draws from a much broader sample of students than the research chair has produced, the likely additional financial benefits accruing from additional education qualifications will likely be in the same region. Similarly, the per student tax benefits to the State will likely be similar to those in the HCD valuation section.

The economic value to the organisations that employ the graduates will likely come in the form of avoided foregone income from delays in recruitment. Further research with such organisations would illustrate the potential costs/foregone income incurred from leaving vacancies unfilled. To avoid over claiming this value, care must be taken to understand how much faster (if at all) the Research Chair’s graduates gain employment relative to those from other pharmaceutical post-graduate academic institutions.

Drug delivery patents

The valuing of patents is a difficult undertaking whichever stakeholder one chooses to value it for. If one chooses to value a patent in terms of the value to the intellectual property holder, one must estimate the potential future usage levels of the patented product, timelines, potential for competitors to reduce market size etc. A similar set of estimations is required if one chooses to estimate the value in terms of the benefits that patented product produces to end users e.g. in terms of lives saved. The potential of many innovative drugs/drug delivery mechanisms makes modelling these considerations a significant exercise.

Both approaches are potentially interesting from a governmental perspective. The first can produce additional revenue for the government through various forms of taxation. The second can potentially reduce the disease burden on a country, reducing government spending, increasing GDP (and indirect tax receipts).

For the government and the choice they need to make as to whether to invest in such a venture, the calculation is if the investment estimated to discover/dispense a treatment is less than a discounted value for system savings after that drug/delivery system is implemented, it is a rational investment assuming you would incur economic costs for the disease. These are the types of studies undertaken by South Africa’s Technology Innovation Agency (TIA).

Positioning as expert in Drug Delivery System (DDS) in global pharmaceutical industry

A key metric for analysing the value of the sector’s positioning as a global player is the foreign direct investment it brings into the country. This investment may be in the form of procurement of health research services, licensing fees for South African products, spending by foreign researchers attracted to South Africa. A sector wide survey using these common valuation metrics would likely yield a richer picture as to the wider value.

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26 See valuation section for NEP/NEPP/SARChI case study on Malaria drug development
4. VALUING CASES FROM THE CENTRES OF EXCELLENCE

4.1. CASE STUDY 3: EXCELLENCE IN INVASION BIOLOGY

This calculation finds that C-I-B’s interventions in the Agulhas Plain are generating benefits worth between R 284,423 and R 1,747,007 per year, with a medium estimate of R 959,573 per annum. These are net benefits accruing to the wildflower and the tourism industries. Assuming the benefits are at work throughout the next decade, the total Present Value of the benefits generated range between a minimum of R2.4 million and a maximum of R14.8 million.

The Centre for Invasion Biology

C-I-B became operational in June 2004 as an interdisciplinary, inter-institutional DST/NRF Centre of Excellence, headquartered at the University of Stellenbosch with a subsidiary hub at the University of Pretoria, and series of associated sub-networks. Its main focus is on providing new knowledge and understanding through research, and capacity development of postgraduate students and postdoctoral fellows in order to reduce the rate and impacts of biological invasions in a rapidly changing natural and socio-political environment.

Summary of Findings (CoE – CIB): Excellence in Invasion Biology

Figure 6: Summary of value proposition of CIB project used for valuation

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27 CIB did significant work in 2012 to document what it regarded as its most relevant impacts at the time. This was required at the time for an assessment meeting facilitated by ASSAf. In view of the work done and the credible sources of evidence, the evaluation team has used these cases to highlight their diversity, and to select one for economic valuation.
Around 80% of Centre work can be classified as use-inspired basic research, 12% as basic research and 8% as applied research. In 2013 C-I-B had 79 active student and post-doctoral fellowship projects, as well as many additional projects involving core team members, research associates and their collaborators. The Centre is currently led by the Director, Prof Dave Richardson28, supported by the Deputy Director, Dr Sarah Davies, 24 core team members (nearly all full-time academic scientists) working in South Africa on invasive species as a major research thrust, 17 South African and international research associates, and 14 South African and seven international (outside Africa) institutional partners and collaborators. C-I-B also has four SARChI Chairs contributing to Centre programmes.29

The Centre has its primary hub at Stellenbosch University and a secondary hub at the University of Pretoria. This set-up, funded in part by the DST-NRF CoE allocation, has allowed for several administrative advantages, such as a core group of support personnel for researchers, students and postdoctoral fellows; a customised archive of Centre outputs, and tracking system for its students; media liaison and outreach capacity in the form of an outreach manager and team; physical facilities that are state-of-the-art; useful monitoring and evaluation encouraged by submission of financial and output reports to the NRF; and access to NRF research management experience and support.

The 24 core team members of the Centre are expected to “solicit applications from good students, to take on these students for training, to work with them in the usual post-graduate student training fashion, to provide additional mentorship where necessary, and to contribute in the appropriate way to ensuring that the students succeed”. The management team provides advice to core team members on how matters can be arranged to support students and help ensure their success. Special actions are also taken to address equity and promote high quality work.

The relevance of C-I-B

South Africa is a ‘megadiverse’ country, and among the places that have been worst affected by invasive species. These pose a substantial and growing threat to the region’s globally significant biodiversity, water and food security. It is therefore essential to explore the problem, the changing roles of different drivers of invasions and of invasions as stressors in changing socio-political conditions, and to devise practicable, efficient solutions and regulatory instruments.

C-I-B’s charge has not changed since its inception. Developing world-class research expertise on biological invasions is in line with national priorities, both over the past decade and at present. This is confirmed by the fact that C-I-B operates in several scientific priority areas in both the NRDS and TYIP, and is well aligned with the outputs listed in one of the twelve South African Presidential Outcomes signed in 2012, as well as with the National Biodiversity Framework (2009) which notes invasive alien species as one of five major pressures on South Africa’s biodiversity. This framework called for the finalisation of the “regulatory framework for the prevention, containment and eradication of alien and invasive species” as one of six top priority actions. The Centre approach has also been explicitly in line with DST’s 10-Year Global Change Research Plan for South Africa and with the Global Strategy on Invasive Alien Species of the Global Invasive Species Programme.

The scope of work of C-I-B has shifted somewhat at times, for example when they have been called upon to play a role in policy formulation. Such interventions drove shifts in emphasis and led to several key research outputs. This type of expertise is crucial in South Africa, where a large proportion of the human population relies on natural capital and ecosystem services. South Africa has in recent years become a leader in this field, in no small part as a result of the work of the Centre.

28 Prof Richardson took over from Prof SL Chown, the previous Director, when the latter left for Australia
29 One since 2007, while the others have joined more recently
Research by C-I-B core team member Prof Brian van Wilgen and co-workers provided the first full quantification of the current and future potential impacts of invasive alien plants on three major ecosystem services\(^\text{30}\). This work showed that reductions in surface water run-off due to current invasions exceeded 3,000 million m\(^3\) (about 7% of the national total), mostly in the fynbos and grassland biomes. Among others, potential reductions would be more than eight times greater if invasive alien plants were allowed to spread to occupy their full potential range. This could have a dramatic effect on the grazing capacity of livestock, for example.

The difference made by C I B

The following are brief descriptions of C I B’s most significant realised or emerging impacts to date, as perceived by the Centre and the evaluation team.

1. **Global Indicators for Biodiversity**

The *Convention on Biological Diversity* selected 22 Headline Indicators to measure progress towards the Millennium Development Goals and the Convention on Biological Diversity’s target of reducing the rate of loss of biodiversity by 2010. The C-I-B was contracted to develop and populate indicators of “trends in invasive alien species”.\(^\text{31}\) Until this was done in 2010, no fully developed indicator for invasive alien species was available that combined trends, used a standard set of methods, and addressed a range of species groups, ecosystems, and regions. This was preventing the objective assessment of this key trend worldwide, particularly in the context of the Convention on Biological Diversity signatories’ commitment to “achieve by 2010 a significant reduction in the current rate of biodiversity loss at global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth”.

Chapter 9 of the *Global Biodiversity Outlook (GBO-4)* deals with the Aichi Targets for addressing Invasive Alien Species (Target 9). Ten C-I-B publications are cited as supporting evidence in the Technical Background Document, to be used by in-country decision makers to inform national policy and action plans for managing invasive alien organisms and their impacts on biodiversity, livelihoods and economy.

2. **Antarctica and the sub-Antarctic Islands**

Extensive research over the past ten years has made the C-I-B a centre for knowledge generation on the Antarctic and sub-Antarctic. South Africa’s involvement in the Antarctic Treaty and presence on that continent, as well as its ownership of the Prince Edward Island group, make the country a key national and international player in Antarctic matters.

C-I-B has conducted research for the South African National Antarctic Programme of the NRF and the Department of Environmental Affairs, Directorate: Antarctica and Islands, as well as for international bodies, addressing all levels of Antarctic conservation, from fundamental research to management planning and the production of handbooks for tourists. The research has been documented in a series of publications in prominent journals. Research findings been taken up into protected area management plans and in the Antarctic Treaty System policy and position papers.\(^\text{32}\)

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\(^{30}\) This information is taken from a C I B report

\(^{31}\) Captured in several publications in, *i.a.* Science(2010), with prior work in Conservation Biology (2006); by the Secretariat of the Convention on Biological Diversity in Montreal; and on websites of the Biological Indicators Partnership (which details the role of C I B), Birdlife International, the IUCN and the National Invasive Species Information Centre.

3. The NEM:BA regulations

The C-I-B has devoted considerable resources to feeding key research findings from its own programmes and from the international literature into assisting with the formulation of the regulations for implementation of Chapter 5 of the National Environmental Management: Biodiversity Act (NEM:BA) relating to alien and invasive species. Several of the core team members participated in a Task Team assembled by the Department of Environmental Affairs and the South African National Biodiversity Institute (SANBI). The Task Team was charged with the development of objective, science-based lists of alien and invasive species to help devise a risk-assessment framework, and to participate in drafting the regulations. The results of diverse C-I-B research projects were used in the process, and expert insights ensured that the regulations were grounded in international best practice from the fields of invasion biology and environmental management.

Section 11 of the National Biodiversity Assessment 2011 Synthesis Report synthesises much of the work of the C-I-B towards understanding the threats of invasive species on South Africa’s biodiversity, with seven C-I-B-funded papers cited as key evidence. A draft of the National Strategy for Dealing with Biological Invasions in South Africa was submitted to the Department of Environmental Affairs on 25 March 2014. The final regulations require amendments to the Act and are likely to be implemented in 2014.

These results were made possible by the accumulated knowledge and experience gleaned over an estimated 6-10 years.

"The Department of Environmental Affairs herewith acknowledges the major role that the Centre for Invasion Biology (CIB) of the Stellenbosch University has played with regards to informing the process of developing national biodiversity legislation, particularly as far as it relates to alien and invasive species. The CIB participated in the development of the draft Alien and Invasive Species (AIS) Regulations and influenced the process by feeding key research findings from its own programs, as well as those from international literature, into the regulations. The DEA has recently appointed the CIB, due to its expertise in the field of invasion biology, as a sole service provider to develop guidelines for the conducting and evaluation of risk assessments related to alien and invasive species."

"Several core CIB members further participated as members of a task team to develop science-based lists of different categories of alien and invasive species, including all taxonomic groups of plants and animals. Prof B Jansen van Vuuren, a core team member at the time, led an extensive process to develop maps of the natural distribution ranges of a number of indigenous mammal species. These maps would form the basis for the regulation of listed invasive species by area."

"Although the implementation of comprehensive AIS Regulations is subject to review of the provisions of NEMBA, the impact of the CIB is nevertheless reflected in the overall structure and details of the draft AIS Regulations. The valuable contributions made by the CIB are appreciated..."

From: Letter by Ms Nosipho Ngcaba, Director-General, Department of Environmental Affairs, 2012

4. Working for Water

The C-I-B has since its establishment been a key research partner of Working for Water, the Natural Resource Management Programme of the Department of Environmental Affairs. Since 2008, a large part of the research efforts have been guided by a formal collaboration between the C-I-B and with Working for Water on research and capacity building entitled Integrated management of invasive alien species in South Africa. The co-funded partnership has produced numerous research products, many of which have been taken up in Working for Water strategies and management plans.

The partnership has also trained post-graduate students (37 degrees have been completed) in a range of disciplines related to conservation biology, environmental management and invasion ecology, and socio-anthropology, and provided regular training to Working for Water staff.
Research at the C-I-B has contributed to raising awareness of problems associated with invasive species and thus helped to justify expenditure of public funds on natural resource management initiatives such as Working for Water and SANBI’s Invasive Species Programme. A research partnership with the South African National Biodiversity Institute guided the implementation of an Early Detection, Rapid Response initiative for dealing with emerging invasive species.

These results emerged based on work done over a period of 3-5 years.

5. **Policy and Strategy for the Kruger National Park**

Recent C-I-B-supported work on the extent, impacts and ecology of key alien invasive species has brought about a holistic, deeper understanding of the patterns and processes of invasion in protected areas. This knowledge enables evidence-based decision making for making decisions about these species as a threat to biodiversity. Results have been incorporated directly into various management strategies and plans, and have informed the development of various protocols that are now in practice and being transferred to national parks in South Africa, including the Kruger National Park.

This national park is one of South Africa’s flagship protected areas. Preventing alien plant invasions along river corridors and across the long boundary is a major challenge for the conservation managers of the Park; almost 400 alien plant species have been recorded there. The C-I-B-supported work has provided fundamental information on the invasion ecology of the most important invasive alien plants in the park. Work on prickly pear (*Opuntia stricta*) reconstructed the invasion history of the species over 50 years to explore the roles of key drivers of invasion patterns. The spread of lantana (*Lantana camara*) into the park was studied using molecular techniques to identify the relative importance of spread along rivers versus diffusion from rest camps.

Protected areas lie within a matrix of human-modified habitats, and the spread of invasive alien plants is inevitable in this context. There was thus also an urgent need to develop predictive methods that allow land managers to prevent, manage and respond to the introduction and spread of plants. A detailed study explored the permeability of the western boundary of Kruger National Park to invasive alien plants and its implications for management, showing that the number of invasive alien plants inside the park was a function of the amount of water run-off and the density of major roads. This information has great value for predicting trajectories of further incursions and for guiding management actions.

C-I-B supported work has been directly integrated into the following policy and strategy documents:

i. The Kruger National Park policy on use and management of alien ornamental plants, as detailed in several Kruger National Park reports in 2006.


iii. A monitoring policy for South African National Parks on invasive alien species in support of one of its ten monitoring programmes which aims to provide information for reducing the rate of introduction, spread and impact of biological invasions in national parks. The monitoring provides information on trends in invasive species for a number of selected indicators.

iv. A SANParks policy brief, forming the basis for a strategy for the Kruger National Park Mapping/Monitoring Programme.

v. An *Alien and Invasive Species Framework* for SANParks (corporate level).

vi. The *Kruger National Park 2012-2013 Clearing Strategy*.

vii. It is also informing the *Global Environmental Change Programme - Alien and Invasive Species*, a SANParks programme aimed at investigating each of the major drivers of global environmental change.
and the impacts for the organisation, and determining the relative risks posed. The assessment collates existing information and knowledge on alien and invasive species in and around parks, and aims to provide the information in a form that is usable for management and policy development. This programme has drawn on a large number of C-I-B publications.

6. Influencing sustainability guidelines for the South African wildflower industry

The collaboration between the Flower Valley Conservation Trust and the C-I-B was initiated to provide innovative, practical, implementable guidelines for the wild flower industry. The sustainable use of floral resources will help secure precious natural resources and provide a sustainable income for flower farmers on the Agulhas Plain and ultimately elsewhere in the Cape Floristic Region. Harvesting wild flowers is an important economic activity in the Cape Floristic Region of the Western Cape, especially on the Agulhas Plain which has higher flower harvesting levels and generates more income than any other fynbos area. The Agulhas Plain is recognised as a biodiversity hotspot and a ‘centre of endemism’, but this biodiversity is being severely affected by alien plant invasions, agriculture and urban development, as well as escalating pressure from the wild flower industry on natural plant populations.

