REPUBLIC OF BOTSWANA

BOTSWANA NATIONAL RESEARCH, SCIENCE AND TECHNOLOGY PLAN

FINAL REPORT

DECEMBER 2005

PREPARED FOR:
Ministry of Communications,
Science and Technology
Botswana

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Acronyms

AIDS	Acquired Immune Deficiency Syndrome
ARV	Anti retrovirals
BIDPA	Botswana Institute of Development Policy Analysis
BOTEC	Botswana Technology Centre
BPC	Botswana Power Corporation
BRSTFA	Botswana Research, Science and Technology Funding Agency
BSA	Bovine serum albumin
CBD	Convention on Biodiversity
EU	European Union
FLOSS	Free/libre open source software
FTE	Full Time Equivalent
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
HEI	Higher Education Institutions
HIV	Human Immunodeficiency Virus
HRD	Human Resources development
ICT	Information and Communication Technology
IKS	Indigenous Knowledge Systems
IP	Intellectual Property
MCST	Ministry of Communications, Science and Technology
MFDP	Ministry of Finance and Development Planning
NDP	National Development Plan
NDP 9	National Development Plan 9
NDP 10	National Development Plan 10
NFTRC	National Food Research Technology Centre
NGO	Non Governmental Organisation
NHRD	National Human Resources Development
NSI	National System of Innovation
PCT	Patent Classification Treaty
PPP	Public – Private Partnerships
R&D	Research and Development
RDI	Research, Development and Implementation
RIIC	Rural Industries Innovations Centre
RIPCO (B)	Rural Industries Promotions Company (Botswana)
RST	Research, Science and Technology
RTO	Research and Technology Organisations

S & T	Science and Technology
SMME	Small, medium and micro enterprises
STCI	Science and Technology Capacity Index
TAI	Technology Achievement Index
TEI	Tertiary Education Institution
TB	Tuberculosis
TRIPS	Trade Related aspects of Intellectual Property
UB	University of Botswana
US	United States
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WTO	World Trade Organisation

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Executive Summary

This National Research, Science and Technology Plan identifies Botswana's priority areas for investment in research and presents an implementation programme for the remainder of the National Development Plan 9 and the whole of National Development Plan 10. The Plan responds to several socio-economic challenges presently facing Botswana, including economic diversification, poverty and unemployment, HIV/AIDS and the sustainable use of natural resources, within a framework of feasibility and affordability.

The report contains the following:

- an outline of the priority areas for investment in research including how these priority areas will meet Botswana's national goals;
- the human resources and institutional structures required to implement the Plan (including the formation of new funding and research agencies); and,
- an implementation plan with estimated financial costs.

The proposed areas of research cover several sectors including health; the service industry; eco and cultural tourism; the software industry; manufacturing; mining; water; energy; agriculture; media; education and human resource development; housing and construction; as well as transport and logistics. The Plan contains four main policy interventions, namely the introduction of a Mission-focussed Programme, the establishment of Centres of Excellence, the stimulation of private sector research through the introduction of an Innovation Fund and research tax incentives, and the improved integration of Line Function research within the overall National System of Innovation.

The Mission-focussed Programme will typically support long term and multi-disciplinary research within the themes of ecosystems; processing and mining; manufacturing, engineering and infrastructure; geomatics; and, biosciences. The Centres of Excellence will focus expertise from existing research institutions into key focus areas including energy for the future; infectious diseases; indigenous knowledge and technology systems; Information and Communication Technologies; software engineering; and, human sciences and policy research. The Innovation Fund will focus on promoting public-private sector partnerships, whilst tax incentives will be introduced to encourage private sector research. The Plan also defines priorities for research activities within existing public sector line ministries including the Ministries of Agriculture; Minerals, Energy and Water Resources; Wildlife, Environment and Tourism; Health; and Communications, Science and Technology.

Several actions are necessary for the effective implementation of the Plan. These include provision of adequate funding, appropriate and efficient institutions, the establishment of

monitoring mechanisms, as well as trained and effective research staff.

These actions require that:

- the Government should commit to a research expenditure of 1% of Gross Domestic Product, which is the minimum level for emerging innovative economies;
- Research funding should largely be allocated on a competitive basis. This is aimed at encouraging more relevant and efficient research focusing on Botswana's priority development challenges.
- the Botswana Research, Science and Technology Funding Agency should be established as a mechanism to manage competitive funding;
- a task team should be established to merge the National Food Research and Technology Centre and the Department of Agricultural Research into a National Food and Agricultural Research Centre;
- the Botswana Technology Centre and Rural Industries Promotions Company (Botswana) should be merged to form a new institution;
- the objectives of the Plan should be incorporated into the institutional plans of all government-funded research entities in order to ensure full alignment within the National System of Innovation;
- performance indicators should be developed for all research agencies in order to monitor both the implementation of this Plan and the actual vs. intended impact of Government-funded research; and
- the University and the Centres of Excellence must play a key role in training highly specialised post-graduate researchers who will be required to lead the research within the identified priority areas.

Investment in the identified research areas and completion of the above actions will make a meaningful contribution to the attainment of the Vision 2016 objectives, namely that of an educated, informed nation; a prosperous, productive and innovative nation; and a compassionate, just and caring nation and generally improve the welfare of Batswana.

1 INTRODUCTION

1.1 Background and approach to developing the National, Research, Science and Technology Plan

This Plan identifies Botswana's priority areas for investment in science and technology research and development (R&D)[1] and presents an implementation programme for the remainder of the National Development Plan (NDP) 9 period and NDP 10.

The Plan was completed in four phases, namely: project inception; inventory and assessment of capacity; identification of priority areas for research; and, preparation of the research plan. The documents produced in the various phases include the *Botswana National Research, Science and Technology Plan: Inception Report* (CSIR, 2005a) which explained the project methodology and outputs; *Botswana National Research, Science and Technology Plan: Inventory and Assessment Report* (CSIR, 2005b) which provided information on the investment, capacity and research outputs of research organisations in Botswana as well as trends in global markets and technology developments; and *Botswana National Research, Science and Technology Plan: Priority Areas for Research – Stakeholder Views and Economic Analysis CSIR* (CSIR, 2005c) which identified the research areas that will support the attainment of national development priorities. This Plan, which consolidates information from all the phases and proposes practical arrangements for implementation, is the final output of the process.

The key sources of information reviewed in preparing the Plan include Vision 2016, Government policies and plans, reports on financial expenditure during NDP 8 and 9, literature on the Botswana economy, annual reports of key research institutions and global literature on benchmarking S&T institutions. In addition, areas in which Botswana has a comparative advantage or disadvantage were identified. The Plan has also been informed by contributions from stakeholders representing the Government, non-Governmental organisations, the private sector and parastatal organisations as well as a detailed questionnaire survey based on the standard approach to the measurement of R&D as developed in the Frascati Manual (OECD, 2002). A Reference Group comprising leaders drawn from both the research users and research suppliers in Botswana provided support to the Ministry of Communications, Science and Technology in monitoring and guiding the preparation of this Plan.

The Plan is structured in eight sections. The introduction sets out the context of the Plan, including its purpose, the rationale for its development as well as the anticipated outcomes. The second section outlines the priority areas for investment in science and technology[2] (S&T) R&D. Section 3 assesses the relationship between the priority areas

[1] For the purpose of international comparison, the OECD definition of Research and Development (R&D) is used. R&D is defined as creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of humanity, culture and society, and the wise use of this stock of knowledge to devise new applications.

[2] The 1998 Science and Technology Policy for Botswana defines science as the pursuit of new knowledge through the systematic study of nature and the behaviour of material and physical universe and is based on observation, experimentation and measurement. Technology is

for research and national goals. Section 4 outlines the human resources required to implement the Plan. Section 5 outlines the institutional structures required to effectively support the priority areas for investment. The implementation plan is described in Section 6. Section 7 is on the estimated financial costs of implementing the Plan. Section 8 contains the conclusions. A summary of the key recommendations on how best to ensure that the Plan is effectively implemented is contained in Section 9.

1.2 Key issues informing the development of the National, Research, Science and Technology Plan

Botswana faces several socio-economic challenges despite major achievements over the last few decades. These challenges, which are discussed in detail in Section 3, are well articulated in various policies, Vision 2016 and NDP10. The national development priorities and challenges include economic diversification, poverty and unemployment, HIV/AIDS and the sustainable use of natural resources (Republic of Botswana, 2003). The key issue relating to economic diversification is the narrow economic base which is dominated by minerals. Key issues relating to poverty and unemployment are the high levels of unemployment which is estimated at 23.8% by the 2002/03 Household Income and Expenditure Survey (especially among young people), higher levels of poverty among women than men, and a declining but still high proportion of people living in poverty. The key features of HIV/AIDS are the high levels of HIV infection which is estimated at 17.1% (Central Statistics Office, 2004a), increasing mortality as a result of AIDS, declining life expectancy and the possible erosion of productivity, knowledge and skills (Central Statistics Office, 2004b). Issues concerning the sustainable use of natural resources include the decline in species, the increasing importance of tourism, recurrent drought, as well as land degradation (Republic of Botswana, 1990a; Republic of Botswana, 1990b).

Science and Technology has an important influence on competitiveness, productivity and economic growth. It is now commonly accepted that science and technology is the largest contributor to economic progress and human development (United Nations Development Programme, 2004). In particular, science and technology has contributed toward reduced mortality rates, improved life expectancy, combating HIV/AIDS and other diseases such as malaria, environmental sustainability, poverty reduction and generally all aspects of the human endeavour to improve the lot of mankind as encapsulated in the Millennium Development Goals**.**

The discussion on international benchmarks for research funding (Section 7.2) strongly suggests that investments in science and technology are increasingly becoming important for economic growth. While it is not possible to demonstrate a direct causation between the rates of investment in research and development and outcomes in terms of increased national Gross Domestic Product (GDP), a growing level of investment in research and development is generally correlated with improved GDP-growth (IAC, 2004).

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defined as the application of science through practical utilisation in the development of products and services which can create wealth and improve the quality of life.

Advances in both biotechnology and information technology including information communications technology, computing and space technology[3] are now acknowledged to be the key drivers of economic and human development progress in this century and possibly beyond. The realisation of the full benefit of these technological advances will involve partners from many sectors: academics, the private sector, national governments, public interest groups, non-governmental organisations and an informed media.

The case that the acquisition of knowledge makes the difference between poverty and wealth has also been well articulated in the literature (Dahlman, 2001). In his paper 'ICT and Poverty: The Indisputable Link,' Alexander G. Flor refers to the correlation between access to information and poverty through the following propositions: that… "Information leads to resources; information leads to opportunities that generate resources; access to information leads to access to resources; and access to information leads to access to opportunities that generate resources. In an information society, the information poor have also become the resource poor.' 'In Southeast Asia, in particular, the correlation is unmistakable. The higher the value of ICT indicators (as in Singapore, Brunei and Malaysia) the lower the poverty index".

The case is also made in the literature that the difference in the income of countries is more attributable to knowledge than to physical and human capital and that innovation and productivity increase is more important in national competitiveness than GDP growth. This would suggest the need for greater investment in research and development, education and information technology than in physical plant and equipment and the adoption of measures to prepare the country for greater globalisation and competition. In this regard Botswana can learn from other countries such as Korea, specifically in formulating a policy framework to provide:

- economic incentives and an institutional regime that provides incentives for the efficient use of existing and new knowledge and support for entrepreneurship;
- educated, creative and skilled people;
- a dynamic information infrastructure particularly to get information to rural and poor communities; and
- an effective national innovation system.

The graph below (Figure 1.1) compares the development paths of Ghana and South Korea and demonstrates more vividly that knowledge makes the difference between poverty and wealth. The two countries had the same GDP per capita in 1958 and today they are worlds apart in terms of the standard of living of their populations and the sophistication and growth prospects of their economies.

[3] Space technology might seem far fetched for countries like Botswana but can have very practical applications for such areas as the use of remote sensing satellites to indicate when soil conditions in a certain area are right to plant a particular crop. Any country that seeks to exploit such a technology must develop its own capacity to understand the technology and shape it to meet its own needs.

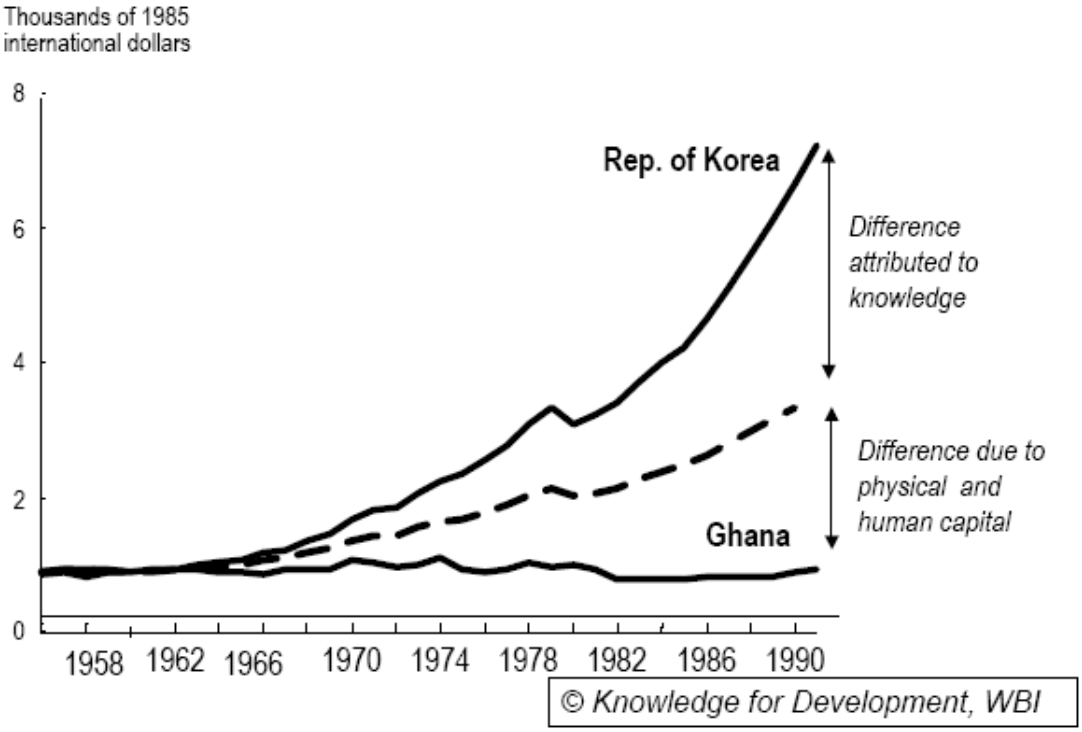

Figure 1.1: Development paths of Ghana and the Republic of Korea (1958-1990)

The key is not only about building national capacity for biotechnology and information technology but the effective use of this knowledge across the economy and society generally getting this knowledge particularly to mothers, farmers, workers, enterprises and government in order to improve their productivity and service delivery. It is also about creating an effective national innovation system with the necessary local R&D capacity to tap into global knowledge, creating and adapting new knowledge and disseminating it in such a way that it can be used by individuals and communities.

Table 1.1 summarises the key attributes of the current National System of Innovation in Botswana. In addition to the low expenditure on R&D, key attributes of Botswana's National system of Innovation that have informed this plan include: low conversion of research outputs, limited involvement of the private sector, and few collaborative partnerships. The positive aspects which should be enhanced by the Plan include a relatively good publications output, and a highly qualified workforce a significant proportion of which is female (CSIR 2005b). These attributes are discussed in more detail in *Botswana National Research, Science and Technology Plan: Inventory and Assessment Report* (CSIR, 2005b)

Table 1.1: Key attributes of Botswana's National System of Innovation[4]

Attribute	Botswana	Benchmark
GERD	0.43%	Minimum 1% for developing nations[5]
Private sector contribution to GERD	3%	70% in Korea
Total number of researchers	2,165	-
Researchers as a proportion of workforce	2.7 per 1000 workers	Singapore and UK 10 per 1000, Korea 8 per 1000.
% Female Researchers	29%	Poland 38%, South Africa 37%, Zambia 14%
% Researchers with MSc or PhD	48%	34% in South Africa
Publication equivalents per researcher	0.7	1.0
Patents	5 International patents in 10 years (1994-2004)	-
Experimental Development as % of Total R&D	19%	60-65% for highly innovative economies[6]

Although it is hard to accurately assess the impact of past investment in R&D, indications are that past research has had limited impact on Botswana's national priorities. This is because the funding provided has been relatively small, the outputs (particularly in terms of patents and other registered intellectual property) have been relatively few and there has been limited uptake of these technologies. There are, however, a number of examples of past and existing research where localised uptake and impact will probably have occurred (CSIR 2005b).

There is a real risk that unless this National Research, Science and Technology Plan is deliberately and actively implemented, Botswana faces the prospect of a growing knowledge gap with the competitors, and an inability to use existing and new knowledge to improve the competitiveness of the traditional sectors and to exploit the development of non-traditional sectors.

1.3 Anticipated Outcomes

As a result of investment in the priority research areas, important outcomes will be achieved in a number of application areas. A key measure of the success of the research effort will be the extent to which it contributes to these outcomes. Outcomes identified in collaboration with key stakeholders and considering national policies are:

i. **Agriculture:** Optimal allocation and use of agricultural resources, improved food production, increased diversity of the agricultural base and improved

[4] Data for Botswana obtained from (CSIR, 2005b). Data for other countries mostly extracted from the 2004 UNDP Human Development Report (2002 data)

[5] IAC,2004

[6] See the OECD Compendium on S&T Indicators, available from ww.oecd.org

marketing and processing strategies creating sustainable jobs, profits and agro-ecosystems.

ii. **Eco and Cultural Tourism and Leisure Industries:** Sustainable jobs, profits and ecosystems as well as optimal linkages to other sectors as a result of integrated and effective marketing strategies, biological diversity conservation in tourism areas, the increased participation of Batswana in tourism, and satisfied clients.

iii. **Energy Supply:** Balance between energy supply and demand and access to sustainable renewable energy for all consumers.

iv. **Health:** An improved ability to reduce and prevent the spread of infections and disease, access to affordable health services, and an informed nation on health matters.

v. **Housing and Construction:** Decent, affordable, safe, durable, energy and water efficient accommodation provided through the use of local resources resulting in new jobs and improved quality of life.

vi. **Manufacturing**: A resilient and diversified economy as a result of the extraction of maximum benefit from the value chain resulting in increased employment.

vii. **Media, Education and HRD**: Improved access to information, skills and knowledge and a well informed, educated and innovative nation.

viii. **Mining:** High value addition and beneficiation, bi-product utilisation, improved efficiency of current exploration and processing through the use of novel methods, increasing employment and incomes.

ix. **Natural environment**: A healthy natural resource base that provides essential ecosystem services and supports the livelihoods of existing and future generations of Batswana.

x. **Research, Science and Technology**: Annual expenditure on R&D grows to a figure in excess of 1% of GDP and Botswana is host to at least two high quality, international-impact Centres of Excellence.

xi. **Service Industry**: Increased access to and improved efficiency of services resulting in improved quality of life and job creation.

xii. **Software Industry**: Improved efficiency and effectiveness in the broader economy creating new employment opportunities.

xiii. **Transport and Logistics**: A cost-effective, efficient, safe, secure, and environmentally friendly sector resulting in improved service delivery, integrated planning, and improved infrastructure.

xiv. **Water Supply**: A balance between water demand and supply, access to safe and adequate water supply and the sustainable management of existing water resources in Botswana.

Aligning research with the above outcomes will enable Botswana's research community to make a meaningful contribution to the attainment of the Vision 2016 objectives, namely that of an educated, informed nation; a prosperous, productive and innovative nation; and a compassionate, just and caring nation and generally improve the welfare of Batswana.