Guidelines provided through research at C-I-B have been used in a Code of Best Practice developed in 2010 for the sustainable use of fynbos resources, in an effort to ensure that all flower farming operations apply the same sustainability principles. The research informing the Code of Best Practice was based on 6-10 years’ prior work.

"CIB was a key contributor to the successful completion of the Invasive Alien Species component of the Cape Action for People and the Environment (CAPE) project.... The CIB played a significant role in the development of the CAPE IAS Strategy.... Having Prof Richardson on the core team not only informed the strategy, but also gave the strategy much-needed scientific credibility. Other CIB members served on specialist working groups .... The CAPE IAS strategy informs the Invasive Species strategies of conservation agencies and municipalities across the Cape Floristic Region. ...."³

"[CIB] continues to provide leadership and direction to invasive animal management in the Greater Cape Floristic Region. ... In addition to the above, the research projects [listed in table 1] were completed through the CIB and inform future policies and management of invasive species, not only in the Greater CFR, but also nationally."

"...the CIB representation on expert working groups contributed to the following strategies: City of Cape Town invasive species strategy; National House Crow strategy; National Mallard Strategy; Guttural toad strategy and implementation plan; Feral pig strategy."

Ms Louise Stafford, City of Cape Town Invasive Species Coordinator, 2012

7. Outreach through limbovane

The experiential learning approach used by the limbovane Outreach Project, implemented in 2006, means that learners and educators who are not regularly exposed to scientific projects can appreciate South Africa’s biodiversity and learn how science works.³³ Monitoring data showed that the project has benefitted science

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³³ Several published articles and reports provide evidence of impact, although the project has not been formally evaluated. It is included here for this reason. See for example Braschler, B. 2009. Successfully Implementing a Citizen-Scientist Approach to Insect Monitoring in a Resource-poor Country. BioScience 59: 103-4
education and conservation by improving understanding of the concept of biodiversity among Life Science learners and educators; establishing a monitoring and inventory protocol for an ecologically important and poorly understood taxonomic group (ants), which helps South Africa to contribute to the monitoring goals of the Convention of Biological Diversity.

Training workshops were held to enable educators to gain in-depth knowledge and field and laboratory experience in order to teach biodiversity in a more confident and thoughtful manner. They produce and receive educational resources such as worksheets, activities and projects that learners can conduct with data from the limbovane Project. All these activities were aligned with the National Curriculum Statement Grades 10-12 (Life Sciences), and microscopes, data projectors and notebook computers are provided to participating schools to allow them to teach biodiversity in a more visual, hands-on and accessible manner.

An important consequence of the project is the promotion of post-school study in scientific fields. Even though data on whether this has been effective is not available, the C-I-B staff who work on limbovane are all women. This sends a powerful message to young people about traditional gender roles, as reflected in some of the comments received from learners and educators.

Of the 28 participating schools in this project, 17 are located in rural and eleven in urban areas, and the vast majority (26 of the 28), serve previously disadvantaged communities. Since 2006 the project has reached six WCED curriculum advisors, and approximately 2,010 educators and 8,900 grade 10 and 11 learners. A total of 180 attended voluntary project workshops at the limbovane laboratories in Stellenbosch. In 2013, six former limbovane learners registered for SET degrees at Stellenbosch University.

“The Ant ladies [the limbovane project team] are role models to our learners, especially the girls. Many girls were inspired to continue with their studies after school.”

Participating educator

8. Significant new knowledge for South Africa’s knowledge economy

The C-I-B has made progress in all the strategic responses to the Global Strategy on Invasive Alien Species. In the process it has made major advances in terms of knowledge generation, as many of the cases noted here highlight. There is substantial evidence in publication data as well as comments in NRF assessment reports that South Africa has become a world leader in the field of invasion science through the work of the Centre.
“As you are aware, alien invasive species (AIS) are an enormous global diversity problem, particularly for countries like South Africa .... Few countries have developed programs to address the threats posed by, and develop solutions to manage, AIS. South Africa jumped to the head of the world stage when it funded the Centre of Excellence for Invasion Biology (CIB). I know of no other country that has marshalled such a co-ordinated effort to address AIS, with top quality scientists mentoring students at all levels as well as interfacing with government agencies responsible for policy development and execution....”

“Dr Richardson is world-renowned for his work on alien invasive plants, but has also made an enormous impact with key papers pertaining to the theoretical aspects of invasion biology. David has published a very large volume of work that has been hugely influential in the field. His (2012) h-score is 65, with almost 17,000 citations in total and nearly 3,000 (in 2011) last year alone. ....Two ....papers have more than 1,000 citations, a remarkable achievement in science.... In 2008, Dr Richardson hosted what I believe is the most influential conference every held on alien species.....”

Source: Letter dated 20 Aug 2012, Hugh J MacIsaac, Director, NSERC Canadian Aquatic Invasive Species Network

The role of the CoE Funding Instrument

Before the Centre was initiated, South African scientists were recognised in this field, with scattered innovations and high quality contributions to knowledge. Yet according to those interviewed, the NRF support for the establishment of the Centre of Excellence was “transformative”. The following summarise the key reasons for stakeholders’ view that the NRF CoE support has been transformative.

Working on ‘invasion science for society’ represents an innovative effort to harness research expertise to address a highly complex, context-dependent problem. The DST-NRF grant has allowed the C∙I∙B to develop its tiered network model - consisting of core staff, a core team, a research associate network and partner organisations - leading to a large but well-integrated research network with a critical mass that can address complex multi-disciplinary problems (i.e. so-called ‘wicked problems’) such as biological invasions. In other words, the collective has become more than the sum of the parts. This is reflected in the increasingly positive accumulated results achieved over the lifetime of the Centre, which has moved South Africa to become one of the top performing countries in the world in spite of smaller numbers of active researchers. Without the funding it is clear that the network would not have existed in its current form.

Through the innovative partnership model that involves all South African researchers working substantially on invasions, as well as organisations involved in or mandated to manage biological invasions, the CoE was able to address all ten strategic responses of the Global Strategy on Invasive Alien Species. This would not have been possible without implementation of the CoE concept.

The network and objectives of the Centre enabled it to address invasions beyond ecology, bringing in social and economic aspects, for example. In other words, it encouraged multi-, inter- and/or trans-disciplinary research are encouraged. Success in this regard is still limited (perhaps visible in only 10 % of outputs, according to the Director), but there is an increasing interest in such integration in spite of certain disincentives and practical obstacles.

It enhanced opportunities to combine the benefits of different NRF funding instruments, drawing in particular from the CoE, NEP and SARChI funding instruments. Collaborative work done since 2007 has led to the successful joint application for a biodiversity-focused SARChI Research Chair submitted by the University of Venda and Stellenbosch University, one of few joint Chairs awarded to date. There is a spirit of collaboration between the Chairs and the Centre and the different sources of funding and students enhance their reach.

34 Defined as making a significant difference to performance, activating new ways of working, shifting mind sets about work, greatly enhancing research profiles, and/or fundamentally influencing research directions
when collaborating, enabling them to work with students who span multiple disciplines, with diverse skills sets.

The collective identity of the Centre, i.e. its ‘branding’ as “invasion biology”, helps to position the scientists and their research in forums and platforms nationally, regionally and globally. The ‘gravitas’ of being known as a “Centre of Excellence” also helps to attract better quality postgraduate students and postdoctoral fellows, and even well-known international collaborators who want to spend time with them. It supports their roadshows held around the country – something that is novel for the scientists, and demanded by the six Key Performance Areas\(^{35}\) that each CoE should satisfy and report on every year in order to enable and assess progress towards established goals.

The DST-NRF grant has enabled the C I B to leverage funding from external sources; over time the proportion of funding from DST-NRF supporting Centre programmes has fallen from 92 % to 51 %.

The development of long-term collaborations and monitoring projects is regarded as one of the strongest and most unique benefits of the CoE model. The nature of biological invasions is such that this long term perspective is needed for an effective understanding to be developed over time in the local context, and management solutions to be devised. Long term sustained funding from the DST and NRF has allowed the Centre to develop long-term collaborations and biodiversity monitoring projects without concerns about funding being cut short unexpectedly.

There are also negative aspects to being a Centre of Excellence, although these are, according to those interviewed, far overshadowed by the benefits. The most severe challenge is that of sometimes unrealistic expectations from stakeholders, given the few permanent researchers on the staff of the Centre. Most of the Centre collaborators at other universities have other commitments; the Centre programmes are only a small part of their workload. Yet with the profile of the Centre of Excellence comes the expectation that should respond to many calls for assistance, advice and service.

They also struggle with the balance between their strengths in research which should be their main focus, and the need to attend to advocacy, advice and outreach services. Their unique position in the sectors in which they work also require them to position themselves carefully; it remains difficult to determine whether they should be an ‘honest broker’ or focus on advocacy with respect to their research results.

Finally, one of the main purposes of being a “Centre” is complicated by disincentives to multi-, inter- and/or trans-disciplinary collaboration, in particular the struggle to find appropriate journals for publication, the need to keep a profile in a disciplinary area, and to attract students to an interdisciplinary area where the research areas might lack clear definition and often does not have a high profile\(^{36}\). This has negatively affected both collaboration and productivity, according to those interviewed.

\(^{4.2.}\) **VALUATION FOR CASE STUDY 3**

This valuation analysis focuses on one of the work components of the C I B, namely the creation of sustainability guidelines for the South African wildflower industry. This work contributed directly to the Code of Best Practice developed in 2010 for the sustainable use of fynbos resources in the Western Cape, particularly in the Agulhas Plain. It consisted of two strands:

1. Contribution to promoting sustainable harvesting of fynbos by the wildflower industry in order to ensure the sustainability of the resource. The guidelines created have been adopted by the industry over an area of 60,000 hectares in the Agulhas Plain.

\(^{35}\) Research; education and training; information brokerage; networking; service rendering; management.

\(^{36}\) For example, environmental sociology struggles to attract students in spite of the interesting nature of the work.
2. Contribution to biodiversity maintenance and restoration, consisting most notably in controlling Alien invasive species and reintroducing native species in the same area.

These two strands respond to the key drivers of ecosystem degradation in the Cape Floristic Region, namely over-exploitation and depletion of terrestrial resources and invasive species.

*Figure 7: Ecosystem services from an economic standpoint*

![Diagram of ecosystem services and valuation steps]

This impact analysis stems from the literature dealing with the economic valuation of ecosystems and biodiversity. Biological conservation is not only important for its own sake, but equally because of the socioeconomic services ecosystems underpin and support. Ecosystems generate numerous economic benefits, the sum of which generates their Total Economic Value (Figure 7).

The steps followed to create the analysis are presented in Figure 8 below.

*Figure 8 Valuation steps*

![Diagram of valuation steps]

**Beneficiary identification:**

The principal beneficiaries considered in this analysis are a) the wild flower industry, b) the tourism industry, and c) water consumers, which include the broader population of the Cape Floristic Region and the industries e.g. other agricultural activities, located in it (including the wild flower and tourism industries).

Other beneficiaries excluded from the analysis include:

- The marine-based tourism industry, due to the potential impacts of terrestrial conversation on coastal and marine ecosystems.
- The fishing industry, as per above.
- The broader South African society, independently of location of residence. The value accruing to the South African society can be expressed in terms of existence, bequest and altruistic values of the ecosystems in question.

**Impact description**
By enhancing sustainable harvesting practices of fynbos and controlling alien species in the Agulhas Plain, the CIB's contribution prevents both biological loss and potential economic losses which would be induced as a consequence of a reduction of ecosystem services. More concretely, this analysis considers in detail four key impacts:

1. By enhancing sustainable harvesting of fynbos, the project reduces the mortality rate of fynbos. This translates into an avoided economic loss for the wildflower industry, in the sense that future harvests are not jeopardized.

2. By controlling alien species invasion and restoring biological characteristics, the project averts further fynbos mortality, thus avoiding additional losses for the wildflower industry.

3. By controlling alien species invasion, the project helps maintain additional ecosystem services, such as tourism revenue.

4. Finally, alien plant infestation can significantly affect river catchments and water yields. Indicatively, it has been estimated that whereas an uninvaded catchment yields 2,310 m$^3$ per hectare, a 15% extent of alien plant cover can reduce water yields by 11.7%, resulting in a loss of 270 m$^3$ of water per hectare per year. As such, by preventing an increase in alien plant cover, the projects can also prevent a decrease in future water yields.

Table 3 describes the key benefits considered in this analysis.

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
<th>Type of value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Avoided future income loss due to overharvesting of fynbos</strong></td>
<td>Over-harvesting significantly increases the mortality of fynbos, thus reducing future yields for the wildflower industry. By implementing sustainable harvesting practices the costs associated with mortality (non-regeneration of plants) of fynbos is avoided.</td>
<td>Direct use value (consumptive)</td>
</tr>
<tr>
<td><strong>Avoided future income loss due to invasive non-indigenous species</strong></td>
<td>Invasive alien species disrupt the indigenous ecosystem and increase the mortality of indigenous fauna and flora. By limiting and controlling invasive species, the mortality of fynbos is avoided. This prevents additional losses to the wildflower industry.</td>
<td>Direct use value (consumptive)</td>
</tr>
<tr>
<td><strong>Avoided future income loss due to a reduction in tourism</strong></td>
<td>The degradation of ecosystems in the Cape Floristic region might reduce tourism in the region. Existing evidence from the Cape Floristic region suggests that the more the landscape is degraded the less visitors and willing to visit it. Avoiding further degradation avoids future losses due to a likely reduction in tourism visitors.</td>
<td>Direct use value (non-consumptive)</td>
</tr>
<tr>
<td><strong>Avoided future loss of water yields due to invasive non-indigenous species</strong></td>
<td>Invasive alien species disrupt the indigenous ecosystem and substantially affect river catchments. This results in a decline of water yields.</td>
<td>Direct use value (consumptive)</td>
</tr>
</tbody>
</table>
The impacts listed in Table 3 above are by no means exhaustive. It is important to list additional potential benefits which should be taken into account even if they are not quantified in the present research:

- Firstly, the present analysis entails direct use values only. Additional values stemming from ecosystems of the Cape Floristic Region are excluded from the analysis. These include indirect use values (e.g. pollination services and impacts on bee-keeping), or intrinsic values of the ecosystem.
- Secondly, a degradation of terrestrial ecosystems can also impact on coastal and marine ecosystems. This additional avoided loss (e.g. to the fishing industry or marine-based tourism) is not accounted for.
- Finally, we only consider the net direct avoided losses (in terms of value added) to the wildflower and tourism industries. However, the avoided losses for these industries also prevent a loss for other sectors of the South African economy, i.e. those sectors linked to respective industries.

As such, our analysis can sensibly under-estimate the benefits (avoided losses) generated by the C I B.

The impacts listed above affect an area of 60,000 hectares in the Agulhas Plain. The remaining part of this section focuses on the measurement and quantification of these impacts in monetary terms.

**Data**

We found a variety of studies quantifying the value of, and potential losses associated with, the degradation of fynbos ecosystems and/or invasive alien species, both in biological and economic terms. For example, De Lange et al estimate that (Rand 2008) 6.5 billion are lost every year due to alien species invasion in South Africa. However, the most comprehensive study eliciting the value of the Cape Floristic ecosystem specifically is the one undertaken Turpie et al. As such, the values used to simulate the impacts of the C I B in the Agulhas Plain mostly draw from Turpie et al’s estimates.

Turpie et al (2003) have attempted to measure the Total Economic Value (see figure 7 above) of the Cape Floristic Region. Overall, they find that the ecosystems of the Cape Floristic Region provide a yearly economic value of approximately (Rand 2000) 9.6 billion, distributed among:

- **Consumptive use values (harvesting of fynbos, forests and marine resources), worth R1.4 billion per year**
- **Non-consumption use values (adventure tourism and ecotourism), worth R7.4 billion per year**
- **Indirect use values (honey and orchard pollination services), worth R593 million per year**
- **Existence values for the terrestrial fynbos area and for the coastal area, worth respectively R153 million and R28.8 million per year.**

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The findings suggest that more than 90% of the total economic value is down to the direct contribution of the Cape Floristic Ecosystem to economic activities, i.e. consumptive and non-consumptive use values. This means that any ecosystem degradation can considerably affect, and eventually disrupt, critical economic activities in the area.

Turpie et al (2003) also measure the marginal impact of alien species invasion and broader land degradation of the value of these ecosystems. For example, they find that the current losses could cost the wildflower industry, an average of R 1,444,995 per annum, assuming an 8% discount rate over the next 30 years.

Impact considerations

The C∙I∙B is not the only organisation contributing to the promotion of sustainable harvesting practices and control of invasive species. Most notably, the FVCT has recently initiated an alien clearing project which is funded by the Department of Environmental Affairs. The project was established to control alien plants and to restore native biodiversity.

Likewise, the FVCT was also involved in the process of diffusing the Code of best practice to the industry as well as enhancing ecological restoration through the re-introduction of native species and control of invasive species.

Finally, the wildflower industry contributes to conservation by implementing the guidelines and adopting sustainable harvesting practices.

The contribution of these additional actors means that only part of the benefits generated are directly attributable to the C∙I∙B. However, no reliable figures are available for assigning attribution in a quantitative way.

Net value creation

Because the impacts of the intervention on the Cape Floristic ecosystem have not been quantitatively documented, we run different sets of scenarios based on a variety of assumptions in terms of:

- The impact of sustainable harvesting on fynbos mortality rates – and thus returns to the wildflower industry (compared to a business-as-usual scenario).
- The impacts of the project in terms of controlling invasive species introduction – and thus fynbos mortality rates and returns to the wildflower industry (compared to a business-as-usual scenario).
- The impacts of the project in terms of avoided tourism reduction (compared to a business-as-usual scenario).
- The impacts of the project in terms of an avoided reduction in water yields (compared to a business-as-usual scenario)

These assumptions are based in the extant literature. For example, Turpie et al estimate that whereas the average returns to tourism per hectare are of R18.65 annually for the entire area, areas with dense levels of invasive species (thus relatively degraded areas) generate a return of just R2.59 per hectare per year. Similarly, areas with scattered invasive species generate a return of R18.1 per hectare per year. As such, if we assume that a business-as-usual scenario could lead to either 1) a dense level of invasive species or 2) a scattered level of invasive species, then the cost of business-as-usual is equal to current average returns minus returns in a further degradation scenario (either R2.59 or R18.1 per hectare). Finally, if the project manages to maintain the ecosystems in their current condition (by controlling the spread of alien invasive species), then the costs of a business-as-usual scenario (whereby the spread of alien invasive species is not controlled) are avoided. These avoided losses are then modelled as a benefit of the intervention, in this case to the tourism industry.

The same rationale (and range of possible business-as-usual scenarios) was applied for the three key benefits considered. This provided us with a low impact, a medium impact, and a high impact scenario. The minimum
impact scenario uses the most conservative assumptions, notably simulating what the benefits are in a situation whereby the intervention has a limited effect in mitigating current trends. The high impact scenario assumes that the project manages to effectively avert the worst possible business-as-usual scenario over the next ten years, while the mid-bound scenario is based on the most moderate estimates.

**Table 4: Values generated annually and Present Value of benefits under variety of discount rates – R2014**

<table>
<thead>
<tr>
<th>Impact Scenario</th>
<th>Average annual value created (undiscounted)</th>
<th>Present Value (3% discount rate)</th>
<th>Present Value (10% discount rate)</th>
<th>Present Value (12% discount rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low impact scenario</td>
<td>R 11,037,691</td>
<td>R 94,150,469</td>
<td>R 67,814,344</td>
<td>R 62,357,280</td>
</tr>
<tr>
<td>Medium impact scenario</td>
<td>R 42,538,293</td>
<td>R 362,843,916</td>
<td>R 261,341,963</td>
<td>R 240,310,174</td>
</tr>
<tr>
<td>High impact scenario</td>
<td>R 76,288,027</td>
<td>R 650,719,633</td>
<td>R 468,682,029</td>
<td>R 430,963,025</td>
</tr>
</tbody>
</table>

*Assuming a 10-year benefit period

The overall range of results is presented in Table 4. We find that the C I B’s interventions in the Agulhas Plain is generating benefits worth between R 11,037,691 and R 76,288,027 per year, with a medium estimate of R 42,538,293 per annum. These are net benefits accruing to the wildflower and the tourism industries. Assuming the benefits are at work throughout the next decade, the total Present Value of the benefits generated range between a minimum of R 62,357,280 and a maximum of R 650,719,633.

Note that whereas high discount rates reflect typically the industry rates (*i.e.* time preferences for private agents), a 3% discount rate is more reflective of broader societal preferences. As such, for the purpose of eliciting the social value created by the C I B, the results obtained under a 3% discount rate are more relevant.
4.3. CASE STUDY 4: PREVENTING AND MANAGING FOREST INFESTATIONS

The Centre of Tree Health Biotechnology (CTHB)

The Centre of Tree Health Biotechnology (CTHB) was formally launched in 2005, one of two partially-funded Centres of Excellence (CoE) supported by the NRF at that time. The CTHB was developed as a research platform in the Forestry and Agricultural Biotechnology Institute (FABI) of the University of Pretoria (UP), with the vision and primary goal to promote the health of native trees by making use of biotechnology.

FABI also houses the Tree Protection Co-operative Programme (TPCP), a 25 year-old programme established and part-funded by the SA Forestry Industry to conduct research on pests and diseases threatening the long-term sustainability of plantation forestry. It was therefore fitting that the CTHB was chosen to function alongside the TPCP, which already had a substantial international footprint in the field of tree health. The relationship between the CTHB and TPCP is highly synergistic because of the human and intellectual resources available to the combined programmes. Furthermore, pests and pathogens affecting native as opposed to plantation trees commonly overlap, which enhances the synergy between the programmes.  

Late in 2009, DST/NRF made the decision to fund the CTHB fully. This led to a substantial expansion of the CTHB’s research scope and the inclusion of additional factors that play a role in understanding and promoting native tree health. These include, for example, plant genetics and physiology, climate change, and human needs regarding food, medicine, fibre and fuel.

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41 CTHB inputs, NRF evaluation (April 2014)
42 In contrast to 50% partial funding from 2004-2009
In 2011, FABI built a R6 million biocontrol centre at the University’s Experimental Farm. This allows for the creation of a controlled research environment. Since the industry could not commit to funding for such a facility, the University of Pretoria provided the necessary financial support. It has established itself as a model for other facilities at the UP Experimental Farm and has attracted national and international researchers because of its reputation, well equipped molecular laboratories, a 24 hour quarantine facility to help in studies of insect and their biocontrol agents in captivity, and availability of glass-houses.

The CTHB/TPCP collaboration also offers a disease and insect pest diagnostic clinic which received over 1,750 samples in 2013. The Centre manages various databases and houses a collection of more than 30,000 fungal and bacterial isolates originating from indigenous and commercially propagated plants. The collection is growing by about 1,500 new isolates per year and is a valuable biological resource for South Africa which could be used in other agricultural, medicinal and industrial applications.

The CTHB is under the directorship of Prof Mike Wingfield, the director of FABI, and is managed as a virtual Centre of Excellence (CoE) which is multidisciplinary and inter-institutional. Prof Emma Steenkamp is the CTHB Programme Manager. The CTHB originally consisted of ten core team members from various disciplines at UP, three other South African institutions and one institution abroad. From 2009, the CTHB included 27 PhD-level researchers (12 from UP, 14 from other SA institutions, and one from abroad). It also maintains active collaborations with more than 50 researchers from more than 20 countries worldwide.

The research of the CTHB is regarded as 100 % use-inspire basic research. The Centre works in several key national priority areas related to the NRDS and TYIP, including the bio-economy/plant biotechnology, global change/mitigation and adaptation, and indigenous knowledge systems/biodiversity.

New research directions

Since the NRF allocation of more resources to CTHB in 2011, a broader research focus has been adopted. It now includes the following research areas:

- The biology, ecology, genetics, population biology and systematics of insects and microbes associated with native woody plants
- The biology and ecology of specific tree species, as well as the effect that human practices might have on these species, the ecosystems in which they occur and the conservation of natural habitats
- The possible impacts of soil properties and nutrients, microbial symbioses and climatic factors on the health of woody plants in diverse landscapes, and
- The effects of drought, frost, fire and human activity on the sustainable use of indigenous woody resources.

The University of Pretoria assumes the majority of the research work focusing on insects and microbes associated with native woody plants. Research on the effects of environmental and anthropogenic factors on the health of native woody hosts and natural habitats are conducted largely at the other participating institutions.

The relevance of CTHB

From the beginning, the CTHB focussed its research on the application of biotechnology to promote the health of trees indigenous to South Africa. Despite tree diseases and pests being associated with dramatic losses to native ecosystems globally, virtually no previous research attempted to understand how these factors might affect South Africa’s biodiversity. The establishment of the CTHB represented the first concerted effort to understand the health of plants in native SA woody ecosystems. This is particularly relevant for a country where indigenous forests make up only 0.5 % (500,000 ha) of all woodlands as compared to 1.3 million (1.1 %) forestry plantations and 40 million ha (33 %) of woodlands/savannas.
Similarly, in the commercial forestry setting the programme’s research activities have resulted in detailed knowledge regarding the biology of the insect pests and microbial pathogens of plantation trees, which in turn has revealed various potential avenues for controlling the respective insects and microbes in their natural setting. The CTHB, working jointly with the 25-year old Tree Protection and Conservation Programme (TPCP) has thus developed and improved the practices and strategies for the efficient management and control of numerous microbes and insects affecting plantation trees. These extend from accurate disease/insect diagnoses, through to the actual practices used in forestry to eradicate them or to control their establishment and spread. The latter includes practices at various levels, for example, basic plant pathology / mycology / bacteriology / entomology, silviculture, biocontrol and breeding for resistant planting stock.

The joint programme’s work is also beginning to impact significantly on the technologies used for maintaining indigenous tree health. Among others, projects seeking to determine the cause of a dramatic die-off of *Euphorbia ingens* in SA are suggesting a role for pests and pathogens as well as an impact of climate change. Research on the unexplained death of Baobab trees in South Africa is raising an awareness that these trees have disease problems and that the way in which these iconic trees are managed will determine their long term survival. Furthermore, studies in crucially important natural heritage sites (e.g. the Kruger National Park) are illustrating the importance of pathogens associated with elephant damage and the serious need to contain this problem.

While not directly related to the research outputs of the CTHB, there are significant economic risks that need to be considered. Given the national priority to promote broad-based black economic empowerment and to increase the numbers of small growers in South Africa, the management of tree health is equally critical to the 30,000 small commercial and largely eucalyptus growers. Whereas larger (11) and medium mixed-crop (1,300) commercial growers could face massive large-scale losses, it is the small single-species growers who will be decimated. The research work undertaken at the CTHB assists in reducing the risk and can, through its research, pre-empt potential pathogens and pests before they reach outbreak proportions. Given that there is a move away from pine plantations towards eucalyptus and the risk of cross-vectoring from plantation to indigenous trees, e.g. *Syzygium, Eugenia* and primary crops such as guavas, South Africa may be at increased risk. CTHB’s role in BiCEP may therefore become an important factor in understanding eucalyptus pests better and decreasing the risk through international collaborative research, such as research on *Leptocyba* infecting Eucalyptus.

**The contributions of the CTHB**

The work of the CTHB, in synergy with other research within FABI and the TPCP, has contributed substantial national and international recognition to the University of Pretoria and South Africa. A relatively small initial investment has resulted in a world-class research centre delivering groundbreaking work in tree pest management. Research outputs have yielded results which can be quantified (and monetised in some cases, particularly in the development and deployment of biocontrol agents). The CTHB has attracted increasing numbers of graduate students through the quality of its research staff and facilities, and promoted international research collaboration on combating common global tree health problems. It continues to play a role in reducing risks of future outbreaks in plantations and indigenous forests in the country, regionally and globally.

The following has been identified as the most significant impacts resulting from the work of the Centre to which NRF CoE funding has contributed.

1. **Reducing risk and saving South Africa’s trees**

One of the key drivers for establishing the CTHB was an exponential increase in the arrival rate of pests due to globalization. Previously pests and pathogens would appear every 10-20 years, whereas new pests are now appearing at least once a year thus presenting an ever-increasing risk. At the time of the establishment of the
CTHB, tools to characterise pests did not exist and new tools were needed to manage what was becoming a significant threat to the forestry industry, and South Africa’s tree biodiversity.

For example, in 2005 an invasion of the Sirex woodwasp caused damage of around R 300 million per year in the forests of KwaZulu Natal alone. It effectively wiped out about 50% of the commercial pine plantations that existed at the time. Sirex infests all the major commercial pine species and none have high natural resistance to infestation. Industry partners therefore needed a rapid solution. The CTHB researched possible biocontrol agents (the nematode Deladenus (Beddingia) siricidicola), and subsequently developed the management protocol for the Sirex woodwasp. This is still the only tool available to combat this type of infestation.

CTHB-TPCP collaboration has resulted in the development and implementation of strategies to avoid the effects of Chrysoporthe canker in commercial plantations (including Eucalyptus species), while research on the potential impacts of this pathogen on native trees (Myrtales sp.) was undertaken. More recently, numerous non-native pathogens/pests have been discovered during surveillance activities that threaten South Africa’s tree diversity, for example, the myrtle rust pathogen, Puccinia psidii, which poses a possible threat to planted and native Myrtales hosts.

Even in cases where a specific pathogen or insect pest is relevant exclusively to the TPCP or the CTHB, knowledge produced from the respective research activities has invariably been used to promote the health of both native and non-native trees. Thus, the lessons learned during the pursuit of plantation tree health provide substantial value towards ensuring the health of trees in native ecosystems, and vice versa. Evidence of pathogens jumping from commercial plantations and native species to primary crops may also pose new future threats, all of which will require an integrated approach to tree health management.

2. Influencing regional and global initiatives in combatting tree diseases

Pathogens and pests do not recognise geographic boundaries, hence the need for regional and international collaboration. This has included the decision to develop intellectual property jointly as it is believed that this will be a more effective way of combating future tree diseases more effectively. The CTHB currently maintains active collaborations with more than 50 researchers from more than 20 countries worldwide. Several of the collaborative ventures are particularly important in cross-border efforts to combat tree diseases:

- CTHB, through FABI, was one of the founding partners of BiCEP, an international network to focus on the Biological Control of Eucalypt Pests. The partnership includes IPEF, the Brazilian-based Forestry Science and Research Institute. Invasive Australian pests are rapidly spreading to eucalyptus plantation growing regions of other parts of the world, including South Africa and Brazil. The lack of biological data requires coordinated efforts to develop biocontrol programmes. BiCEP will coordinate the identification, evaluation, selection, collection and shipping of natural biocontrol agents to affected regions.