This first section has provided a background, the rationale and the expected outcomes of the Botswana National Science and Technology Plan. The next section describes the priority areas that have been identified for research focus in Botswana. Later sections describe the institutional arrangements, staffing and funding necessary to enable this research.

2 PRIORITY AREAS FOR SCIENCE AND TECHNOLOGY RESEARCH AND DEVELOPMENT

2.1 Priority Areas for Research

The areas of research cover several sectors namely health; the service industry; eco and cultural tourism; the software industry; manufacturing; mining; water; energy; agriculture; media, education and human resource development; housing and construction; as well as transport and logistics. The priority areas for research are grouped into several research platforms.[7] A research platform is a collection of complementary technologies, skills and competencies able to deliver a variety of research products and services into the market place. The three types of platform identified for Botswana are Mission-focused Programmes, Centres of Excellence and Line Research. In recognition of the dynamic nature of any NSI, provision should be made to allow these different research platforms to evolve and change form as appropriate. For example, it is quite possible that Line Research or Mission-focused Programmes could with time evolve into a Centre of Excellence.

The research areas and associated priorities described in this section cover the full spectrum of the innovation chain from new knowledge development to application and experimental development[8]. Research undertaken in line departments will be largely applied in nature whereas that undertaken within Centres of Excellence will have a higher proportion of directed basic research and the mission focused programmes will need a healthy balance of both to ensure success. This will require and encourage the formation of cross-institutional (including private sector and NGO participants where appropriate) multidisciplinary research teams in these programmes. There is a degree of overlap between platforms which will also encourage a regular exchange of knowledge and skills, thus contributing to a vibrant innovation system. The Plan describes research areas at a broad level, leaving room for research teams made up of individuals with local knowledge to develop detailed research programmes in line with the desired outcomes as expressed in section 1.3.

[7] The process of research prioritisation for this plan involved: the analysis of areas where Botswana has comparative advantage and disadvantage; agreement on expected research outcomes (described in section 1.3); the development, acceptance and application of a set of criteria for prioritisation (see appendix 3); extensive stakeholder participation and involvement in research prioritisation; further categorisation, aggregation and analysis by the consultants; as well as, a review of emerging technologies elsewhere (see appendix 4); and, review by stakeholders and an international review panel. The research areas are not presented in any order of priority. It would not be desirable to trade-off various fields of research (e.g. ecosystems against human health) against each other because both are recognized as being critical to national development. The areas identified for research are, however, a product of the prioritisation process described above, which resulted in the exclusion of number of possible research areas identified in earlier stages of the preparation of this Plan (CSIR, 2005c).

[8] This report adopts the OECD (2002) definitions of research across the technology innovation chain (see appendix 1).

2.2 Mission-focussed Programmes

The research prioritisation process resulted in the identification of five Mission-focussed Programmes. These programmes deal with ecosystems; manufacturing, engineering and infrastructure; processing and mining; geomatics; and biosciences. Investment in Mission-focussed programmes will encourage inter-institutional cooperation, promote multi-institutional collaboration by leveraging the relative strengths of participating institutions, provide for a comprehensive problem solving approach by bringing together the right expertise for each stage of the R&D process, and provide a critical mass of researchers. A key criteria in awarding research contracts will be the extent to which the intended research will contribute to the outcomes outlined in section 1.3.

Ecosystems

Healthy ecosystems are fundamental in supporting human wellbeing and form the basis for Botswana's important ecotourism industry. Botswana's ecosystems also hold the raw materials for potential future resource exploitation. The following areas of broad-based ecosystems research and modelling will be undertaken:

- Catchment area management research, arid area hydrology, wetlands research and water resources management modelling (supported, where appropriate, by remote sensing technologies and data monitoring systems);
- Understanding the implications of global change on water supply in Botswana;
- Ecosystems carrying capacity (including tourism carrying capacity);
- The inventorisation and characterisation of indigenous plants, organisms, forestry and animal resources and biodiversity mapping to support an understanding of the distribution of genetic resources for conservation purposes;
- Research into indigenous tree plantations; and
- Wildlife management research.

Manufacturing, engineering and infrastructure

Strengthening and diversification of Botswana's economy requires research support leading to improved efficiency of existing processes and additional opportunities for job creation linked to value addition to the country's natural capital. Research will be undertaken in the following areas:

- Research on veld products manufacturing, including cosmetic products based on local products (e.g. aloe extracts) as well as food/feed processing of essential foods and indigenous products;
- Research into value added products from agricultural produce (e.g. collagen, bovine serum albumin, gelatin);
- Research into the use of local materials in construction and water saving devices such as improved design of sanitary fittings;
- Manufacture of effective communication technologies appropriate to Botswana (e.g. satellite); and,
- Research to support vaccines manufacturing.

Processing and mining

Botswana's remarkable economic progress has largely been due to mining – especially diamonds. Research aimed at contributing to improved value addition and beneficiation of natural capital will be undertaken in the following areas:

- Research into mining bi-product utilisation;
- Research into downstream beneficiation of mining products;
- Research seeking to improve the efficiency of current processing technologies including environmentally cleaner production technologies;
- ICT research to support process control; and,
- Chemical sciences and engineering research into improved extraction and processing technologies.

Geomatics

Botswana is a vast country of 582 000 km^2, with a low average density of population of 3 people per km^2. It also is a country well endowed with natural capital (particularly minerals and wildlife). Spatial Technologies (including Geographical Information Systems and Remote Sensing) are key to support the management of this natural capital and to enable access to scarce resources such as water and energy. Research and technology also have an important role in supporting good governance, particularly in the realm of accountable decision making. Geomatics covers the development of new means of acquiring, analyzing, manipulating, presenting and using spatial information. This is a cross cutting theme and will need to interact closely with related Mission-focussed Programmes, Centres of Excellence and line ministries. Research will be undertaken in the following areas:

- Geomatics support to develop ecotourism potential maps as well as spatial information products for tourists;
- Geomatics to support water resources management through the mapping of the nature and extent of both surface and underground water resources;
- Biodiversity mapping to support an understanding of the distribution of genetic resources for conservation purposes;
- Mapping of the agricultural potential of Botswana;
- Geological mapping and the identification of the nature and extent of Botswana's mineral resources;.
- The modelling of disease prevalence and relationship with certain vectors;
- Water resources management modelling (supported, where appropriate, by remote sensing technologies and data monitoring systems);
- Intelligent transport systems and transport logistics research; and,
- Modelling and simulation of manufacturing processes.

Biosciences

Advances within the biosciences worldwide are poised to make a huge contribution to many application areas including agriculture, medicine, environmental management and manufacturing. These advances have been enabled through initiatives such as the human genome project which have generated a wealth of information on biochemical and cellular processes. Although it would not be appropriate for Botswana to invest in such

fundamental research, it is important that the Research, Science and Technology Plan clearly identifies important areas of application for the country, and fully resources the required applied research in order to ensure that these applications are fully realised.

The research areas are:

- Clinical science research leading to the evaluation of new pharmaceuticals; and,
- Nutrition and HIV/AIDS.

2.3 Centres of Excellence

Centres of Excellence are expected to earn a reputation as a significant resource for the progress of science and technology and the spread of innovation. Such centres will perform at world standard in terms of scientific production and technological innovation. Typically, Centres of Excellence will demonstrate:

- a "critical mass" of high level scientists and/or technology developers;
- a well-identified structure (mostly based on existing structures)
- capability to integrate connected fields and to associate complementary skills;
- capability to maintain a high rate of exchange of qualified human resources;
- a dynamic role in the surrounding innovation system (adding value to knowledge);
- high levels of international visibility and scientific and/or industrial connectivity;
- a reasonable stability of funding and operating conditions over time (the basis for investing in people and building partnerships); and,
- the ability to attract additional sources of finance which are not dependent over time on public funding.

The research prioritisation process resulted in the identification of five Centres of Excellence focusing on energy for the future; infectious diseases; indigenous knowledge and technology systems; Information and Communications Technology; and human sciences and policy research. Expected outcomes of the research conducted in these centres should be fully aligned with those identified in section 1.3 of this report.

Energy for the Future

Botswana has a strong dependency on imported fuel such as oil and electricity. In 2004, the country imported over 70% of electricity requirements. It is projected that surplus generation capacity in the Southern African Power Pool will run out in 2007 (Republic of Botswana 2005b). A Centre for Energy for the Future will be established to investigate alternative energy sources to power Botswana into the future. Research areas to be covered by this centre include:

- Research into appropriate renewable and alternative energy sources and technologies such as solar (including photovoltaics), wind energy, geothermal and energy from biomass;
- Comprehensive mapping of existing and potential energy sources;
- Ecosystem-based research into renewable and alternative energy sources;
- Socio-economic research into opportunities for increasing employment and income through the utilisation of renewable energy:
- Energy efficiency research, including improved building design and construction; and,

- Environmental issues such as: clean energy supply, modelling to improve the understanding of environment–economy-energy interrelationships in Botswana and climate change-energy relationships.

Infectious diseases

Botswana has experienced a resurgence of diseases, such as TB whose incidence had been declining. HIV-related infections are the main reason for hospital admissions (Republic of Botswana 2003). A Centre for Infectious Diseases will focus research on:

- Ecological prevalence and spread of disease;
- Interaction between wildlife, livestock and humans (host vector research);
- Developing an understanding of HIV mutation;
- Epidemiology of HIV/AIDS;
- Treatment of infectious diseases through the use of traditional medicine;
- Emerging diseases (eg SARS); and,
- The modelling of disease prevalence and relationship with certain vectors.

Indigenous Knowledge and Technology Systems

There is a wealth of untapped indigenous knowledge in traditional Botswana society. There is a danger that this knowledge will be eroded with time or pirated and lost to the National System of Innovation in Botswana. A Centre of Excellence is needed to identify, evaluate and commercialise products based on Botswana's indigenous knowledge. In particular this Centre will focus research on:

- Curatorial research to catalogue and conserve traditional knowledge;
- The development of new products for the tourism market that harness traditional creativity and innovation;
- The evaluation, protection and commercialisation of African traditional medicines;
- Treatment of infectious diseases through the use of traditional medicine; and,
- Sustainable use of traditional medicines and substitutes.
- Domestication of indigenous plants and tubers.

Information and Communications Technology

Information and communication technology (ICT) is vital for the country's future as a pervasive enabler of industry and developmental solutions. The pervasiveness of ICT provides a challenge in terms of focus. To make a real impact in the short and medium term, Botswana needs to focus its investment in a few key areas within the broader ICT space. A Centre of Excellence in ICT should provide this focus. This centre's focus will initially be on two major areas to build an appropriate track record in solving real challenges within the Botswana context. Building this track record and critical mass through focused effort and appropriate partnerships will attract further investment and people development opportunities in other areas within the ICT space.

The initial focus areas suggested are:

- Appropriate access technology; and,
- software Engineering.

Appropriate access technology

A focus area on research aimed at improving access will be established with an emphasis largely on communications aspects. With a land area of 582 000 km^2 and a population of 1,700,000, Batswana face a number of challenges in terms of access to basic services and knowledge.

Mobile and wireless technologies offer a significant potential to address these challenges. This is evident in the successful expansion of cellular phone networks in developing and developed countries, exceeding any other technology in terms of impact. Many opportunities, therefore, exist for Botswana to become the authority in the R&D of certain wireless technology and applications, given the challenges that exist in the Botswana context. The appropriate access technologies focus area will comprise a long-term interdisciplinary group to conduct research in appropriate mobile, wireless and satellite technology. The R&D activities should also find application and linkages with a number of other initiatives, such as software engineering and application areas such as e-health.

The specific research areas will be on: ad-hoc wireless networks; software defined radios; mobile applications; and, telemetry.

The key application areas will be in the domains of:

- Call centres (especially in terms of infrastructure) and shared service provision to support economic competitiveness;
- The improvement of home and public connectivity to knowledge systems; and,
- Applications in e-health, both directly to the public and to health service providers in remote areas, e-education and e-government.

The aim of the focus area would be to create widely applicable communications platforms that are well suited to Botswana's needs. This should create opportunities for significant industry involvement and export opportunities to markets faced with similar telecommunication challenges.

Software engineering

The software industry is globally recognized as one of the industries with fairly low entry barriers in terms of capital and operations cost while delivering a significant multiplying economic effect (estimated at 1.7) on up and downstream business. The pervasive opportunities for software development and applications range from application in the quality of life domains (such as health and education) to industry creation and economic competitiveness (such as automation, software products and services.)

At the same time where a software business, even an industry, might be easy to start it is difficult to grow and sustain. The key issues to be addressed for sustainability are the steady stream and availability of appropriately qualified human resources and a solid understanding of the principles of software development, engineering and management. These issues cannot be addressed on a small scale, but need to build an appropriate level of skills and knowledge to impact positively on the sustainability of a software

industry and the quality of software applications developed for the Botswana environment.

The establishment of a software engineering focus area will play an important facilitating role in bringing together fragmented efforts in both industry and academia and provide the necessary focus to build a critical mass. The strategy is therefore to try to achieve critical mass in the area of software engineering with a focus on a few key research and application areas. The approach should be to develop technology platforms and appropriate human resources that can be applied in a number of areas that deal with software development and application.

The specific research areas will be: software engineering practices; software process improvement; open source methodologies; software architectures; and, human computer interface methodologies, including human language technologies.

The key application areas would be in the domains of:

- Support for the development of call centres (both in terms of infrastructure and interfaces) and shared service provision;
- The development of locally appropriate tools for the creation, consumption and distribution of content;
- Development of software products in support of e-tourism, e-government, e-health and e-education;
- e-enablement of small, medium and micro-enterprises;
- Development and implementation of new software products based on data warehouse, knowledge management and programming tools; and
- Information management systems to collate, store and disseminate knowledge.

The area of Free/Libre open source (FLOSS)[9] provides specific opportunities for countries such as Botswana. The centre could also provide specific support in the domain of open source, from advocacy, support and development perspectives. The open source focus should form a key part of the ICT centre.

Human sciences and policy research centre

Building capacity in the social sciences is important for national development. In the developing world, the need to work together in an interdisciplinary and systems-level fashion is critical. To this end, the development of capacity in social science should be regarded as important as R&D in the other areas of science and technology. A critical mass of appropriately skilled economists, sociologists, anthropologists, political scientists, public administrators, and other social-science professionals, with local contextual insight and international networks of expertise, are especially important for providing policy analyses, informing decision making, developing the S&T culture, building institutions, and maintaining the public-private interface necessary for S&T promotion. A Centre of Excellence focused on research relevant to the developing world context in general, and the Botswana context in particular, would build this critical mass.

[9] http://www.opensource.org/

Several areas in the human sciences and, in particular, in the policy domain have been identified for research investment. These include:

- Behavioural research in key areas such as on low CD4[10] cell count individuals;
- Policy research to support private sector involvement in service provision (e.g. water, waste and energy);
- Socioeconomic research into the removal of barriers to the use of renewable energy technologies and treated wastewater;
- Understanding the relationship between environmental impacts and socio-economic responses;
- Policy research to develop appropriate legislation to support manufacturing in Botswana; and,
- Improved legislation to support responsible mineral exploitation.

2.4 Line Research

Line Research refers to those areas of research which are needed to support the functioning of line ministries. The research in these institutions should focus on delivering in line with the relevant outcomes outlined in section 1.3. The following areas of particular relevance to the Ministries of Agriculture; Minerals, Energy and Water Resources; Wildlife, Environment and Tourism; Health; and, Communications, Science and Technology will be the focus of line research in Botswana:

Agricultural Research

The desired outcomes of agricultural research are: optimal allocation and use of agricultural resources, improved food production, increased diversity of the agricultural base and improved marketing and processing strategies creating sustainable jobs, profits and ecosystems. The following research has been identified to support these desired outcomes:

- Precision agriculture to reduce input costs and improve productivity;
- Research into new agricultural products (crops, animals, plants and wildlife) better suited to the ecosystems of Botswana;
- Range management research to support the sustainable management of rangeland-livestock interactions; and,
- Research into the improvement of existing crops and livestock including new plant varieties and livestock diseases.

Minerals Research

Botswana is exceptionally well endowed with mineral resources. Research in this area should aim at high value addition and beneficiation, bi-product utilisation, improved efficiency of current exploration and processing. Areas prioritised for research are:

- The use of novel exploration methods;
- Research into effective means of limiting and eliminating mine waste;
- Research into technologies that result in improved and safer mine structures;

[10] CD4 T cell - T cell with CD4 receptor that recognises antigens on the surface of a virus-infected cell and secretes lymphokines that stimulate B cells and killer T cells; helper T cells are infected and killed by the AIDS virus.

- Geomatics to support geological mapping and the identification of the nature and extent of Botswana's mineral resources;
- Adding value to the bi-products of mining; and,
- Development of new processes (better suited to Botswana's terrain) for mineral exploration.

Water Research

Botswana needs to seek a balance between water demand and supply and in so doing, ensure access to safe and adequate water supply and the sustainable management of existing water resources in Botswana. Research should focus on:

- Water resources management modelling (supported, where appropriate, by remote sensing technologies and data monitoring systems);
- Wastewater management research;
- Research into water treatment, including groundwater desalinisation;
- Research into water recycling and re-use;
- Research to support the identification of sources of water pollutants;
- Research to support the control of water loss; and,
- Geomatics to support water resources management through the mapping of the nature and extent of both surface and underground water resources.

Research to support Environmental Management

Environmental Management is a broad area and there will need to be a strong degree of collaboration between research programmes, centres and the ministry to ensure a healthy natural resource base that supports the livelihoods of existing and future generations of Batswana. Line research should include:

- Waste disposal, recycling and incineration research;
- The development of appropriate environmental monitoring systems;
- Risk assessment and disaster preparedness;
- The gathering, transfer and dissemination of environmental information to the public; and,
- Research on pollution control and waste minimisation (including mine waste).

Health Research

In addition to the health related issues identified in the Mission-focussed programmes and Centres of Excellence, Line Research should focus on the development of sport sciences and appropriate health monitoring systems.

Communications Research

The research areas specific to the Ministry of Communications, Science and Technology are:

- Strengthening of e-government services to the sector;
- Supporting the National System of Innovation (e.g. innovation and technology management, knowledge management);
- Development of a suite of instruments for leveraging research and strengthening the uptake of technology, through, for example, science parks, and industrial extension;

- Supporting the creation of a Futures Research function (technology tracking, technology foresight, technology roadmapping, competitive research, comparative advantage, emerging technologies etc); and,
- Supporting scarce skills development.

Energy Research

In addition to the energy-related issues identified in the mission-focussed programmes and Centres of Excellence, Line Research should focus on the development of:

- Energy for rural areas: and,
- A clear understanding of the linkages between the economy, energy and the environment.

2.5 Supporting Public-private Partnerships

Botswana has a low rate of market uptake of the outcomes of the research done in the country and output levels are below par for all forms of registered intellectual property and technology demonstrations (CSIR, 2005b). Indeed a wider search on all patents registered over the period 1994 to 2004 indicates that only 1 US patent and 4 EU patents were granted to Botswana citizens out of a total number of 20 applications. In the period 2001 to 2003 there were 3 PCT filings (equivalent to international applications).

To encourage an increased level of uptake of research, in addition to encouraging the application of appropriate output targets and measures, this Plan endorses the four public-private partnership funding models proposed by the Ministry of Communications, Science and Technology (2004, unpubl. memo) whereby matching funding is provided through an Innovation Fund to support collaborative research, in the form of:

- *technology Linkup Grants* – aimed at increasing the awareness of, and facilitating access to, technology or technology capabilities new to the private sector;
- *grants for Private Sector R&D* – aimed at increasing the number of successfully commercialised products, processes and services through increased levels of enduring R&D investment within firms;
- *technology Fellowships for Industry and Business* – fellowships to employees in private firms to build an enhanced level of S&T-based human capital within commercial R&D environments; and,
- *public-Private Research Consortia* – investment partnerships between private sector firms and the Government leading to successfully commercialised, high technology, high value products, processes and services through targeted R&D.