- Borders with other African countries are not well-regulated regarding the movement of plant materials, resulting in increased risk for the cross-border transmission of pests and diseases. The CTHB and the TPCP have developed a strong collaborative network with scientists at higher education institutions and research institutes in African countries with similar types of tree biodiversity. They include IRAD (Institute for Research and Agricultural Development), Cameroon; Forestry Research Institute of Ghana (FORIG); Eduardo Mondlane University, Mozambique; Kenya Forestry Research Institute (KEFRI), Kenya; University of Makerere, Uganda; University of Namibia; Bindura University, Zimbabwe; the National University of Science and Technology, Zimbabwe; and forestry companies in Ghana, Kenya, Mozambique, Uganda, Tanzania, as well as the Sawlog Production Grant Scheme (SPGS) in Uganda.

- Kenya and South Africa share many similar invasive exotic tree pests and diseases, all of which could lead to severe economic losses should an outbreak occur, e.g. Leptocybe invasa, Thaumastocoris peregrinus and Gonipterus scutellatus on Eucalyptus species. South Africa, through the CTHB, is a world leader in the development of appropriate management options for these and other pests. In July 2014, Kenya imported the biocontrol agent for Leptocybe invasa (Selitrichoides neseri) and will be instituting
laboratory and field trials through the Kenya Forestry Research Institute (KEFRI). The principal forest entomologist at KEFRI, Eston Mititu, forged linkages with the CTHB through the pursuit of his doctoral studies the CTHB/FABI. The intention is to close a collaboration agreement between the institutions for the sharing of knowledge of mutual benefit, networking and exchange of scientific research results, the training of staff, and the undertaking of more collaborative research to address both Kenyan and South African needs in tree pest management.

Furthermore, this will assist in providing more funding for Kenyan researchers to build their capacity in this area. This is particularly relevant for increasing Kenya’s Eucalyptus productivity, currently estimated to be worth Ksh 30 billion. Eucalyptus contributes about 75% of rural energy as woodfuel for cooking and light and is a major source of income for rural areas. No specific value can be put on estimated losses but it is likely to amount to millions of US dollars.

3. **Influencing policies and regulations for managing tree biodiversity and health**

When the CTHB came into being, there were no structures in place to manage the release of biocontrol agents. The Centre was instrumental in changing this situation. A committee was established made up of two CTHB members, DAFF and DEAT representatives. These newly-formed relationships allowed the CTHB to import plant materials in order to pre-empt possible outbreaks and future threats, and reduced the application turnaround time from as much as ten years to about six months.

The CTHB has played a crucial role in the drafting of the *Integrated National Forest Protection Strategy*. At the time of writing (July 2014), the strategy had not been publicly released by the Minister of DAFF\(^3\). The strategy addresses the need to change practice, with more active industry involvement due to their key role in deployment. It also makes allowance for engagement with a larger number of stakeholders.

The CTHB assisted in drafting SANBI’s *Biosystematics Research Strategy* for South Africa. The increased research capacity in genomics established through the work of the CoE is set to change the way in which biocontrol is understood and deployed.

4. **Leveraging funding**

<table>
<thead>
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<th></th>
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<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<th>2012</th>
<th>2013</th>
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<tr>
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<td>2,120,000</td>
<td>2,247,200</td>
<td>2,471,920</td>
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<td>600,000</td>
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<td>850,000</td>
<td>850,000</td>
<td>1,385,000</td>
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<td>600,000</td>
<td>1,640,000</td>
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<td>1,781,150</td>
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<td>10,506,075</td>
<td>12,240,061</td>
<td>14,251,599</td>
</tr>
</tbody>
</table>

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\(^3\) Interviews confirmed that it is unclear what impact the strategy will have, how the strategy is to be implemented and what budgetary allocations will be made for implementation.
The NRF’s CoE programme has been instrumental in helping the CTHB to leverage funding from other sources; Table 5 and Figure 10 clearly illustrate the CTHB’s ability to do so from a variety of sources: from its host institution, the University of Pretoria; the forestry industry through the TPCP; and indirectly through industry funding instruments such as THRIP.

**Figure 10: Funding trends for the CTHB for the period 2005-2013**

5. **Creating and leading a national critical mass in tree health and pest management research**

The CTHB is contributing to the development of a critical mass of active existing and emerging researchers in this field of significant importance in South Africa. The Centre originally consisted of ten initial core team members from various disciplines at UP, three other South African institutions and one institution abroad, the Centraalbureau voor Schimmelcultures (CBS) in the Netherlands. From 2009, there has been a significant increase, and the CTHB now includes 27 PhD-level researchers - 12 from UP, 1 from abroad and 14 from other SA institutions.

During the period 2005 – 2014, a total of 22 postdoctoral fellows were accepted to work in the Centre. In total during this period, 126 students were supported, of whom 89 were female (71 %) and 41 Black (33 %). By April 2014, CTHB had registered an impressive number of graduate students - 77 Honours (69); 115 MSc (63) and 71 (29) PhD students. Only 8 (4%) had dropped out. Furthermore, in 2005, the introduction of a mentorship programme for 2nd and 3rd-year BSc students by postgraduate CTHB students has resulted in high retention rates. Based on 2013 figures, of the 118 students who were supported through the programme between 2005 and 2013, 72 continued to do an Honours degree, 48 continued to do a Master’s degree, 12 continued to do their PhD degrees (two at Oxford and one at Cambridge) and two students are doing post-doctoral research (one at Oxford and one at Cambridge University in the UK).

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44 Numbers in brackets indicate the number of students who have graduated, as opposed to those registered


46 Eleven dropped out of the programme, 7 were not accepted for a 2nd year because of poor results, 30 had two years of support and four students had three years of support; 11 changed career paths; 18 students are working in industry or research laboratories, five are pursuing teaching careers, two in academia (post-docs) and 49 are continuing with their academic studies. A total of 29 of the mentorship students could not be traced.
The CTHB’s leading role in a field of national importance in South Africa (and regionally and globally) can be seen in the large number of achievements of its Director, staff and collaborators. Among others, the high profile of the work of the CTHB is confirmed by the leadership roles played by its members in important international organisations. For example, the CTHB director is currently President of the International Union of Forest Research Organisations, the largest professional association in the world; he is also past vice-president of the International Mycological Association (IMA) and currently on its executive committee. Prof J Roux is Deputy Coordinator of Division 7 (Forest Health) of IUFRO, and Prof Brenda Wingfield is Secretary-General of the International Society for Plant Pathology (ISPP). CTHB is also extensively represented in industry-driven steering committees, where it plays a role as both research advisor and research supplier.

Research at the CTHB has resulted in an in-depth understanding of the occurrence and distribution of pests and pathogens associated with indigenous trees in South Africa, and movement between native and commercially planted trees. Figure 11 illustrates the impressive increase in the number of articles published and cited since the CTHB was launched.

The role of the NRF CoE Funding Instrument

The NRF CoE funding has been “transformative”, according to the Director. The CoE label is inspirational: “You try to get more excellent as your reputation is at stake. You cannot get into a comfort zone”. The design and management of the funding instrument also contribute: the five service level agreement (SLA) conditions, monitoring and evaluation activities and reporting to a Board contribute to expectations which have to be met and managed, driving performance. It is pressure brought to bear through the SLAs that encouraged the CTHB to establish better linkages with policymakers in order to provide advice and other services. Without this ‘nudge’, their influence on policy and regulations would have been significantly less. Full funding over a five-year period has also allowed the CTHB to plan research priorities and human resource allocations over a longer time horizon, resulting in increasing research excellence. Dependence on industry funding alone with their short-term financial allocations would have made such planning much more difficult.

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47 The document, Activities of the DST-NRF Centre of Excellence in Tree Health Biotechnology (CTHB) 2013 provides an extensive list of all research undertaken by the CTHB.

The NRF funding is also perceived to have been “catalytic”, allowing a broader research focus to be adopted embracing four substantive areas of work, an “integrative”, enabling more work to be done across disciplines, as demonstrated by the journals in which Centre researchers publish. It enabled the Centre to attract and retain top class researchers in the country, and to leverage funding; the Director regards it as unlikely that the host institution would have invested to the same extent in the CTHB without the 50% initially awarded by the NRF. Sufficient funding in the long term also enables the Centre to build from that basis and act immediately if expertise is needed to resolve policy or technical challenges outside the scholarly environment.

The CTHB/TPCP has to maintain genomic sequences of the species on which it publishes and all have to be made available in the public domain. The CTHB/TPCP collaboration also offers a disease and insect pest diagnostic clinic which received over 1,750 samples in 2013. The collection is growing by about 1,500 new isolates per year and is a valuable biological resource for South Africa. Such collections are expensive to maintain, and the NRF CoE funding has made this possible, in turn allowing leveraging of further funding from UP and the NRF.

It also allowed the CTHB to establish balance and harmony between the main stakeholders whose needs have to be addressed - the university which requires the production of quality students and research publications, and the industry which requires short-term thinking and a focus on making profits. This has resulted in closer collaboration with the forestry industry, helping among others to mobilise a R 8 million grant from the Sector Innovation Fund.

Finally, the CoE funding has contributed to the long-term sustainability of the whole research effort. It has been a springboard that gave impetus to FABI, established five years earlier. The CoE funding enabled a critical mass of high quality researchers. According to the Director, “The larger number of people tripled the energy, and motivated others to come in. FABI will survive without me because of the CoE.”

4.4. VALUATION FOR CASE STUDY 4

This valuation analysis focuses on the development by the CTHB of controls for the future management of the Sirex woodwasp. The management protocols were developed after the Sirex woodwasp outbreak of 2005 devastated large parts of the South African pine plantation industry. During that outbreak, the researchers learned that adoption of approaches developed in other countries were not necessarily appropriate for South Africa’s environment. They therefore developed bespoke management protocols for South Africa’s different regional environmental conditions.

The steps followed to create the analysis are presented in Figure 12.

**Figure 12: Valuation steps for Sirex woodwasp analysis**

![Valuation Steps Diagram]

**Beneficiary identification**

With a clear economic focus to the valuation analysis, the key stakeholder impacted by the infestation is the forestry industry. In this analysis, we consider the forestry industry to include growers and processors. There are no small growers of pine (the tree variety at risk from the Sirex woodwasp) in South Africa, only medium scale (anything from 500 hectares upwards) or large scale (hundreds of thousands of hectares). The majority of
production is by large scale growers. As such, we do not consider additional impacts, such as livelihood (social) impacts, as might be applicable for small scale growers of other varieties of non-native species such as eucalyptus.

Impact description

The key impact considered in the analysis is the financial impact of preventing a future outbreak of Sirex woodwasp. The financial impact consists of both avoided foregone income and prevention costs. Figure 13 presents the pathways to economic impact.

![Figure 13: Pathways to economic impact, Sirex woodwasp analysis](image)

Thinning is a practice widely employed by the industry for trees grown for saw wood or poles for the purpose of providing more light, nutrients etc. for the remaining trees to grow. However, it is not common practice when growing trees for pulpwood. The mid-2000s outbreak identified the thinning of pulpwood as a beneficial silviculture prevention approach against Sirex infestation. Biocontrol measures such as impregnation of trees with nematodes (the key weapon to combat Sirex) that neutralise the Sirex woodwasp’s larvae fall under inoculation costs.

Data

This valuation analysis draws on the economic analysis undertaken by Forestry SA in 2007 into the impact of Sirex. The experience of the industry during the outbreak of 2005 provides the basis for the estimates for financial losses (foregone income) for both growers and processors on a per hectare basis. Losses (foregone income) are presented for both the affected areas of 2005 as well as the areas at potential risks (based on planted area and age distribution of the trees).

For this valuation analysis, we only use area and volume figures (hectares and cubic metres) that relate to the potential area (volume of wood) at risk, rather than the affected area (volume of wood) of 2005. While the overall planted area has not changed significantly since 2007 due to regulations controlling planted area, the age and type distribution and of the trees may have altered and the presence of the Sirex woodwasp has also become widespread. It is beyond this valuation analysis to model the changes the age distribution and

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50 Sirex only attacks pine trees over a certain age. Over 10 years for pulpwood, over 15 years for saw wood and over 13 years for poles.


52 For example, while 160,000 hectares were deemed at risk in Northern KwaZulu Natal, Mpumalanga and Limpopo, there was no recorded presence of the Sirex wood wasp and therefore no affected area within the area at risk in 2005
prevalence of the woodwasp might have on the volume of planted area at risk and the subsequent potential financial losses from an outbreak.

To estimate the net benefit of adherence to the management protocol, industry data pertaining to prices (roundwood and processed), recovery rates, monitoring, inoculation and thinning costs (operational and foregone income) are combined with volumetric data.

**Impact considerations**

Critical to the prevention of another outbreak of *Sirex* woodwasp is regular monitoring and environmentally appropriate responses (silviculture, parasitic wasps and nematodes). Interviews with Forestry SA officials suggest that preventative measures employed are not always optimal, relative to the management protocols. The financial and logistical implications involved in changing the management of pulp stands means that thinning (as a preventative measure) has not always been adopted. These factors will have a bearing on the probability of their being another outbreak of *Sirex* and the accompanying financial losses that entails. We therefore run three scenarios to estimate the net benefits of the protocol\(^\text{53}\).

1. Full monitoring and 10% thinning of pulpwood areas = 5% chance of *Sirex* outbreak.
2. Moderate monitoring and 5% thinning of pulpwood areas = approximately 30% chance of *Sirex* outbreak.
3. Low monitoring and 0% thinning of pulpwood areas = estimated 80% chance of *Sirex* outbreak.

Based on outbreak volumetric losses from 2005, it is estimated that an outbreak in areas at risk would, on average, equate to 8% of standing trees. The likely standard deviation about this mean is likely to be high due to varying environmental conditions among different plantations.

In the absence of any reliable figures to assign attribution between CTHB (who created the protocols and continue to provide nematodes and wasp dissection research), Forestry SA (who support adherence to the protocol and via government support pay for monitoring) and industry players (growers and processors - who pay for thinning), we assume that CTHB’s contribution is a percentage and not the total value presented below.

**Net value creation**

Based on the above assumptions and data, the net value creation of implementation of the CTHB’s management protocols for the *Sirex* woodwasp has been calculated. Table 6 presents the avoided losses plus costs and Figure 14 presents the net benefits for the three scenarios considered above.

| Scenario 6: Net benefit figures for levels of adherence to *Sirex* management protocols (R million) |
|-----------------|-----------------|-----------------|-----------------|
| **Scenario**    | **Scenario 1**  | **Scenario 2**  | **Scenario 3**  |
| Avoided income losses – *Sirex* | 1,814           | 1,337           | 382             |
| Prevention costs – operational | 102             | 90              | 77              |
| Opportunity cost - growers | 470             | 234             | 0               |
| Opportunity cost - processors | 2,091           | 1,045           | 0               |

\(^{53}\) The probabilities assigned to each scenario are estimates drawn from conversation with industry officials. The probability for scenario 2 is very difficult to estimate and therefore is likely to have quite a degree of variance.
We have presented net benefits including and excluding the opportunity cost for processors because the industry is not fully integrated (there is a mixture of independent growers and combined grower/processors). The decision – the opportunity cost – of whether to thin or not will therefore be different for these two groups.

Under scenario 1, the significance of the foregone income from thinning outweighs the value of avoiding another Sirex outbreak. It is likely that the reality of adherence to the protocols is probably closest to scenario 2. Under this scenario, there is a significant (approximately R 1 billion) in net benefit accruing the industry as a whole. Even if one takes just 50% of the net benefit accruing to the industry as a result of a partial adherence to the protocol, the value created by the research of the CTHB is approximately R500 million.

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This is because on average an outbreak destroys approximately 8% of trees, as opposed to the 10% lost through thinning under scenario 1.
4.5. CASE STUDY 5: FROM TB RESEARCH TO CLINICAL TRIALS

Note: As noted in the introduction to the previous case study, this one was also not aimed at addressing CBTBR as a whole, as was done in the first two cases. If this was the focus here, the extent of CBTBR activities and impacts would have been similar to those of the two already described. Instead, this case focuses on one Centre activity only in order to demonstrate how a CoE investment can ripple out to achieve an impact in an unexpected, serendipitous manner. In this case it catalysed a successful entrepreneurial public-private partnership with only a small, short-term contribution from the NRF. It also highlights the potential of clinical trial facilities for neglected diseases in Africa, in terms of both research and economic benefits.