Several countries[11] have successfully used tax concessions to encourage more private sector investment in R&D. In addition to the collaborative funds mentioned above, a tax concession to increase the level of R&D being conducted by Botswana companies along similar lines to those instituted elsewhere should be instituted[12]. This concession should be broad-based and market driven with the applicants having sole discretion on the

[11] For example USA, Canada, Ireland and the United Kingdom.

[12] For example, Australia – see http:/www.ato.gov.au/large/pathway.asp?pc=001/009/023&sf=1

scope and timing of the research. Applicants will be eligible to a rebate for eligible expenditure incurred from assessable income on submission of their income tax returns. (Further details are provided in section 7.3).

The expected outcome of the public-private partnership incentives outlined above is the stimulation of commercialisation and entrepreneurship in the National System of Innovation coupled with an increased recognition of the value of innovation to business in Botswana.

This section has presented priorities for research in Mission-focussed Programmes, Centres of Excellence and Line Research programmes. Mechanisms to encourage greater public uptake of research have also been recommended. A key condition for research uptake by the market is its relevance to the needs of society. Section three provides an overview of the relationship between the identified research priorities and Botswana's needs and priorities.

3 RELATIONSHIP BETWEEN PRIORITY AREAS FOR INVESTMENT AND NATIONAL GOALS

The priority areas for investment in research have been presented in Section 2 of this Plan. This section describes how these priorities are related to the goals set in Vision 2016, NDP 9 as well as current national policies.

3.1 Vision 2016

Botswana's development since 1997 has been guided by Vision 2016 which sets high level goals for the nation, identifies major challenges for achieving them, and proposes strategies to meet the challenges (Presidential Task Force, 1997). The key aspirations of the Nation for 2016, which will mark 50 years since the attainment of independence, are that Botswana will be:

i) an educated, informed nation;
ii) a prosperous, productive and innovative nation;
iii) a compassionate, just and caring nation;
iv) a safe and secure nation;
v) an open, democratic and accountable nation;
vi) a moral and tolerant nation; and,
vii) a united and proud nation.

The goals of Vision 2016 guide all aspects of national planning, and form the basis of government policies and development plans. The achievement of the goals depends on the effective implementation of development programmes and policies through improvements in productivity, as well as through scientific and technological innovation which can provide a comparative advantage for the country in specific sectors.

The first three goals listed above (an educated, informed nation; a prosperous, productive and innovative nation; a compassionate, just and caring nation) are particularly relevant to the development of S&T. The first goal seeks to ensure that the economic, educational, legal and institutional system will empower citizens to become innovators and the best producers of goods and services, and produce entrepreneurs who will create employment through the establishment of new enterprises. It also aims to ensure that the country will have acquired the best available information technology and become a regional leader in the production and dissemination of information, acquired communications capacity, particularly in the electronic media, radio and television, and improved access to the operations of the Government, private sector and other organisations.

The second goal of creating a prosperous, productive and innovative nation, will be reflected through sustainable economic growth and diversification, the protection of the environment, and improvements in per capita incomes, increase in employment, and access to decent housing and shelter. This goal requires that Botswana supports creativity and will actively contribute to the scientific and technological civilisation of the future. It is envisaged that prosperity, productivity and innovation will be achieved through

sustainable economic growth and diversification, the sustainable use of natural resources, as well as increases in incomes, employment and access to shelter.

The third goal of creating a compassionate, just and caring nation, will be reflected through better income distribution, supporting the poor, providing social safety nets, providing access to health and supporting people infected and affected by HIV/AIDS.

Vision 2016 envisages that the strategy for building an educated and informed nation will include attaining universal and compulsory education up to secondary level, improving the quality of education and aligning it with the needs of the job market, improving access to information, and establishing a body to oversee research.

The strategy for building a prosperous, productive and innovative nation includes the strengthening of monitoring mechanisms, the setting of quantifiable targets and implementation schedules, the establishment of new industries based on the country's natural resources, improvements in the use of natural resources, as well as performance-based pay and monitorable performance objectives for senior civil servants.

The strategy for building a compassionate, just and caring nation includes creating sustainable jobs and enterprises, providing support to households in need, and the review of policies to improve equity and their effectiveness, the provision of adequate health facilities, the control of infectious diseases, and stopping the spread of AIDS.

Table 3.1 outlines the ways in which the research outlined in this Plan will support Vision 2016 in the various socio-economic sectors of Botswana.

3.2 National Development Plan

Botswana's past and current development plans, which outline the medium term development objectives, have been based on the principles of Democracy, Development, Self-reliance and Unity. Their common objectives have been to achieve rapid economic growth, social justice, economic independence and sustained development.

The key themes of NDP 9 which will be supported by research are economic diversification, employment creation, public sector reform including privatisation, environmental protection, rural development, human resource development, disaster management, HIV/AIDS, and S&T development. Research in agriculture, eco and cultural tourism, manufacturing, and mining will contribute towards both economic diversification and employment creation. Environmental protection will be enhanced through research on water, energy and other natural resources. The improved management of HIV/AIDS will result from research in health as well as in agriculture through improved nutrition. Research on climate change as well as on environmental management will assist in dealing with natural disasters. The development of the rural areas will be assisted through research and innovations in agriculture, eco and cultural tourism, environmental protection, water, and energy.

Table 3.1: Contribution to Vision 2016 of planned research in various sectors of Botswana.

SECTOR	PLANNED OUTCOME OF RESEARCH	CONTRIBUTION OF RESEARCH TO VISION 2016	CONTRIBUTING RESEARCH PLATFORMS
Agriculture	The optimal allocation and use of agricultural resources, improved food production, increased diversity of the agricultural base and improved marketing and processing strategies creating sustainable jobs, profits and agro-ecosystems	Research in this sector will contribute towards Vision 2016 of a prosperous, productive and innovative nation by creating a productive, profitable and sustainable agricultural sector.	Line Research in agriculture. Research in the Centre of Excellence for Indigenous Knowledge and Technology systems. Mission-focussed research in geomatics.
Eco and Cultural Tourism	Sustainable jobs, profits and ecosystems as well as optimal linkages to other sectors as a result of integrated and effective marketing strategies, biological diversity conservation in tourism areas, the increased participation of Batswana in tourism, and satisfied clients.	Research in this sector will contribute towards the Vision 2016 objective of creating a prosperous, productive and innovative nation by diversifying the economy through tourism	Line Research in environmental management. Mission-focussed research in ecosystems. Research in the Centre of Excellence for Indigenous Knowledge and Technology systems. Research done in the Human Sciences and Policy Centre of Excellence. Mission-focussed research in geomatics.
Energy	Ensure a balance between energy supply and demand and access to sustainable renewable energy for all consumers in Botswana	Research in this sector will contribute towards Vision 2016 goal of creating a prosperous, productive and innovative nation by promoting the use of renewable natural resources.	Line Research in energy. Research within the Energy Centre of Excellence. Research done in the Human Sciences and Policy Centre of Excellence.

SECTOR	PLANNED OUTCOME OF RESEARCH	CONTRIBUTION OF RESEARCH TO VISION 2016	CONTRIBUTING RESEARCH PLATFORMS
Health	To improve Botswana's ability to reduce and prevent the spread of infections and disease, access to affordable health services, and an informed nation on health matters.	The research will contribute towards achieving the Vision 2016 objective of creating a compassionate and caring nation by addressing unexpected epidemics, and the breakout of new diseases; promoting the use of traditional healing systems in cooperation with modern practices, within the framework of modern law; and providing adequate nutrition to all citizens	Line Research in health. Research in the Infectious Diseases Centre of Excellence. Research done in the Human Sciences and Policy Centre of Excellence. Research in the Centre of Excellence for Indigenous Knowledge and Technology systems. Mission-focussed research in the biosciences. Mission-focussed research in geomatics. Mission-focussed research in manufacturing, engineering and infrastructure.
Housing and Construction	The provision of decent, affordable, safe, durable, energy and water efficient accommodation through the use of local resources.	Research in this sector will contribute to the Vision 2016 goal of a prosperous, productive and innovative nation by helping to ensure that Batswana have access to good quality shelter.	Mission-focussed research in manufacturing, engineering and infrastructure.
Manufacturing	A resilient and diversified economy as a result of the extraction of maximum benefit from the value chain resulting in increased employment	These research areas will support Vision 2016 objectives of creating a prosperous, productive and innovative nation through sustainable growth and diversification including in agriculture,	Mission-focussed research in manufacturing, engineering and infrastructure.