Figure 15: Value proposition of the CBTBR project used as case study

Summary of Findings (CoE – CBTBR): From TB Research to Full Clinical Trials

The Centre of Excellence for Biomedical TB Research

The DST/NRF Centre of Excellence for Biomedical TB Research (CBTBR) has been pivotal in leading edge research on tuberculosis in order to enhance understanding of this disease and its epidemiological impact on South Africa. Initiated in September 2004, CBTBR is a tri-nodal entity with laboratories at Stellenbosch University, Wits University and the University of Cape Town. The creation of the CBTBR brought together two well-established tuberculosis (TB) research groups with long histories of support by the Medical Research Council (MRC) and the NHLS, and which previously had very little formal contact, namely the MRC/SU Centre for Molecular and Cellular Biology directed by Prof Paul van Helden, and the MRC/NHLS/Wits Molecular Mycobacteriology Research Unit directed by Prof Valerie Mizrahi.

CBTBR aims to make significant contributions to the development and evaluation of new tools for the diagnosis, treatment and prevention of TB, and to creating significant research capacity in this area. It maintains a balance in how it wants to contribute to the world - at least half of its financial resources are allocated to pure basic research, one third to pure applied research, and around 20% to use-inspired basic research.

It has also been well aligned with national priority areas for development, delivering knowledge and human capital in several national priority areas – in the bioeconomy and innovation (TYIP) and in human health, biotechnology, clinical trials, medical diagnostic and animal health, as well as in contributions to policy, enabling innovation skills, and commercialisation models.
The relevance of the tuberculosis health challenge

South Africa faces many health challenges which threaten to undermine its development. The principal scourge has come from the convergence of two deadly, rampant epidemics in the form of tuberculosis (TB) and HIV/AIDS. Expectations are that science will come up with the next generation of interventions and treatments that will alleviate the morbidity and mortality associated with these diseases, and CBTBR has for a decade spearheaded the national scientific effort in this arena.

Such expertise is essential in a country like South Africa: *Mycobacterium tuberculosis*, the causative agent of TB, is estimated to infect one third of the world’s population and is responsible for the largest number of deaths attributable to a single infectious agent. Tuberculosis has a long and close relationship with humans, causing outbreaks particularly in (often-poverty-stricken) communities of high density. According to the 2012 WHO Global Tuberculosis Report, South Africa are among the countries with the highest number of incident cases of all forms of TB - around 1,000 per 100,000 of the population. New drugs are urgently needed.

The rapid development of new research technologies means that there are an increasing number of options to accelerate the development of new diagnostics and drugs, and to explore new prevention strategies and treatment modalities.

The contributions of CBTBR

This case study does not attempt to highlight the different types of achievements and impacts by CBTBR and thus its value proposition as a Centre of Excellence. Instead, it focuses on only two illustrative cases selected to demonstrate how (i) expertise built up over years through basic research can lead to entrepreneurial initiatives with significant benefits outside the academic environment; and (ii) a relatively small effort aimed at resolving a specific practical challenge has potential for major socioeconomic benefit.

It is clear that these two case studies do not do justice to the achievements and potential impact of this Centre of Excellence. CBTBR reports and publications offer insight into the scope and type of contributions it has made, among many others:

- pioneering the use of molecular methods to characterise strains of *M tuberculosis*, now used throughout Africa to gain insight into the mechanisms driving the epidemic
- pioneered the use of molecular methods to diagnose drug resistance in TB, with the relevant information used throughout the world to develop instruments to diagnose drug resistance
- standards prepared for the use of GeneXpert are being rolled out worldwide
- houses the largest biobank of *M tuberculosis* strains in the southern hemisphere
- developed new tools which are being applied in three major international drug discovery consortia
- provided the biological base for large-scale screening of new candidate antibiotics for TB through a large international consortium
- played a fundamental role in developing the South African Tuberculosis Research and Innovation Initiative (SATRII), a TIA initiative to develop a locally based, virtual TB drug discovery consortium
- evaluated the drug resistance molecular diagnostics kit, which has enabled the NHLS to adopt this strategy to reduce turnaround time for the diagnosis of second line drug resistance in TB; and
- showed that isolates resistant to ofloxacin may still be susceptible to moxifloxacin, resulting in a recommendation currently considered worldwide that the critical concentration of moxifloxacin be raised to 2ug/ml.

Establishing a premier TB clinical trial facility in the Western Cape

The CBTBR engagement with clinical trials had its genesis in relationships established years earlier, in the 1990s. Prof Paul van Helden, the visionary and acclaimed current Director of CBTBR, started a collaboration with paediatrician...
and later A rated researcher in childhood TB, Prof Peter Donald. They were motivated by their mutual interest in useful, high quality research on TB to address the dire situation caused by the disease among South Africa’s poor communities. They continued their collaboration in the Centre after its establishment in 2004.

Both regarded early on a clinical trial facility in the Western Cape with its high incidence of TB as essential. It was, however, difficult to establish without private sector funding, which was not available at the time. The CoE funding provided an opening: it was not project-bound, and basic laboratory facilities could be set up to support small clinical trial activities that could complement the TB research focus of the CoE. A few minor trials were conducted on an ad hoc basis. It could soon be placed on a more professional footing when, in 2005, they were approached by Tibotec Therapeutics\(^56\), a subsidiary of Johnson and Johnson, to evaluate a potential new drug.

With the advice of Prof Donald, and under supervision of Prof Andreas Diacon\(^57\), a Swiss pulmonologist at the University of Stellenbosch recruited to lead the effort, the work was done in 2005, making use of the infrastructure established with the NRF CBTBR funding.

It became clear soon after this first trial that a university does not provide the required environment for clinical trial work; Tygerberg Hospital, the academic hospital of the University, did not have sufficient space. TB is a highly contagious disease that requires appropriate facilities for patient care, with highly intensive work and quick decision-making and delivery demanded by the industry. As a result, and with funding generated from the first full-fledged clinical trial facilitated by CBTBR, Task Applied Science (TASK) was spun off under the leadership of Prof Diacon, in collaboration with Stellenbosch University and the CBTBR as a separate company aimed at accelerating the development and evaluation of novel TB drugs.

TASK is administratively located at the Karl Bremer Hospital in Cape Town, with as its central facility a research centre in Bellville and peripheral sites in several local communities (Mfuleni, Delft and Brooklyn). It has become a premier clinical trial site in the world for the evaluation of new candidate TB antibiotics and combination therapies. It has its own management structure and hospital facilities with beds for 25 patients, who are recruited in partnership with the University of Cape Town. TASK currently employs 80 persons; of these, one third work inside and use the CBTBR facilities. Until mid-2014, the CBTBR supplied a full time permanent staff member to run the BL3 lab facility used by Task.

TB is not considered attractive in the pharmaceutical industry’s search for blockbuster drugs, but there has been a stronger focus on TB in recent years. New drug development initiatives have become more frequent, and to date TASK has successfully concluded between 20 and 30 trials. All promising new candidates in the last decade have been trialled at the site, and although full commercial release of new drugs takes many years, it is clear from the results that some of these will soon become available for use globally.

Two drugs trialled for the treatment of multi-drug resistant pulmonary TB with CBTBR and TASK Applied Science involvement have been provisionally approved: Delamanid (USAN, codenamed OPC-67683) was recommended in 2012 by the European Medicines Agency for conditional marketing and use by patients without other treatment options because of resistance or tolerability. It was the first new drug submitted for approval to a stringent regulatory authority in 40 years. In July 2012, Janssen Therapeutics announced its filing of a new drug application for bedaquiline (TMC207) with the US FDA. Bedaquiline received conditional approved by the US FDA. Interim guidance for its use has also been issued by the WHO. It is seen as a potential cornerstone of novel TB regimens currently in development, with potential for significant impact on TB disease through inclusion in a first-line regimen and/or as a component of a simpler, more affordable drug-resistant TB regimen.

This example of a working industry-academia partnership has been mutually beneficial in spite of different incentives and approaches. Complementary objectives drive the collaboration. CBTBR is trying to find new candidate compounds, among others through participation in a project aimed at screening 500,000 compounds to find promising candidates for the treatment of TB, and continues to conduct related scientific work in close partnership with TASK. Both continue to publish the work in which they are jointly engaged. TASK has sponsored seven Masters and PhD students, fully fund a complement of staff in CBTBR, and participate in at least 10 joint academic papers.

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\(^56\) Since 2011 Janssen Therapeutics
\(^57\) Now Principal Investigator for Clinical Trials at CBTBR
published per year. CBTBR also had to obtain certification from the South African National Accreditation System (SANAS) to comply with ISO requirements for laboratory facilities used in conjunction with TASK paid staff.

TASK has to be entrepreneurial. Although there has been an increase in TB related trials, and there are very large numbers of potential patients in Cape Town, all infrastructure, staff and activities of TASK are funded through private contracts from the pharmaceutical industry and other relevant organisations. The DST agreement with SARS around a tax incentive for R&D is seen as having been very beneficial in enabling the facility to operate successfully. Yet there is always risk involved in sustaining this type of business, even though TASK and CBTBR are collaborating with all prominent international bodies involved in TB R&D, such as the Global Fund to Fight AIDS, Tuberculosis and Malaria (The Global Fund or GFATM), the European Union, BMGF and the National Institutes of Health in the US. It is highly dependent on developments in the pharmaceutical and related industries, and several commercial laboratories in South Africa such as PathCare have started to deliver similar services. Partly in response, TASK intends building on its expertise, infrastructure and reputation to expand its horizons.

The role of the CoE funding instrument support

“There would have been none of this without NRF CoE funding.”

Prof Andreas Diacon, TASK CEO

It is the freedom, predictability and long-term (at least 10 years, now 15) nature of the CoE funding, coupled to the interaction between three committed experts in or linked to the CBTBR – one a renowned specialist in microbiology and molecular biology, leading a Centre of Excellence engaged in TB research, and who desired to span the basic to applied continuum; one a paediatrician, later an A rated researcher in the field of childhood TB, inspired to contribute to research on TB in adults; and a pulmonologist motivated to use academic excellence to deliver solutions in collaboration with the private sector – that triggered the evolution of a clinical trial site from a small university-based initiative to a full-fledged international clinical trial facility.

NRF CoE funding has been a trigger and catalyst in this initiative. Through the facilities it helped to establish, the first clinical trial in the heartland of TB infection in the country was made possible. This attracted the attention of others. This small initial contribution triggered a development trajectory from a purely academic initiative to a clinical trial site that has received certification and support from the US FDA and other key bodies in the world, and that is perceived by some to be a model for private sector/academia partnerships. It is doubtful that other sources would have been readily available at the time for the initial facility. It had to be established and get a chance to prove itself. This was made possible by the NRF CoE funding.

From a broader perspective, the CoE funding stimulated a focus on application of the research beyond the academic sector. Prior to the CoE allocation CBTBR work had little or no application. Although the researchers had recognition for their basic research, it was not taken up or applied either nationally or on a wider scale. In the experience of the director, the CoE funding stimulated and helped to define the relationship between the scientists and clinical specialists in CBTBR. This led to greater integration and richer research directions and results. CBTBR now has a continuum of research, from pure basic to use-inspired to pure applied research, yielding results and a variety of benefits.

4.6. VALUATION FOR CASE STUDY 5

The approach employed to value the creation of the TB clinical trials facility is presented in Figure 16.

Figure 16: Valuation steps for the TASK Applied Science Facility
Beneficiary identification

Beginning with the actors most closely connected with the facility and then working outwards, the beneficiaries for this valuation include the employees of the facility, participants of the trials, the state and the wider economy.

Impact description

This valuation analysis focusses on the direct and indirect economic values of TASK Applied Science facility as listed in the previous section. The areas of potential value are described in Table 7.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Description</th>
<th>Type of value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional employment</td>
<td>The clinic has created nearly 100 new jobs in the sector.</td>
<td>Direct economic value</td>
</tr>
<tr>
<td>Health cost savings</td>
<td>Approximately 100 trial participants per annum benefit from avoided medical bills.</td>
<td>Direct economic value</td>
</tr>
<tr>
<td>Foreign exchange earnings</td>
<td>All income earned by the facility is from organisations based overseas</td>
<td>Direct economic value</td>
</tr>
<tr>
<td>Additional taxation</td>
<td>While TASK benefits from R&amp;D government tax relief schemes reducing its organisational tax bill, it still contributes via income tax and VAT.</td>
<td>Indirect economic value</td>
</tr>
<tr>
<td>Multiplier economic impacts</td>
<td>The clinic will add value to the South African economy through demand for laboratory infrastructure, such as building rental and equipment.</td>
<td>Indirect economic value</td>
</tr>
</tbody>
</table>

It is important to recognise additional economic value from health benefits of research which have not been included in this work but could be examined in more depth in a follow up study. The return on investment from TB research has the potential to be very high. The clinic has contributed to the discovery of 2 classes of TB drugs that have been approved for use already. TB research could, for example, benefit the South African economy and government could through:

- Improved (more effective, cheaper) treatment for TB leading to direct health cost reduction (current treatment costs for TB range from $26,936 to $257 per person, depending on the type of TB)\(^58\)
- Indirect cost reduction from increased productivity and reduced morbidity
- Job creation in the chemical industry, pharmaceutical industry, and the healthcare industry to manufacture and distribution new treatments.
- Revenue from new treatment products.

Data

Data for this case study valuation analysis was limited. TASK is a commercial operation and as such was not in a position to release significant amounts of financial data to the researchers. As such certain assumptions had to be made in the valuation calculations. For example, in the absence of turnover figures for the facility (to help then calculate multiplier effects), we needed to estimate the facility’s profit levels. While it is recognised that development of TB treatments is a high risk investment and may not always yield results, research suggests that managers of public health programmes require a minimum 15% savings over the course of the programme. We therefore assume here a conservative 15% multiplier on the value of the investment\(^59\), the investment being the facilities’ capital and recurrent costs\(^60\).

\(^58\) http://www.ncbi.nlm.nih.gov/pubmed/23349933
\(^59\) http://www.health-policy-systems.com/content/11/1/10#B6
\(^60\) We assumed a 25%:75% split of costs between capital and labour.
We draw from input-output tables for estimated GDP multiplier created by the facility, selecting the classification: Medical, dental and veterinary services\(^6^1\). We draw on national South African research on costs to TB treatment to calculate potential savings from participation in clinical trials\(^6^2\).

**Impact considerations**

All funding attracted by the clinic itself represents direct added value because the TASK facility is 100% funded by foreign investment. It is unlikely that the clinic is displacing other research facilities that would otherwise have attracted investment due to TASK’s unique specific high-level human capital resources and knowledge (though this could be explored in further research).

In the absence of detailed financial and non-financial contributions of the different actors behind the eventual creation of TASK, we are hesitant to assign an attribution percentage to NRF funding. As such, we present the value creation figures as total values in the table below, not attributing a percentage to NRF funding.

**Net value creation**

Based on the above assumptions and data, Table 8 presents the estimated value created through the work of the research team in terms of direct industry revenue, additional jobs (full-time equivalent) created plus indirect (multiplier) revenue for the periods 2011-2014 and projections through to 2018.