SECTOR	PLANNED OUTCOME OF RESEARCH	CONTRIBUTION OF RESEARCH TO VISION 2016	CONTRIBUTING RESEARCH PLATFORMS
		manufacturing and the tourism sector. This will in turn contribute towards poverty alleviation, food security, the improvement of the quality of life and the sustainable use of natural resources	Research in the Centre of Excellence for Indigenous Knowledge and Technology systems.
Media, Education and Human Resource Development	Improved access to information, skills and knowledge and a well informed, educated and innovative nation.	Research relating to Media, Education and Human Resource Development, including on the curriculum and skills, the improvement of connectivity to knowledge systems, is expected to contribute to improved access to information and knowledge and help to create a well informed, educated nation.	Line research relating to communications. Research done in the Information and Communications Centre of Excellence.
Mining	Improved value addition and beneficiation, bi-product utilisation, improved efficiency of current processing, the use of novel exploration methods, and increasing employment and incomes.	Research in the mining sector should aim to contribute to improved value addition. These research areas will help to meet the Vision 2016 objectives of creating a prosperous, productive and innovative national through sustainable economic growth and diversification and the protection of the environment. Sustainable economic growth and the sustainable use of natural resources will be achieved by promoting diversification in the mining sector and improving the efficiency of the use of natural resources respectively.	Line Research in mining. Mission-focussed research in processing and mining. Mission-focussed research in geomatics.
Service Industry	Increased access to and improved efficiency of services resulting in improved quality of life and job creation.	The research will contribute towards achieving the Vision 2016 objectives of an educated, informed nation and a prosperous, productive and innovative nation through the development of technologies in the ICT arena as well as through policy research to support private sector involvement in service provision	Research done in the Human Sciences and Policy Centre of Excellence. Line research in communications.
Software	Improved efficiency and effectiveness in	Research supporting the software industry is	Research done in the Information and

SECTOR	PLANNED OUTCOME OF RESEARCH	CONTRIBUTION OF RESEARCH TO VISION 2016	CONTRIBUTING RESEARCH PLATFORMS
Industry	the broader economy and create new employment opportunities.	expected to lead to improved efficiency and effectiveness in the broader economy and create new employment opportunities. Research in this area will support the Vision 2016 objective of creating an educated and informed nation because it will help Botswana to enter the information age, and make information on the operations of the Government freely available and enable access to the use and application of electronic information systems.	Communications Technology Centre of Excellence.
Transport and Logistics	A cost-effective, efficient, safe, secure, and environmentally friendly sector resulting in improved service delivery, integrated planning, and improved infrastructure.	An efficient transport system is essential for economic development. The research in this area will contribute towards achieving the Vision 2016 objective of a prosperous, productive and innovative nation.	Mission-focussed research in geomatics. Line research in communications.
Water	Ensure a balance between water demand and supply, access to safe and adequate water supply and the sustainable management of existing water resources in Botswana	Research in this sector will contribute towards Vision 2016 goal of creating a prosperous, productive and innovative nation by limiting the pollution of water.	Line Research in water. Mission-focussed research in geomatics. Mission-focussed research in ecosystems. Research done in the Human Sciences and Policy Centre of Excellence.

The objectives of NDP 9 are consistent with the themes of Vision 2016 in regard to creating an educated, informed nation; creating a prosperous, productive and innovative nation; and, creating a compassionate, just and caring nation.

3.3 National Policies

There is synergy between various national policies which are relevant to S&T and NDP 9. These policies address agriculture, energy, health, wildlife, water, education, settlement, housing, population, tourism, culture, industrial development and privatisation (CSIR, 2005b). Themes that are common to most of the policies include:

- the promotion of a sustainable form of development (long term development that meets the needs of current and future generations of Batswana);
- the improvement of the quality of life of Batswana;
- the conservation of the environment;
- diversification of the economy;
- value addition to local products and sectors;
- national human resources development;
- job creation;
- resource security; and,
- increased citizen participation and economic empowerment.

The priority research areas will also advance the implementation of the policies which are related to S&T.

The research in eco and cultural tourism is consistent with the Tourism Policy (Republic of Botswana, 1990a), some of whose objectives are to create employment and to stimulate the provision of other services in other parts of the country. It is also consistent with the objectives of the National Policy on Natural Resource Conservation and Development (Republic of Botswana, 1990b) which advocates the conservation of all main ecosystems, wildlife and cultural resources as well as the improvement of the value derived from natural resources; as well as the National Policy on Culture (Republic of Botswana, 2001) which seeks to protect the cultural heritage as well as intellectual property.

The research in manufacturing is consistent with the objectives of the SMME policy (Republic of Botswana, 1999) one of whose objectives is to create sustainable employment opportunities and to achieve economic diversification, as well as the Industrial Development Policy (Republic of Botswana, 1998b) which encourages the development of highly productive and efficient export industries based on the country's natural resources.

The research envisaged in agriculture is consistent with the National Policy on Agricultural Development (Republic of Botswana, 1991) and the National Master Plan for Agriculture and Dairy Development (Republic of Botswana, 2002), some of whose objectives are to diversify the agricultural sector production base, commercialise small

scale farming, improve household security and conserve scarce agricultural and land resources.

Research contributing to media, education and human resource development supports the objectives of the Revised National Policy on Education (Republic of Botswana, 1994) as well as the National Policy on Vocational Education and Training (Republic of Botswana, 1997b) which aims to emphasise S&T in the education system and to deliver skills that meet high standards and quality targets.

Research on energy will support the envisaged Energy Policy (Republic of Botswana, 2005c) by improving access and affordability and ensuring environmental sustainability of energy supply.

The priority areas for research also specifically support the objectives of the Science and Technology Policy (Ministry of Finance and Development Planning, 1998) which are to:

- Support the commerce and industry sector through application of S&T; to increase the national capacity for industrial production and economic growth; raise the quality and variety of products for local consumption and export; promote commercial and scientific marketing methods for locally produced goods; to facilitate the creation of alternative engines of growth via the industrial sector and to support small and medium scale business policy development initiative.
- Develop adequate human resource capacity with an optimum mix of capabilities to generate and apply S&T based on the needs of industry and the society.
- Cultivate and nurture a culture of S&T in all sections of the society.
- Research, develop and promote the supply, availability and utilisation of affordable, efficient, sustainable and environmentally friendly energy sources and technologies.
- Develop and strengthen educational activities, research programmes, technologies, and measures aimed at promoting environmental protection and conservation of the country's natural resources and biological diversity for sustainable development.
- Support S&T for the improvement of health and the overall physical, social and mental wellbeing of the population.
- Develop institutional capacity and to promote meteorological R&D with focus on enhancing agricultural production, aviation, environmental and natural resources conservation.
- Promote environmentally sound exploration and utilisation of mineral resources for the benefit of the nation through appropriate diversification of industries.
- Support and promote S&T activities related to population and human settlement planning and management, and facilitate efforts to improve and maintain good health and raise the quality of life of the population.
- Promote and support relevant S&T activities for the advancement of tourism to contribute more effectively to the diversification of the country's economic base, conservation and sustainable utilisation of natural resources, cultural heritage and monuments.

- Promote and support S&T activities for the enhancement of the transport and communication sector in Botswana, through R&D, and involvement of the private and public sectors.
- Promote S&T applications to improve the quality, quantity, efficient and effective utilisation and conservation of ground and surface water and adaptation of appropriate technology, with the aim of providing a secure water supply to the entire nation, and to provide water for other developmental applications.
- Promote and support relevant S&T applications for conservation, management and sustainable utilisation of wildlife.

This section has shown how the research will support Botswana's national vision and development goals. Section four considers the human resources that will be required for the implementation of the Plan.

4 HUMAN RESOURCES REQUIRED TO IMPLEMENT THE PLAN

Key to the implementation and ultimate success of this Plan is the quality of the S&T workforce. This section describes the current Botswana S&T human resources capacity, provides an overview of the future human resources requirements needed to implement the Plan and defines the strategies required to ensure that these future requirements are met.

4.1 Current HR situation

The key features of human resources in S&T institutions in Botswana include the small base of researchers, the small growth in the number of researchers, the low GERD (gross expenditure on R&D as a percentage of GDP) per researcher and a significant number of female researchers (CSIR, 2005b).

In comparison with similar countries, the Botswana S&T resource base is very small with about 2,165 employees within the S&T system. Not only is the absolute number small, but the proportion of R&D personnel as a percentage of total employment is below the optimal level at less than 2.7 researchers per 1000 employed (See Figure 4.1).

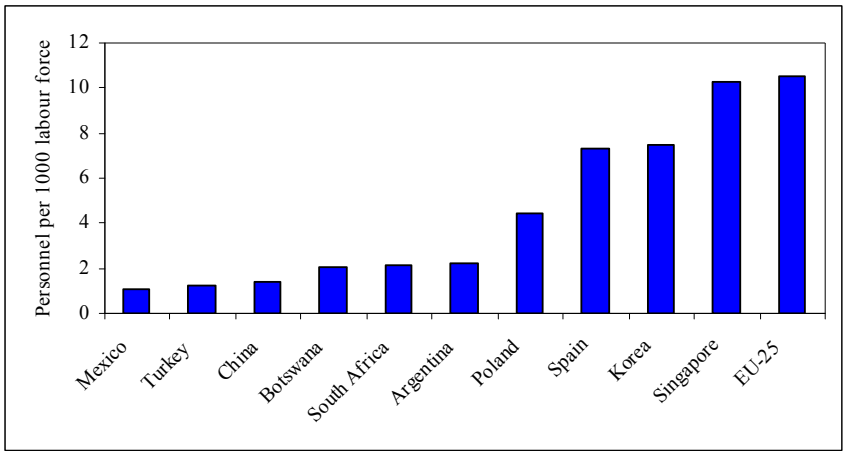

Figure 4.1: Country comparison of R&D personnel per thousand total employment (2003/4).

There is little indication of growth in these numbers and ratios, despite a relatively healthy supply of graduates within the system. Figure 4.2 shows that 27 % of students in tertiary institutions are enrolled in science, mathematics and engineering. The growth in the enrolment numbers in the sciences and engineering disciplines illustrated in figures 4.3 and 4.4 further indicates a healthy supply of graduates within the system. (About 300 graduates with a S&T based degree enter the job market each year from the University of Botswana. With a typical turnover rate of 10% per year, the projections are that 550 new graduates will be available to the system in 5 years.) Apart from the University of Botswana, the other relevant training institution in the country is the Botswana College of

Agriculture whose enrolment in 2003 was 1,178 students (CSO, 2005). It is envisaged that a second university with a curriculum focusing on science and technology will be built during NDP 9 and a Faculty of Medicine and Applied Health Sciences established at the University of Botswana (Republic of Botswana, 2005a). The supply of S&T graduates from Botswana institutions is augmented by students who acquire qualifications from outside Botswana. Since 2000, over 1,400 scientists and engineers have graduated from institutions abroad (See Appendix 2).