<table>
<thead>
<tr>
<th>Total impact</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional employment (headcount)</td>
<td>99</td>
</tr>
<tr>
<td>Estimated health cost savings for participants (R 000’s – 2014 prices)</td>
<td>193</td>
</tr>
<tr>
<td>Estimated annual foreign exchange earnings R million)</td>
<td>26</td>
</tr>
<tr>
<td>Additional annual taxation (R million)</td>
<td>2</td>
</tr>
<tr>
<td>Indirect annual (multiplier) impacts (R million)</td>
<td>13.4</td>
</tr>
</tbody>
</table>

To put the facility’s numbers in perspective, its annual turnover is estimated to be over twice the annual investment by the South African government in TB research for 2013.

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\(^6^2\) http://www.resource-allocation.com/content/4/1/11
5. VALUING CASES FROM NEP/NNEP AND SARCHI

5.1. CASE STUDY 6: EQUIPPED TO LEAD - CELL BIOLOGY, LIPID CHARACTERISATION AND OTHER APPLICATIONS

Investment in state-of-the-art research equipment

The University of the Free State (UFS) has, since 2005, taken advantage of both the NRF’s National Equipment Programme (NEP) and the National Nanotechnology Equipment Programme (NNEP), to acquire state-of-the-art research equipment. All these conditions were met by the UFS Departments of Physics and Chemistry when, in 2009, the university set out to create a state-of-the-art surface characterisation laboratory with the best measuring capabilities in Africa. The new Chemistry facility was commissioned with investments in four new instruments, two of which were funded through the NRF\(^6\) – 1). A Setaram Differential Scanning Calorimeter (DSC) capable of measuring gas adsorption energies; 2) An ASAP 2020 Accelerated Surface Area and Porosimetry System (Micromeritics) which could measure chemi- and physi-sorption coverage; 3) an XPS/ESCA for surface analysis and 4) a NanoSAM. The XPS and NanoSAM were partially NRF-funded. 2012 saw a further NRF investment in an RC1 Reactor and in 2013 the UFS invested R26 million in a new Physics laboratory.

- **ESCA**: The Physical Electronics PHI 5000 XPS/ESCA -X-ray Photoelectron Spectroscope/Electron Spectroscopy for Chemical Analysis (ESCA) is a multi-technique surface analysis instrument based on scanning x-ray microprobe technology. The XPS is the most widely used surface analysis technique in advanced labs because of its relative simplicity in use and data interpretation. The XPS apparatus, together with the nanoSAM described in the next paragraph, were acquired in 2008 as a joint application by Prof Jannie Swarts, Department of Chemistry (NEP) and Prof Hendrik Swart, Department of Physics (NNEP), at a total cost of R23 million. The XPS was purchased for R8.2 million of this total. The NEP and NNEP provided equal contributions of R6 million each with the remainder provided by industry (R3 million from SASOL) and R8 million by the University. The equipment is operated jointly by staff from the Departments of Physics and Chemistry; advanced doctoral students assist in making routine measurements. Due to the complexity of operating the equipment, only trained operators are allowed direct access, but the equipment is used by numerous institutions – industry (Mintek, Sasol, Mittal Steel), research institutions (CSIR, iTHEMBA LABS) and universities (UNISA, Witwatersrand, Rhodes, NMMU, Pretoria, departments at UFS). The existing equipment will need replacement within the next five to ten years.

- **NanoSAM**: The Nano Scanning Auger Microprobe (NanoSAM) was acquired in 2008, together with the XPS described above, with its contribution to the total cost being R12.85 million. R6 million was contributed by the NRF and R6,85 million by the UFS. This state-of-the-art performance Auger Electron Spectroscopy (AES) system provides elemental and chemical state information of sample surfaces, thin films and interfaces, and allows for the analysis of rough sample surfaces, multi-layered structures, nanoparticles and fractured surfaces. Recently, through ground-breaking research at the UFS, biological samples can now be analysed using a new technique called Auger architectomics, which is described in more detail later in this case study. The NanoSAM is used by numerous institutions - industry (Mintek, Sasol, Ferrol), research institutions (CSIR, National Laser Centre (NLC)) and universities (Witwatersrand School of Pathology; Pretoria (Chemistry); other departments at UFS – Physics, Geology, Microbiology).

- **RC1 Reactor**: The Mettler Toledo RC1su MP10 HC RTCalTM was acquired in 2012 at a cost of R3.43 million of which the NRF contributed R1.95 million, the UFS R1.18 million and Sasol R300k. It is currently housed in the

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6\(^1\) A Mettler Toledo thermal analysis system was also purchased in 2005 at a cost of R2.4 million, with a R1.8 million contribution from the NRF and R600k from the UFS. The equipment, originally requested by Prof Jannie Swarts, is now housed in the Department of Chemistry but is made available to other university departments, industry and research institutions. The equipment is used largely for the training of students and to generate high quality research results; further details have not been included in this case study.
Department of Chemistry at UFS. This medium pressure reactor has the ability to carry out real time calorimetric measurements while a reaction is in progress. Its capabilities include the measurement of thermodynamic reaction enthalpies under pressure of up to 10 bar. It also has a high-pressure Infrared reaction detection system. The latter allows researchers to study complete reactions and side-reactions. Two lecturers and two PhD students from the Department of Chemistry were trained to operate the equipment. By 2013, it had been used by the Department of Chemistry and SASOL, but no research results were as yet available as the equipment was only commissioned in 2013. It is estimated that this equipment will need replacement within 10-12 years.

The Thermal Analysing System and the RC1 reactor are housed in the Department of Chemistry, whereas the XPS and the NanoSAM are housed within the Department of Physics under the leadership of Prof Hendrik Swart, the nanotechnology expert at UFS. The facility at the UFS, with its combined range of state-of-the-art equipment, is said to be the only one of its kind in Africa. All the instruments are available for use by other research institutions and industry. There is no charge other than immediate running costs for collaborative research, but non-collaborating academic researchers are charged R1,000 per hour and the industry R 2,500 per hour. This income partially covers the high maintenance costs.

The strategic importance of the equipment to the University and to the industry has been proven through:

i. the financial contribution by SASOL, which saw the benefit in having a national facility where future company employees could be trained; and

ii. the R26 million the UFS has invested in building a new facility which now houses the Physics Department on the main campus in Bloemfontein, and the R60 million refurbishment of the Chemistry Department, motivated on the basis that the facility with the combined NRF-funded equipment would produce about 40 research publications. In reality, more than 100 publications have already been produced.

This case study will not attempt to cover all the research which can be directly attributed to the use of the NRF-funded equipment. Instead it will focus on areas where

i. the development of a new and innovative breakthrough technology, Auger architectomics, has placed South Africa at the forefront of yeast research and possibly future medical breakthroughs in cancer research, and

ii. the equipment has contributed directly to strengthening South African research capacity for industry.

An African breakthrough: the development of Auger architectomics using NanoSAM

In 2010, Prof Lodewyk Kock and his team at the UFS Department of Microbial, Biochemical and Food Biotechnology discovered a new technique, Auger architectomics, which allows researchers to slice open the cells of living organisms. This was adapted from NanoSAM, a technique generally used to study the surface structures of metal and inanimate materials such as semi-conductors. The new technique uses argon gas to open the cells and, in combination with scanning electron microscopy (SEM), creates a three-dimensional view of cells which allows researchers to examine the internal functioning of living cells. The development of this new technique has placed Prof Kock and his team as pioneers in biosensor architectomics research.

The original research was carried out on yeast cells and has resulted in a paradigm shift for the brewing and baking industries by proving that CO₂ gas bubbles are formed within yeast cells. This has significant implications for industries using fermentation technology, and has already resulted in interest from SABMiller. At this stage, the UFS findings are still seen as “blue-sky” research with no direct commercialisable outcomes, but future research directions could yield major breakthroughs in this and other fields. For example, further research has revealed that the mitochondrion is regarded as a target to reveal compounds that may be used to combat various diseases. Yeast sensor research carried out by the UFS team has shown that chloroquine, a standard malarial treatment, is a widespread and potent pro-mitochondrial fertility drug in fungi. This may contribute to the spread of malaria by stimulating the sexual stage of Plasmodium. Yeast sensor bio-assays could also be used for tracking various anti-mitochondrial drugs that may be toxic to humans and that are directed, amongst others, against fungal diseases and cancer. Such bio-assays could fast track studies aimed at discovering new drugs as well as their mechanisms.
Since 2012, the technique has also been applied to human tissue. This application has opened up new opportunities for international research collaboration, e.g. with the US-based Mayo Clinic (Tumour Angiogenesis and Vascular Biology Research Centre) to examine the impact of chemotherapeutic drugs on cancer, and to provide an accurate assessment of how effective treatment regimes are in targeting cancer cells. Researchers from the clinic visited South Africa in July 2014 and pancreatic cancer cell samples have been provided for further analysis. Potential patenting opportunities are being pursued and the collaboration has resulted in additional research funding for the UFS from this collaboration.

The international recognition accorded to Prof Kock and his team has resulted in the research being selected as a Key Scientific Article from 20,000 articles by Global Medical Discovery in 2012. The research was also promoted on the front page of the leading yeast journal, FEMS Yeast Research for a year in 2013. Since 2011, Prof Kock has presented ten keynote/opening addresses at international conferences and was awarded the 2013 IAAM Medal at the Advanced Materials World Congress in Turkey, based on this ground-breaking research.

The increased recognition has resulted in more postdoctoral research requests and at July 2014, ten applications were under consideration, as compared to only two PhDs and two postdoctoral fellows in 2012. According to Prof Kock, this research breakthrough would not have been possible without the NRF funding for the NanoSAM.

Supporting the pig Industry in South Africa: improving the quality of back fat in pigs through CLA dietary supplementation

The Departments of Chemistry and Food Science (UFS) carried out collaborative research to examine the effect of dietary Conjugated Linoleic Acid (CLA) supplementation on the lipid structure of pigs. This R400k study was requested by the Red Meat Industry Trust and was published in 2014. The DSC (Differential Scanning Calorimetry) results show that this type of supplementation has a number of positive effects. Firstly, there is an increase in CLA levels and saturated fatty acids, both of which have positive health effects when pork is eaten. The melting properties of the back fat are changed resulting in harder back fat, fewer cutting losses when the meat is processed, and a longer shelf life. The increased CLA also has anti-carcinogenic properties.

At this stage, the South African meat processing industry has not implemented CLA supplementation, largely because it is under current circumstances uneconomical to do so, and sufficient incentives are not (yet) in place. It is possible that this will be introduced in South Africa within three to four years, following the European trend already underway.

The DSC analysis could not have been done without the NRF-funded equipment. The research, with the critical contribution of the NRF funded equipment, is said to have resulted in ‘putting the UFS on the map’, with publications in high-quality research journals. This type of analysis can also be applied to other oils, providing for future post-doctoral research and increased usage of the equipment. The additional funding generated through contract research and publications can be used to maintain the equipment.

Growing South Africa’s research capacity in academia and the industry

The NRF-funded equipment has increased the research capacity of the UFS in a number of ways. Firstly, the equipment has allowed for higher quality research to be conducted, resulting in increased research output and more publications being accepted in higher quality journals. Prior to the acquisition of the XPS/ESCA, eight publications were produced per year (2007 and 2008). This increased to 19 in 2009 and to 26 in 2010, while 2012 saw the publication of 22 articles, one book chapter and nine peer-reviewed papers delivered at conference proceedings. Another 16 articles where published in 2013. In 2012 alone, research using the NanoSAM resulted in 41 peer reviewed publications, four book chapters and one paper in conference proceedings.
For the XPS/ESCA, an analysis of graduates from 2010–2013 indicates an increase in the number of doctoral and post-doctoral students, particularly of non-South Africans. Around 80% of post-doctoral students are non-South Africans from the Netherlands (University of Amsterdam), Germany, India, England, France and Poland (Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Poland) as well as African students from Kenya, Tanzania, Sudan, Cameroon and Malawi. This may be as a result of both the increased reputation of the UFS and growing research collaborations. There is also a growing number of South African students who have since 2010 passed through various levels of graduate studies at the University and who have recently entered doctoral and post-doctoral studies – an indication of the importance of developing national expertise in advanced technology.

Figure 17: Overview of Graduates using the XPS/ESCA, UFS (2010-2013)

Recently Dr Daniel Freiner, a research scientist from Mettler Toledo AG, the company which built the RC1 reactor, spent three months at the Department of Chemistry as a visiting scientist, giving credence to the enhanced international standing of UFS.

South Africa’s industry, and in particular Sasol, is benefitting from the combined research equipment facility in that South African students can be trained in the country, whereas previously there was no national capacity in the use of the equipment. Sasol provides bursaries for graduate studies and uses the UFS to train their research staff and technicians on these equipment. Generally, Master’s’ students are introduced to research that culminates in two high quality international publications whereas research PhD students would be trained in the use of the equipment for advanced technologies in oils and the development of catalysts using also 3D crystallographic structures. Previously students who would require these techniques in their training would have to be sent to the Technical University Eindhoven (Netherlands) or Scotland for their PhD training. The excellence of the UFS facility has thus resulted in significant cost savings. This is also the reason given for Sasol’s financial contribution of R3 million towards the acquisition of the XPS/ESCA. Denel and Mintek also make use of the facilities.

The UFS Department of Chemistry has been collaborating with Sasol since the 1980s, largely through the provision of training of researchers in graduate programmes. The intensely competitive environment in which companies such as Sasol and Mintek operate precludes the UFS from publishing much of their research, which does raise a conflict of interest for students whose degrees depend on publications. There is however an agreement with Sasol that the UFS may publish or patent results after four years - if Sasol judges the research results as not placing company secrets in the public domain.

At present there is no shared IP with the UFS since all research and development is done in-house at Sasol. Sasol prescribes the types of problems on which students have to work during their graduate studies, but all research
breakthroughs are carried out by Sasol’s in-house researchers. However, the equipment facility helps the University to produce graduates who can enter companies with experience in working with advanced technologies. This is seen as the most significant contribution it can make towards national priorities; more robust national research competencies mean that international expertise does not always need to be bought and brought into the country.

**Use of the NRF-NEP/NNEP equipment for other applications**

One of the significant outcomes from the combined facility has been the increase in collaborative multidisciplinary and interdisciplinary research. Some examples illustrate the wide range of initiatives done in collaboration with the facility:

- **Profs Arno Hugo and Gary Osthoff** has been involved in a number of studies to characterise the fats (and particularly milk fats) of various wild animals using DSC. This has been carried out in collaboration with Prof Jannie Swarts. More work will be done in future on primates. He has also been involved in research to find the cause for crocodile deaths in Limpopo, achieved through lipid analysis to test for possible dietary causes or the presence of pesticides. 64

- The facility has been used to provide research support for medical research. For example, the UFS’s medical faculty made use of the equipment to test the thermal properties of pig tissue used in the making of heart valves. The XPS equipment has also been used to test materials for use in dental implants.

- Although companies such as Denel, Mintek and Sasol make use of the equipment, they do not make available details about the types of samples. Unidentified samples are provided so that the analyses are carried out without knowledge of what is being measured.

- **Prof Marian Tredoux** from the Department of Geology at UFS has been using the equipment for analysis of meteorites and has also produced research for the mining sector.

**5.2. THE VALUE PROPOSITION FOR CASE STUDY 6**

Only a few specific research areas were discussed in this case study. However, this should not undermine the clear evidence of significant contributions made by the UFS Physics-Chemistry facility to expose the South African research community to state-of-the-art equipment in surface characterisation and more recently, in the nanotechnology of physical and living materials. This presents a unique combination for South Africa in terms of the scope and breadth of multidisciplinary research which can be undertaken with and between physics, chemistry, microbiology, geology and medicine.

The combined facility has succeeded in raising the research throughput of the University and has played a very significant role in putting it on the map internationally, to the point where up to 80% of its post-doctoral fellows are from outside the country. There has also been a very significant increase in publications in quality research journals, helping to raise the profile of South African science internationally.