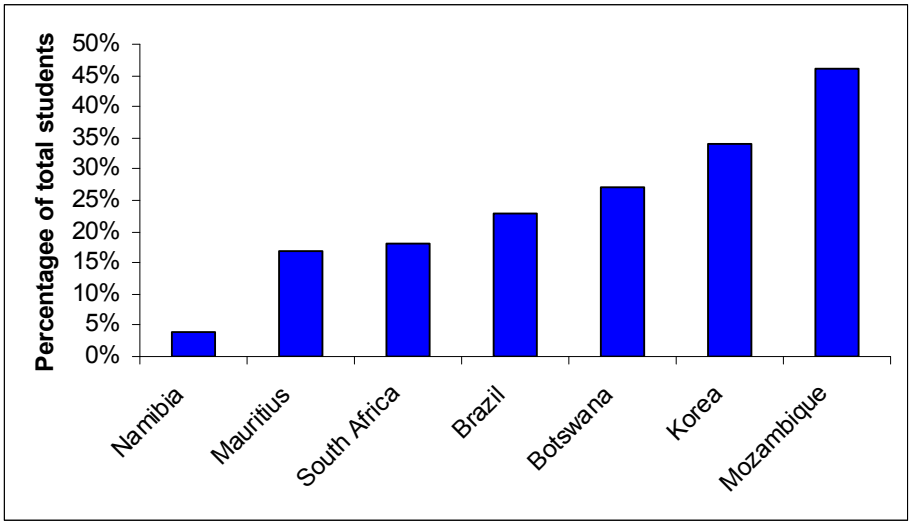

Figure 4.2: Tertiary students in science, mathematics and engineering (% of all tertiary students) 1994-97 (UNESCO).

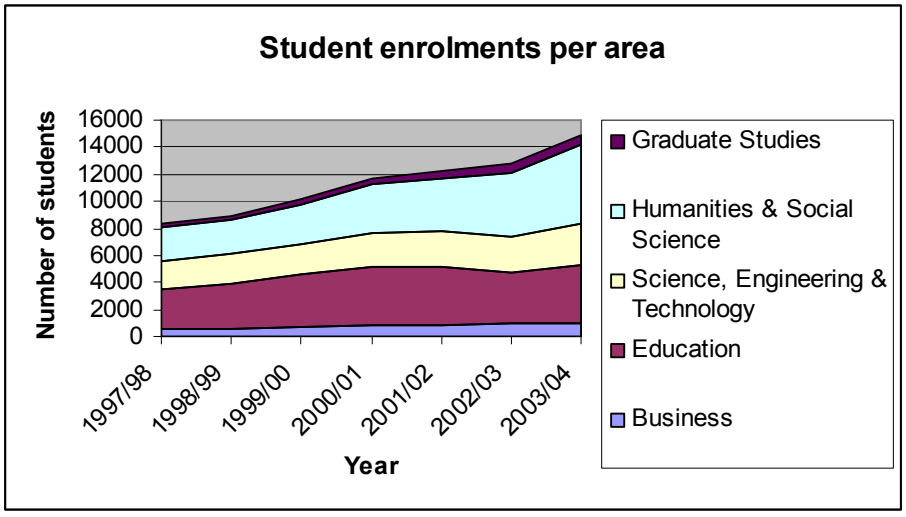

Figure 4.3: Total enrolment numbers at University of Botswana 1997–2004.

Source: University of Botswana Annual Report 2003-2004

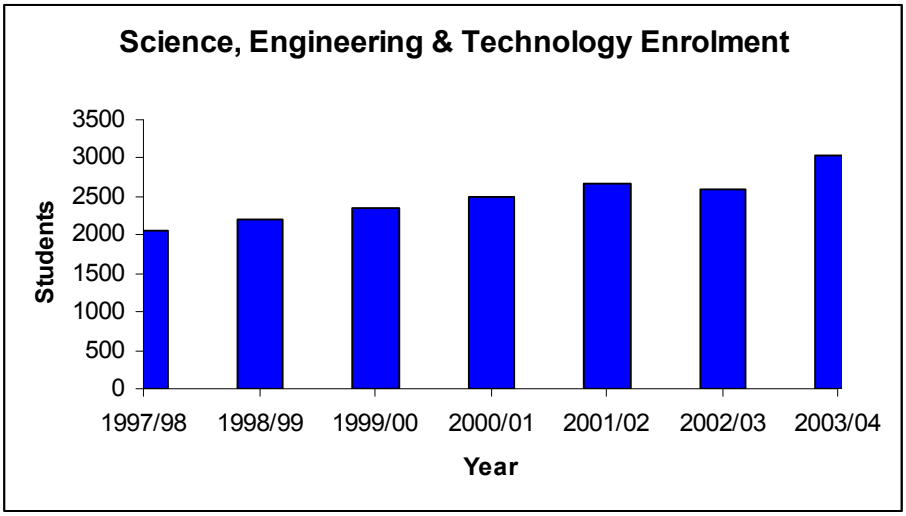

Figure 4.4: Enrolment for science, engineering & technology at University of Botswana 1997-2004.

Source: University of Botswana Annual Report 2003-2004

Table 4.1 shows that the pass rate of graduates in University of Botswana Faculty of Science in 2003/4 and 2004/5 was good and on par with other tertiary institutions. Despite that, concern has been expressed about the employability of graduates and the relevance of some programmes to market needs (Tertiary Education Council, 2005).

Table 4.1: UB Faculty of Science pass rates (2003/4 – 2004/5) [13]

PASS CLASSIFICATION	2003/4 %	2004/5 %
First Class	9.3	4.4
Second Class (First Division)	29.1	24.8
Second Class (Second Division)	48.8	61.9
Pass	12.7	8.8

[13] Based on data provided by the University of Botswana Faculty of Science

The total GERD per researcher is comparatively low despite the relatively high proportion of PhD and MSc employees (at least 48% of the total R&D staff possesses a qualification at MSc or PhD level vs 34% in South Africa) (CSIR, 2005b).

Botswana has a significant number of female researchers. Currently women constitute 29% of R&D workforce. Although this figure compares well with countries such as Republic of Korea (12%) and Zambia (14%), South Africa (37%) and Poland (38%), the country needs to encourage more female researchers to follow a research career path and thus contribute to growing the R&D sector (CSIR, 2005b).

Various global indicators have been developed to evaluate S&T human resources capacity. Three indices (Table 4.2) highlight specific issues regarding human resources within the science system, namely:

- **Science and Technology Capacity Index (STCI**): Science and technology capacity is defined as the ability of a country to absorb and retain specialised knowledge and to exploit it to conduct research, meet needs, and develop efficient products and processes[14]. The STCI is a composite index which includes three components on internal capacity (R&D expenditures, number of scientists and engineers, production of knowledge-intensive products) and three components on external linkages (number of scientific publications, number of patents filed, infrastructure and communication facilities).
- **Technology Achievement Index (TAI)[15]:** The TAI is the measure of a country's achievements in four areas: technology creation, diffusion of recent innovations, diffusion of old innovations and human skills.
- **Technological Capabilities Index (ArCo Index)[Archibugi and Coco, 2004]:** The ArCo Index takes into account the three main dimensions of technological capabilities: creation of technology, diffusion of technology and the development of human skills.

[14] "Can Science and Technology Capacity be Measured", CS Wagner, E Horlings an A Dutta, 2003

[15] The TAI was first introduced in the UNDP 2001 global Human Development Report on "Making New Technologies Work for Human Development". However, due to lack of data, a TAI was not calculated for Botswana. Subsequently the Botswana Human Development Report 2005 has calculated the TAI for Botswana at 0.377, which places Botswana at about 35th place in 2001.

Table 4.2: International indices related to human capital development in Botswana.

Index	Category score range	Classification	Comparative Countries (score) [ranking]
Science and Technology Capacity Composite Index (STCI) RAND]	1 - 5	Scientifically Advanced	*United States (5.03)*
	0 - 1	Scientifically Proficient	*South Africa (0.04)*
		Scientifically Developing	*Mauritius (-0.22)*
		Scientifically Lagging	**Botswana (-0.45)** Oman (-0.45), Jamaica (-0.45), Lebanon (-0.465), Nigeria (-0.47), Kenya (-0.472).
Technology Achievement Index (TAI)16[UNDP]:	TAI > 0.5	Leaders	*Finland (0.744), USA (0.733)*
	0.35 – 0.49	Potential Leaders	**Botswana (0.377) [35]** Argentina (0.381), Romania (0.371), Costa Rica (0.358)
	0.2 – 0.34	Dynamic Adopters	*South Africa (0.343)*
	TAI < 0.2	Marginalised	*Kenya (0.129)*
Technological Capabilities Index (ArCo Index)	0.5 – 1.0	Leaders	*Finland (0.83)*
	0.393 – 0.49	Potential Leaders	*Argentina (0.426)*
	0.225 – 0.392	Latecomers	**Botswana (0.254) [103]** Zambia (0.240), Egypt (0.269), Mauritius (0.284), South Africa (0.372)
	0 – 0.224	Marginalised	*Uganda (0.134)*

The relative positioning of Botswana suggested by these indicators implies the following:

- The prevalence of old technologies, with little evidence of innovation, showing a delay in the technology diffusion;
- Botswana falls within the category of countries that are below the international mean for most of the components of the S&T-related indices;
- The category in which Botswana falls represents countries with generally high skills levels (although these skills may be few in number), and evidence of growth in the creation of human skills; and
- In many cases, countries similar to Botswana have little or no capacity to conduct international level science.

[16] Botswana Human Development Report 2005

4.2 Future human resource requirements

The estimation of future human resource requirements is based on international benchmarks, the new institutional structures which will be established (i.e. Centres of Excellence), as well as the anticipated growth in research activities.

Assuming an increase of research funding to at least 1% of GDP during the next five years (see Section 7) and based on the average investment required per full time equivalent (FTE) researcher this translates to 2,565 (FTE) researchers in five years, an increase of 400 researchers.