The significant investment made by the University to create this facility has, together with the investments from the NEP/NNEP programme, created a draw-card for South African students. This gives it greater value than if it had been merely a research facility. In addition, evidence of the importance that the industry places on having such a facility available in the country is provided by their financial support, the on-going education of their future specialists through the University (saving money in the process) and the use of the equipment to train its staff.

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64 Personal communication, Prof Hendrik Swart
The challenge remains in retaining and increasing this competitive edge, with valid concerns about the on-going cost of maintenance and upgrading of the equipment.

**Value Proposition of the High Field NMR Facility at UCT**

### Outputs & Dissemination

- **NRF Contributions**
  - 140 peer reviewed articles (NMR)
  - 5 book chapters (NMR)
  - 18 PhD graduates (NMR)
  - 33 Master’s graduates (NMR)
  - 85 Honours graduates (NMR)
  - 500 students/11 staff trained (NMR)
  - Structural & characterisation studies for MenAfriVac meningitis vaccine (NMR)
  - WHO regulations/licensing regime
  - First malaria clinical trial candidate from Africa, in record time (NMR/SARCHi)
  - 50 new specialist staff by 2015

### Strategic & Socio-Economic Benefits / Impacts

1. Enhanced SA reputation in priority areas
2. New knowledge for competitive knowledge economy
3. Strong multi-disciplinary research group across value chain in priority area
4. Strong international industry/academia partnerships
5. World class infrastructure
6. Inspired students, esp. of designated groups

### Contributions to Direct Monetisable Benefits & Impacts

1. High level graduates - incl. many from designated groups - with specialised technical skills delivered into NST
2. Significant efficiency gains in meningitis vaccination campaigns
3. Significantly lower cost of meningitis vaccinations
4. Jobs created in research facilities
5. More than R100 million leveraged over 4 years
6. Potential for release of drug for multi-drug resistant malaria
7. Potential for revenue & attraction
8. Potential for savings in treatment costs

### Contributions to Wider Societal Impacts

1. Technical & specialist leadership in science enhanced
2. 20,000 African lives saved/year from meningitis deaths
3. Lowered costs of disease & death in Africa
4. Potential for eradication of malaria
5. Potential for nearly 1 million lives saved/year from malaria deaths

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### 5.3. CASE STUDY 7: AFRICAN FIRSTS - NMR, VACCINES AND MALARIA DRUGS FOR AFRICA

**Nuclear Magnetic Resonance Spectrometry at UCT**

Today, nuclear magnetic resonance spectroscopy (NMR) is a basic technique used in almost any active Chemistry department across the world. Modern NMR spectroscopy is ideally suited to the qualitative and quantitative analysis of complex biological mixtures without separating them into constituent parts. It is a crucial tool for work in emergent fields of enquiry such as systems biology, genomics and proteomics. High-field NMR analysis does not require separation or ionisation of samples or mixtures for detection. It is thus a powerful non-destructive tool to complement other sophisticated analytical techniques used in chemistry and related fields of research. The NRF has for many years provided support to South African universities to acquire the essential yet expensive
spectrometers needed to conduct NMR experiments. Its total investment in four such instruments only between 2009 and 2013 was R28.78 million.

In 2007, an NEP grant for a new Bruker 400MHz NMR spectrometer was allocated to Prof Graham Jackson, Director of the NMR facility at the University of Cape Town, as an institutional facility. The NEP contributed a total of R 2.5m, supplemented by a University contribution of R 0.9m for the instrument and just over R0.4 million for the facility in which it was housed.\(^6\) The spectrometer was fully dedicated to research and use by postgraduate students; as a consequence, an older 400 MHz NMR spectrometer could be freed for more general student training.\(^6\)

The Department of Chemistry at UCT manages the NMR Unit. In addition to the operator, Mr Pete Roberts, the NMR unit has two academic consultants, Profs Graham Jackson and Neil Ravenscroft, with extensive experience in high-field NMR. The Unit is run as an independent facility, with samples submitted and run according to a queue. Charges to the users to cover operating and maintenance costs, and funding for repairs are covered by the University under a budget of around R 125,000 per year. The spectrometer is constantly busy, and handles approximately 9,000 samples each year.

In four years, between 2008 and 2012\(^6\), a total of 140 peer reviewed articles were published with some reference to the use of the 400 MHz NMR spectrometer, as well as three book chapters. Eighteen graduated PhDs, 32 Master’s and 85 Honours students made substantive use of the facility. Around 100 students were trained in the use of NMR, and at least 11 staff members.

There have thus been many users for whose work such instrumentation is crucial. Within the scope of this case study we have not attempted to trace all contributions to knowledge generation and application that would have been impossible, or much more challenging, without this on-site spectrometer. Instead, we have focused on two impacts outside the academic environment that emerged as likely the most significant to date to flow from the use of this spectrometer.

The two cases discussed here are examples of the role that NMR has played in supporting major discoveries linked to an important national priority area. In 2002 the NRDS identified the creation of vaccine development and biopharmaceutical industries as priorities in an effort to address the devastation caused by communicable diseases; this was later again reflected in the Bioeconomy Grand Challenge.

**In support of a meningitis vaccine**

Prof Neil Ravenscroft is the head of the Bioanalytical and Vaccine Research Unit (BioVac) of the Department of Chemistry at UCT, and a pioneer in using high-field NMR in the analysis of vaccines. In 2004 he was approached to assist in the work of the Meningitis Vaccine Project (MVP), a consortium established in 2001 with funding from the Bill and Melinda Gates Foundation through a partnership between the World Health Organisation and PATH (Programme for Appropriate Technology in Health), a non-profit global health group. The consortium set out to eliminate meningitis from sub-Saharan Africa by developing a conjugate meningococcal vaccine against epidemic meningitis (group A). This meant designing, or redesigning, vaccines specifically for the needs of the developing world, rather than unquestioningly embracing the complex vaccines invented for the west.

\(^6\) Contract income amounted to just under R 0.4 million, while operating costs were recovered through the full cost recovery model within which the University operates.

\(^6\) In a 2010 report, in other words in a 1-2 year period, it was noted that 33 students had already been trained on the older instrument.

\(^6\) Data for 2011 were not available
Meningitis is a disease that infects the meninges, the membranes surrounding the brain and spinal cord. The infamous ‘meningitis belt’ runs across West and East Africa - a strip of 25 countries that stretches from Senegal in the west to Ethiopia and Eritrea in the east. Some 450 million people live in this belt, and about 200,000 suffer from meningitis every year during the dry season when wind spreads the bacterial spores. It account for the bulk of the world’s meningitis epidemics, which sweep the region every seven to 14 years. Mortality is about 10-15 per cent, and morbidity is very high. Of those who survive infections, thousands are left deaf, retarded or disabled. The first vaccine against meningitis had failed to contain the disease, and had several disadvantages that made it largely ineffective as a vaccine for the difficult conditions found in sub-Saharan Africa.

A breakthrough came when MVP developed MenAfriVac, a new vaccine that stimulates the body’s immune system to produce antibodies against the polysaccharide of the meningitis bacterium. The vaccine, manufactured by the Serum Institute of India, is effective for group A Neisseria meningitidis, the bacterium responsible for nearly 90 per cent of all meningococcal infections in the meningitis belt. It has many advantages. It can be used with children as young as one, needs only one shot, and costs only around US$0.50 (around R5) a dose. This is far less than the price of the conjugate vaccines designed for the meningitis strains that occasionally break out in the developed world. At the time the latter cost about $5 dollars and was not effective in curbing the disease, as it provided only short-term immunity and hence could be given only during an epidemic. This means that the cost of a vaccination campaign is within reach of many African governments who normally would not be in a position to launch such an effort with the expensive vaccines available for use in developed countries.

Prof Ravenscroft provided advice to the MVP during the search for this vaccine, and with his team used NMR as one of his main analytical techniques to conduct structural investigations and characterisation studies in support of their work. Physiochemical studies, in particular NMR characterisation of the polysaccharide lots, intermediates and vaccine were done to demonstrate maintenance of the structural integrity of the carbohydrate antigen between batches, and later during production of the conjugate vaccine.

In December 2010 a mass vaccination was launched targeting 33 million people aged 1-29 years; millions more have been vaccinated since. In 2013 MenAfriVac made another breakthrough. In Chad, the MenAfriVac vaccination campaign could not reach all children, because of limited cold chain capacity. There were outbreaks of lethal meningitis A in those communities that missed out. The Indian regulatory authorities gave approval for the use of the vaccine outside cold conditions, and it was successfully tested at ambient conditions during a large-scale vaccine campaign in the Republic of Benin. In the first-ever use in a developing country, the vaccine remained stable outside the cold chain at temperatures of up to 40 degree C for up to four days (It should normally be kept at 2-8 degree C).

This means that the vaccine does not have to be transported in refrigerators on trucks or ice boxes carried by volunteers on foot across rivers and mountains to children who live in the intense heat of Chad or Mali. The improvement greatly increased the effectiveness and efficiency of the vaccination campaign: coverage was increased in a few areas where access was a problem and electricity was unreliable; the health workers stayed in the villages for three consecutive days before returning for a refill and could hence cover more ground; the logistic burden as well as wastage was reduced; and they could vaccinate more people. It was also cheaper. A study published in the WHO Bulletin showed that it reduced the cost of campaigns in countries like Chad by up to 50%, increasing the affordability by under-resourced African governments.

This was the first time that a vaccine intended for use in Africa had been tested and submitted to regulatory review and approved by the WHO for this type of use. In December 2013, the WHO launched mass vaccination campaigns in Burkina Faso, Mali and Niger. It aims to vaccinate 300 million people by 2015, ridding the region of the disease.

MenAfriVac could be the first of many vaccines to work without cold storage, for diseases such as yellow fever, hepatitis B, rotavirus and pneumococcal disease. More than 150 million people in the African meningitis belt have
been vaccinated with MenAfriVac since it was launched in 2010. No case of meningitis A has been identified in those vaccinated. As the disease is only transmitted between people, MenAfriVac has the potential to wipe out meningitis completely.

Over the years, many people and organisations have had a hand in the success of this breakthrough vaccine. Its impact has rippled out far beyond the work done in the academic laboratory, including the laboratory of the team at UCT, and the work done on the UCT NMR facility. Aspects of the studies were presented at an international conference on meningitis in 2008, and a publication with MVP published in the high impact journal Vaccine. Prof Ravenscroft not only participated in the consortium that developed MenAfriVac, but also prepared with UCT colleagues the first draft of the WHO Recommendations for the vaccine, and presented the final draft of the document to the WHO Expert Committee on Biological Standardisation. He was part of the team that in 2009 prepared the Common Technical Document for licensing the vaccine. This document contains spectra recorded with the Bruker 400 NMR spectrometer.

A first malaria clinical candidate out of Africa

In 2008, the DST/NRF SARChI Research Chair in Drug Discovery was established with Prof Kelly Chibale, then Professor in Chemistry at UCT as incumbent. The Chair was charged with the discovery and pre-clinical development of novel potential medicines or treatment modalities for the major communicable diseases in South Africa. A new generation of South African scientists was to be equipped with the skills required by the modern pharmaceutical industry in order to discover new medicines that could meet the many critical health challenges in Africa for which there is a paucity of effective drugs.

An integrated approach was imperative to achieve this goal, with the attendant establishment of enabling technologies and platforms. Different disciplines needed to be brought together towards a critical mass to conduct biomedical research that can address and support the whole value chain required to bring new drugs to market. In order to strengthen institutional and national capacities to do this, Prof Chibale founded Africa’s first integrated modern Drug Discovery and Development Centre at UCT. Known as H3-D, the Centre was established as a UCT accredited research centre in 2010 and officially launched in April 2011. H3-D has been positioned to inspire the next generation of young scientists, and to harness the facilities and expertise needed for a pharmaceutical industry motivated and able to address the challenges of infectious and non-infectious diseases endemic to Africa.

The technique of NMR spectroscopy has been of critical importance to this work. Before the biological evaluation of potential drugs, all molecules have to be analysed to confirm the accuracy of their structures and their desired purity. The Bruker 400 MHz NMR spectrometer has therefore been indispensable for progress in the research projects of the Chair and H3-D. For the synthetic chemistry, all 6,000 NMR analyses were done at UCT, using an inverse detection probe. For the computational work on drug design, higher-field NMR is needed. This work (with 20 samples) was done at the University of Washington (USA) and Debrecen University in Hungary.

NMR was also essential for the work on the biggest breakthrough in their work to date. Malaria is rife across the continent. It is estimated to kill up to 1 million people every year – mostly in Africa, and mostly children under the age of five. Anti-malarial drugs are in use, but the parasite is increasingly resistant to the existing drugs. The first ever malaria clinical candidate (MMV390048) to be researched and developed in Africa by Africans was announced to the press in August 2012 by the then Minister of Science and Technology, Hon Naledi Pandor. On the basis of initial results in animal trials it was selected for further development – making it the first compound researched on African soil to enter preclinical development in partnership with MMV.

The aminopyridine series from which the compound derives was initially identified by Griffith University scientists in Australia in 2008 as part of MMV’s extensive malaria screening campaign of around 6 million compounds. In April 2009 a team of scientists from H3-D, led by UCT Professor Kelly Chibale, with MMV further scrutinised and
explored the antimalarial potential of the series. With parasitological, pharmacological and contract chemistry support from the Swiss Tropical and Public Health Institute (Switzerland), the Centre for Drug Candidate Optimisation at Monash University (Australia) and Syngene (India) respectively, the H3-D team selected the most promising compounds from the series to be optimised and retested.

The breakthrough came in 2010. This means that H3-D and MMV achieved MMV390048 as a pre-clinical trial candidate in the record time of 18 months by the time of the August 2012 public announcement. In January 2012 MMV and TIA agreed to build on the success of the programme and signed a four-year collaborative deal to deliver back-up chemical series and to develop additional chemical compounds to take forward. After a year of pre-clinical development at H3-D, phase I clinical trials are now on-going at UCT’s Groote Schuur Hospital.

The compound shows significant potential. It is active against resistant strains of the malaria parasite. It not only has the potential to become part of a single-dose cure for all strains of malaria, thus improving patient compliance, but might also be able to block transmission of the parasite from person to person, as it works at the critical life cycle stages of the parasite.

The work that resulted in this discovery was led from H3-D, and the NEP funded 400 MHz Bruker NMR spectrometer played a crucial role throughout the process.

Other projects where in-house NMR has been crucial

- Together with Prof Jackson, collaborators at McGill University, Canada, H3-D is embarking on a program involving the application of NMR in drug discovery and fragment screening, including targeting G-protein coupled receptors (GPCRs) for chemotherapeutic intervention.
- The Strategic Health Innovation Partnership (SHIP) unit of the South African Medical Research Council (MRC) fund research on an anti-tuberculosis drug discovery project.
- The Bill and Melinda Gates Foundation funded research through McGill University in Montreal on antihelminthics, with partners at the University of Botswana and McGill University.
- Absorption, Distribution, Metabolism and Excretion (ADME) assays are being done on compounds for various teams and for partners in South Africa and other clients.
- Research is being conducted to develop a species-specific insecticide against the malaria mosquito and migratory locust.

The following are some of the users (including the number of samples run in a particular year). Each has a story to tell, and has made contributions in different ways:

- Prof Timothy Egan, on the bioinorganic chemistry of the malaria parasite (195 NMR spectra).
- Prof David Gammon, working on natural products chemistry, phytochemical studies on medicinal plants and carbohydrates (430 NMR spectra)
- Professor Roger Hunter, synthesis of indole alkaloids as anti-cancer and HIV drugs (1,313 NMR spectra)
- Professor Graham Jackson, insect neuropeptides and design of metal containing drugs; copper and rheumatoid arthritis (368 NMR spectra)
- Dr Anwar Jardine, medicinal chemistry and chemical biology (231 NMR spectra)
- Dr Gregory Smith, organometallic chemistry and catalysis (2,200 NMR spectra).

An alternative?

- Could the same results have been achieved by using NMR facilities elsewhere, either in South Africa (which in all likelihood would have used NEP funded spectrometers) or abroad? Some samples had to be
done on higher-field spectrometers in the US and Europe. This is expensive and impacts negatively on productivity. A modern high-field NMR is necessary in order to accelerate analyses and to increase chemical shift dispersion in biological and vaccine samples, for example. High-field NMR spectrometers are available elsewhere in South Africa, such as the decade old 600 MHz spectrometer at nearby University of Stellenbosch, but it is unable to run modern pulse sequences required for biological studies.

- Importantly, the intensity of analyses makes working at another institution a challenging option. H3-D generated 6,000 samples in 2012, all of which required NMR spectra for characterisation – an average of 16 new samples a day, every day. This does not include the rest of the University, or the private sector. Even with the help of two routine 300 and 400 MHz instruments, the facility was overloaded. Efforts to work with similar equipment at the Universities of Kwazulu-Natal, Rhodes and the Free State also presented challenges in coping with the volume of usage emanating from the UCT research group. The stability of some of the compounds in transit also created problems.

- This situation was a key reason why the NRF NEP in 2013 allocated to Prof Chibale funding of R7.31m towards the R10.8 million required for a new 600 MHz NMR spectrometer. It has the sensitivity to carry out full structural studies on molecules in the range of sizes and quantities normally encountered in the synthetic and medical chemistry research. In addition, a cold probe obtained for an additional R1.6 million is able to facilitate significantly faster analysis of small samples, as well as greater sensitivity.

- This will allow complex mixtures with components in the microgram range to be studied – thus increasing efficiency, lowering related costs and expanding the range of potential users. It is the first NMR facility in Africa with these capabilities.

5.4. THE VALUE PROPOSITION OF THE NMR FACILITY AT UCT

The projects described are just two of the many projects using the NMR facility at UCT since 2008. Although these two were perhaps the most visible in creating potential and actual impacts beyond the academic sector, there are others with significant potential to do the same. Well managed, modern NMR facilities have been indispensable to these projects’ success. Using facilities elsewhere in South Africa depletes efficiency, and only specialised cases are analysed outside the country, at significant cost.

The most obvious, direct benefits of the facility follow from the relatively large number of South African staff and students exposed not only to modern NMR techniques, but to how such instrumentation can be essential to solving real-world challenges.

The staff and students produce and disseminate knowledge that highlight the use of modern NMR facilities in South Africa. Although a much larger study will be needed to confirm this, it is likely to have helped enhance South Africa’s profile among relevant scientists as a country with state-of-the-art expertise in NMR, including for applications outside the academic environment.

Most importantly, NMR is seen as having been indispensable in contributing to the scientific breakthroughs with direct application in practice. Doing the same with facilities outside UCT would have been cumbersome, with several practical difficulties that would have delayed the work significantly, and perhaps even made it impossible for UCT to participate in such major pioneering initiatives. Over the years, many people and organisations have had a hand in the success of this breakthrough vaccine and potentially breakthrough drug. The vaccine is likely to have saved many lives already. The malaria drug, if brought to market, has even greater potential to do so.

68 Supplemented by a total of R2.3 million from the University
It is noteworthy that the project that led to the malaria clinical candidate has resulted in a number of high level science jobs being created, and has been critical in building infrastructure and expertise, which is now being used to tackle other diseases. Furthermore, the malaria drug breakthrough has provided inspiration that Africa can innovate in this area of health.

The exact contributions of the UCT NMR spectroscopy facility and expertise to such successes and to raising its scientific profile cannot be estimated and quantified, but they have rippled out far beyond the academic environment of UCT. This is an indirect but very important result of the investment the NRF has made in these instruments, upon which a price cannot be set.

5.5. CASE STUDY 7A: SYNERGIES - THE SARCHI RESEARCH CHAIR IN DRUG DISCOVERY

Prof Chibale describes the effect of the allocation of his DST/NRF SARChI Research Chair in Drug Discovery in 2008 as “transformative”. He confirmed that it had made a significant difference to his career direction and performance, activated new ways of working, enhanced his research profile, and fundamentally influenced his research directions. It also inspired him to take a step that was to have a great influence on his vision and research approach: taking sabbatical as visiting professor at Pfizer in the UK, the largest drug company in the world, in order to understand better how to deliver on the type of outputs required from a SARChI Chair. During this sabbatical he was exposed to integrated modern drug discovery, and “recognised the essential skills and infrastructure that would be the pillars of a drug discovery centre (H3-D) in South Africa”.

His research team has expanded from four project team members in 2009, to 26 fully contracted scientists as of May 2014, all working on malaria and TB drug discovery. Based on recruitment currently underway, 50 staff scientists are expected to be in place at H3-D by 2015. He believes that the increased visibility, and over time the skills, infrastructure and critical mass of his drug discovery research team, have been major factors in helping to attract significant additional funding, and boosting funders’ confidence that he can deliver on expectations. He can now access major advances in the field of drug discovery, and major funding.

Prof Chibale gives several reasons for this development: firstly, the Research Chair funding has been used to leverage additional funding, and secondly, the “branding” of being a Research Chair with a “government stamp of approval” has enabled increased visibility and leadership at national and international level, making it easier to gain credibility and mobilise funding both locally and nationally. Before taking up the Chair, he was working at UCT and mobilising an average of R2.4 million per year. Over the last four years he has mobilised more than R100 million in research funding — more than R53 million in 2013 alone.

A third reason for his higher profile and ability to attract funding was the contribution of the Research Chair to freeing up his time, which contributed to the dramatic increase in both the quality and quantity of publications. He now had a strong vision for, and focuses on drug discovery, and was able to spend much more time on research and postgraduate students. Over the last five years he has been one of the top five per cent of performers in the entire UCT Faculty of Science; according to the 2013 and 2014 Faculty of Science Block Grant Reports he has twice been ranked number one in the faculty based on peer-reviewed publications and postgraduate student graduation for the period 2010-2012 and again for 2011-2013 - noted by the Chair of the Faculty Research Committee as
“extraordinarily productive, with double the points of anyone else”. The journal impact factors for his publications have been increasing, and publications have appeared in some of the best journals in the field

He has also had a significant change in the composition of his research team. In the three year period before he took up the Chair, his students were 60 per cent white and 40 per cent black; in 2013 his students were 15 per cent white and 85 per cent black, a much greater ratio than the general change in student composition in the country in the past decade.

Prof Chibale has been widely recognised for his outstanding contributions to drug discovery, among many others being the recipient of the 2010/11 National Science and Technology Forum (NSTF)-BHP Billiton Awards in the category TW Kambule NRF Senior Black Researcher; the Alan Pifer Research Award for 2011, the UCT Vice Chancellor’s award to “a single researcher at UCT in recognition of outstanding research that demonstrates relevance to the advancement and welfare of South Africa’s disadvantaged people”; the NRF Special Recognition Award: Champion of Research Capacity Development at South African Higher Education Institutions (HEIs) for 2012; the MRC Young Scientist Award (Silver Medal) for 2013; and in 2013 Medicines for Malaria Venture 2012 Project of the Year for leading a project team that discovered the first ever clinical candidate for malaria to come out of Africa. He also obtained a B2 NRF rating for 2012-2017.

Value proposition of the Research Chair

As described, the SARChI Research Chair in Drug Discovery has been a significant influence on Prof Chibale’s career, contributing to the following:

- A strong increase in the number of researchers employed, from four to an expected 50 in 2015 – all working in an area of significant strategic importance in Africa, and among the expressed priorities of the South African government;
- He is inspiring black students to join this field of work, with a team of 85 per cent black students compared to forty per cent before becoming a Chair. In the process, they have gained high quality training in an area of critical strategic importance in South Africa, using basic research to enable translation of high quality science, helping to build the area of drug discovery for Africa.
- He has raised funding from a variety of national and international sources to the tune of R100 million in four years, a ten-fold increase compared to the period before he became Chair. This enabled international funding to flow into the country.
- His leadership of the first African team to develop a clinical candidate on the continent, his academic achievements and productivity helped to raise the profile of South African science, as indicated by his national and international awards and many invitations to give plenary or keynote addresses at prestigious conferences worldwide.

The integrated approach to the research, and collaboration with experienced international teams supported the further development of skills and expertise, the learning of important lessons in the field of drug discovery, and a model for successful technology platforms for developing drug-based solutions for Africa.

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60 Two of the papers published in Bioorg. Med. Chem. in which he was one of the co-authors ranked among the top most cited papers for 2009/2010 and 2010/2011 respectively.

70 “For outstanding contributions to science, technology and innovation over the last 5-10 years including specific recognition for establishing Africa’s first integrated modern drug discovery centre (H3-D) and setting up various modern technology platforms for the discovery of potential medicines”.

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5.6. VALUATION FOR CASE STUDY 7

The research chair’s focus on drug discovery presents particular difficulties to development of the type of high level valuation analyses common to this evaluation. The evaluation’s focus on impact requires the demonstration of a clear pathway to value. With the potential end value only likely to materialise a number of years in the future and with a large number of influencing variables that will likely affect the final value, it is beyond the scope of this evaluation to provide sufficient rigour to such a valuation analysis as to include one here.

What we instead propose, is to illustrate two potential value stories connected with the malaria research. The first relates to the potential value in terms of reduction of the socioeconomic burden of malaria that a one dose cure for malaria might create. The second focuses on the potential socioeconomic impact of the capability of South Africa to discovery and create its own medicines.

1. Socioeconomic burden of Malaria

The socioeconomic burden of Malaria is significant. The economic impact of the disease is estimated to cost Africa approximately US$12 billion every year. This figure includes lost current and future household income due to illness and death, reduced productivity or lost income for businesses, health care costs for both individuals and institutions. It has been estimated that it imposes an “economic growth penalty” of up to 1.3% per annum in malaria endemic African countries. The vast majority (91%) of annual cases of malaria – 400 million – and deaths – 800,000 are concentrated in Africa with a median age of deaths estimated at 4 years old.

There are a number of prophylactics anti-malaria treatments currently available that tackle the disease in different ways, from attempting to disrupt, to suppress and to address causal issues. These different approaches work against the parasite at different stages of its lifecycle, in sharp contrast to the trial drug featured in this case study that works at all lifecycle stages of the parasite. However, resistance to a number of these prophylactics has limited their effectiveness.

A significant focus of attention in recent years has been on prevention programmes, including insecticide treated bednets (ITN) to indoor residual spraying (IRS) and intermittent preventative treatments (IPT). These have shown to be cost-effective measures in comparison with treatment for the disease. Table 9 presents the median cost per person per year of a range of anti-malaria strategies.

<table>
<thead>
<tr>
<th>Action</th>
<th>Annual cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPT in infants</td>
<td>0.6</td>
</tr>
<tr>
<td>IPT in pregnant women</td>
<td>2.6</td>
</tr>
<tr>
<td>IPT in children</td>
<td>4.3</td>
</tr>
<tr>
<td>ITN</td>
<td>2.2</td>
</tr>
<tr>
<td>IRS</td>
<td>6.7</td>
</tr>
<tr>
<td>Treatment of uncomplicated case</td>
<td>5.84</td>
</tr>
<tr>
<td>Treatment of severe case</td>
<td>30.26</td>
</tr>
</tbody>
</table>

71 Gallup JL, Sachs JD, 2001. The economic burden of malaria. AJTMH 64 (Suppl 1-2)
73 http://www.malariajournal.com/content/10/1/337
Research\textsuperscript{74} suggests that a scale-up in prevention measures in Africa during the first decade of the 2000s resulted in an 8.2% decrease in the number of malaria caused child deaths. This equates to approximately 842,000 deaths avoided. This estimate of lives saved (for which responsibility for 99% is ascribed to ITNs) equates to US$2,770 per life saved.

If we apply this cost per life saved figure to the current 800,000 deaths per annum (a simplistic calculation made purely for illustrative purposes) then an annual additional cost of US$2.3 billion per annum is required to avoid the annual costs of US$12 billion to Africa (mentioned above). While there are many caveats to this simplistic calculation, it does point to the potential net value that elimination of malaria could create, elimination being the goal of the drug reviewed above. A proper analysis of the drug’s potential impact, cost per user, ability to complement or replace existing treatments and probability of success is required to make a robust statement of the value it can produce for Africa.

This type of research may have a value that might only be realised in a number of years, but its potential (as indicated by the crude calculation above) is significant.

2. **Socioeconomic value to South Africa of domestic drug creation**

Evaluating the potential socioeconomic impact of increased capacity of South Africa to research, develop and create its own medicines represents a significant challenge. It is important to recognise that much of the additional economic value for investment in drug research and development will be realised over a long time period, and is likely to be realised through indirect rather than linear pathways. As such, charting a direct relationship between research and outcomes cannot be evaluated in depth in the current study. Therefore, this valuation analysis will instead discuss the potential value arising from increased research capacity and propose this be the focus of future valuation research.

3. **Investment in health research will have direct benefits in terms of:**

   i. Job creation for those working at the research facilities.
   
   ii. Revenue and taxation from commercial production of new drugs.
   
   iii. Savings in treatment costs (related to the above story) resulting from new and more effective health treatments and prevention methods assuming the cost effectiveness of new treatments.

4. **Investment in research and development will increase research capacity in South Africa**

This will be done through the increased skills and knowledge of individuals as well as increased organisational and systems capacity to carry out and disseminate high quality research on malaria. These benefits are difficult to quantify, and furthermore there is an element of potential feedback, where strong research outputs encourage further investment, creating a cycle of value. A high level diagram of how this could happen is presented in Figure 19.

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\textsuperscript{74} Eisele, T et al, (2012) Estimates of Child Deaths Prevented From Malaria Prevention Scale-up in Africa 2001-2010, Malaria Journal 2012; 11(93)
More specifically, potential values could include:

a) **Attraction/retention of skilled and knowledgeable researchers, leading to productivity gains, and increased tax revenue to the state.**

   Accurate figures for loss of skilled professionals overseas and their reasons for leaving are not abundant\(^75\). Where estimates have been suggested, the economic losses can be substantial - it is estimated that the financial cost to South Africa of doctors emigrating has been $1.41 bn\(^76\). A worthwhile piece of valuation research would be to investigate the issue of emigration among researchers as well as the attraction of foreign researchers to NRF funded institutions. It is recognised that sustainable research institutions require a critical mass of researchers to create an enabling environment for academic and research activities, helping maintain mutual support and allowing researchers to keep abreast of recent advancements and debates. A case study approach could provide learnings of the scale required to retain and attract high quality researchers.

b. **Health research more aligned with national and local needs in South Africa, leading to targeted research and further cost reductions.**

   Investment in malaria research in South Africa is small. However, investing locally allows research conducted to be relevant to national needs. This could be measured by considering the fraction of studies/publications targeted nationally and valued by investigating avoided adaptation costs from needing to use other countries’ approaches\(^77\).

c. **Gives South Africa an informed voice in establishing research priorities for global agenda, bringing in foreign investment.**

   Initial investments can often be successful in generating further external research funds, as the institutional reputation is developed. Reputation could be measured through number of publications in international journals and valued in terms of foreign direct investment (FDI) in the health space\(^78\).

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\(^75\) [http://www.queensu.ca/samp/migrationresources/braindrain/](http://www.queensu.ca/samp/migrationresources/braindrain/)

\(^76\) [http://www.bmj.com/content/bmj/343/bmj.d7031.full.pdf](http://www.bmj.com/content/bmj/343/bmj.d7031.full.pdf)

\(^77\) See Sirex woodwasp valuation case study for example of value of locally produced protocols.

\(^78\) See valuation section for case study 3: From TB research to Clinical Trials