This envisaged growth should be attainable given the number of graduates from the University of Botswana, the Botswana College of Agriculture as well as graduates from training institutions outside the country. If the graduation rates remain constant and on the basis of a typical turnover rate for R&D personnel of 10 % per year, the projections are that over 350 new Botswana graduates (over and above the graduates replacing the personnel that leave the NSI) will be available for recruitment annually in the next five years. Supply factors with regard to graduates with first degrees in science, engineering and technology do not pose a major constraint on the anticipated growth. Where they play a role is in the area of prost-graduate qualifications. Even though the current R&D personnel are relatively well qualified, the enrollment and completion rates for higher degrees in the S&T area are not sufficient, negatively impacting on the ability to fill senior research positions within research institutions. External recruitment might be needed to augment the flow of Batswana into National Research Institutions.

Five Centres of Excellence are envisaged (See Section 2). Using international experience as a guideline, a critical mass of R&D skills for a recognised Centre of Excellence comprises approximately twenty full time researchers (senior research leader, two to three senior researchers, 9 to 10 researchers and 7 to 10 entry level researchers). The full-time employees of these centres are typically complemented by 5 to 10 temporary research staff, such as PhD and masters level students and visiting researchers. The total permanent staff complement for the envisaged centres will be about 200-250. This number will be made up of both new and existing staff currently employed by existing S&T institutions in Botswana.

Table 4.3 summarises the projected impact of the RST Plan on future human resources needs.

Research requires the development of human resources. In the early years of implementation of the Plan, research programmes will need to budget for and provide opportunities for post-graduate training and competence development.

Attention needs to be given to the retention of current capacity and the attraction of senior level skills within the areas of research identified in the Plan, as well as the productivity and research competence of available resources. A good research environment increases the likelihood of excellent research and research productivity and influences both the retention and attraction of senior level skills. Numerous studies (eg Ulwadia (1990), Ransley and Rogers (1994), Altschuld and Zheng (1995) and Jordan *et*

al (2003)) have identified a number of key attributes of excellent research environments. In terms of HR development, a few common attributes that are relevant to this plan are:

1. quality of colleagues;
2. research leadership and strong research competencies;
3. sufficient support staff;
4. opportunities for professional development;
5. reward and recognition schemes;
6. access to appropriate facilities and knowledge sources; and,
7. sufficient, unfragmented research funding.

Although an assessment of the impact of HIV/AIDS on human resources in S&T institutions has not been undertaken as part of the development of this Plan, it is recognised that the pandemic is likely to have an impact on human resources. The national indicators of HIV/AIDS, such as prevalence, life expectancy and the incidence of associated diseases suggest that the pandemic affects a large number of people (Central statistics Office, 2004b). All institutions, including those that deal with S&T, are likely to be affected through absenteeism, low productivity, as well as the loss of qualified and experienced staff.

Table 4.3: Projected impact of the National Research Science and Technology Plan on future human resource needs

INITIATIVE	FOCUS	HR IMPLICATIONS AND NEEDS	PROJECTED HR NEEDS
1) Mission-focussed Programmes	Five competitive Mission-focussed Programmes: Ecosystems; manufacturing, engineering and infrastructure; processing and mining; geomatics; and biosciences.	In order to participate sensibly in these Mission-focussed Programmes, adequate research capacity must exist within the bidding consortia. A typical programme in this area will require 6-15 research staff with more than half of these with PhD and masters-level qualifications. In some cases new skills might be required, indicating a need to work closely with tertiary education institutions to influence curriculum choices and post-graduate enrolment.	Building on existing institutions. Expansion over 3 years estimated at 100 researchers.
2) Centres of Excellence	Five Centres of Excellence are envisaged under the proposed plan: energy for the future, infectious diseases, indigenous knowledge and technology systems, ICT and human sciences and policy research.	Using international experience as a guideline, a critical mass of R&D skills for a recognised Centre of Excellence comprises approximately twenty full time researchers (senior research leader, two to three senior researchers, 9 to 10 researchers and 7 to 10 entry level researchers). The full time employees of these centres are typically complemented by 5 to 10 temporary research staff, such as PhD and masters-level students and visiting researchers. In some cases new skills might be required, indicating a need to work closely with tertiary education institutions to influence curriculum choices and post-graduate enrolment.	With the five Centres of Excellence envisaged, the total permanent staff complement will be in the order of 200. This number will be made up of both new and existing staff currently employed by existing S&T institutions in Botswana.
3) Existing Research Providers	Institutional changes, including mergers, and the upgrading of skills in national institutions for research leadership	The consolidation of activities and structural changes are aimed at creating a critical mass of resources in specific areas.	With the institutional changes, the estimated growth in staff complement will be in the order of 15 senior researchers in the existing research organisations over the next 3-5 years.

Monitoring and understanding the health and vitality of the S&T human resources are in the national interest. An essential intervention in this regard is the availability of reliable, up-to-date data to enable the measurement of the efficacy of the Plan or to identify new areas for intervention. The Department of Research, Science and Technology, in partnership with the Ministry of Education, the Ministry of Finance and Development Planning, the Ministry of Labour and Home Affairs and the Ministry of Trade and Industry, should establish and continuously update a systems model of the S&T HR pool and associated data sources. This will ensure that timely interventions are made with regard to the required numbers of personnel, their areas of competence and productivity of the S&T HR pool.

4.3 Strategies for growing national HR capacity through research leadership

There are at least two different skills and knowledge levels that are of strategic importance: the senior or research leadership level and the entry or competence development level. These levels require different strategies and activities to flourish (Table 4.4).

Table 4.4: A framework for managing the development of human resources

FOCUS	ACTIVITIES			OUTCOMES
Senior/leadership level	Developing and growing current capacity	Leveraging national resources more effectively	Leveraging international resources	▪ Absorptive capacity & growth ▪ Research leadership
Entry/competence development level	Appropriate skills within system Flow of new talent into system			▪ Supply & growth ▪ Performance capacity

The relatively small size of the S&T HR pool and the little evidence of strong, internationally recognised research leadership across the whole NSI hampers the growth in absorptive capacity. The proposed interventions to address this issue rest on three pillars for success:

1. developing and growing the existing resources and current capacity (retooling and growth);
2. maximising the utilisation of scarce resources within the country, e.g. the use of the network recruitment approach and joint appointments; and,
3. leveraging international external capacity at senior levels, e.g. through utilisation of grants for the purpose of international exchanges and partnerships such as the EU Marie Curie mobility instruments.

Tied to these three pillars, attention needs to be given to the traditional HR management issues of retention of current capacity and attraction of senior level skills within the areas of R&D identified in the Plan, as well as the productivity and research excellence of the available resources.

Research leadership is a key factor in building a sustainable S&T HR pool. Often the presence of a few passionate research leaders can influence the success of national S&T growth positively. Research often takes years to produce useful results. The presence of world-class research leaders is critical to accelerate this process, initiating new research and sustaining on-going activities. Their presence also plays a key role in the attraction, training and retention of a new generation of scientists and often serves as the human link across projects and institutions.

In terms of developing and growing existing resources and current capacity, the current and planned programmes that support upgrading of the qualifications of existing researchers and employees within S&T institutions to PhD and MSc level should be strengthened both from a dedicated funding and measurement and reward perspective.

A national researcher ranking and recognition framework and attention to professional registration provides additional recognition within the NSI, especially at senior levels. Attention should be given to the establishment of such a national researcher ranking system to be managed by the Department of Communication, Science and Technology.

Given the size of the Botswana NSI, traditional HR strategies of attraction, retention and mentorship focusing on current resources will not be sufficient to achieve growth on its own. Approaches that maximise the utilisation of existing national resources across institutional boundaries need to supplement the strategies of attraction and retention. Utilising and strengthening formal mechanisms for researcher mobility, such as joint appointments between academic institutions and (Research and Technology Organisations (RTOs), should be supported to assist in leveraging scarce national resources more effectively. An example of this type of intervention is to require that the research leader of a Centre of Excellence should be appointed jointly by the relevant RTO housing the Centre of Excellence and the tertiary education institution (TEI) providing the relevant training in the Centre of Excellence competence area. This will allow the Centre of Excellence to influence, through teaching and promotorship, the quality and relevance of the resultant qualifications produced at the TEI and, at the same time, provide key capacity to the TEI to promote research leadership. Current and planned activities such as industry research chairs fall into the same category. Other approaches to growing capacity in the country could include the use of retired researchers for mentorship, structured post-graduate as link to HEI and structured internships as link to industry.

National human resources development (NHRD) in the S&T domains has very strong international dimensions which have both positive and negative impacts. For example, the issue of the brain drain is a reality that most developing nations (and even developed nations) face. Understanding the dynamics of issues such as the brain drain, its causes and effects and addressing key issues within these challenges, the international dimensions can add significantly to building and maintaining the national S&T capacity.

Leveraging international resources has a number of aspects relevant to the Plan. These include, strategies to access incoming expertise to build research leadership, building

and leveraging international networks and Batswana abroad and managing issues of the brain drain.

Where there is a lack of research leadership within the NSI, specific action needs to be taken to source the relevant expertise at senior level from international resources. Part of this strategy is a specific focus on appropriate funding sources for researcher mobility[17] and bi-lateral political agreements. The aim of these strategies is twofold. In the short term it creates the needed research leadership that will attract not only the appropriate human resources, but also open doors for collaborative research projects with their originating institutions. Secondly, incorporated into the human capital development plans for Centres of Excellence, for instance, there should be a strong focus on succession planning, utilising the international skills to build Botswana's own resources.

The Botswana-Harvard AIDS Institute Partnership illustrates the ability of international partnerships to build S&T capacity within Botswana. Building on these types of partnerships and actively engaging in other regional initiatives should produce similar results in other areas of research. These physical collaboration foci should be extended with virtual international (with an emphasis on regional and continental) networks of excellence, each anchored in a physical Centre of Excellence nationally. These virtual networks of excellence are enabled by new communications technologies, linking and creating synergies between research efforts and individuals, geographically dispersed, but focusing on the same area of research or societal challenge.

Policies addressing the brain drain and researcher mobility should be created and managed in a holistic fashion to address key issues within the NSI. A number of international examples of such approaches exist. Countries such as Singapore, through conscious effort, benefited significantly from placing their professionals in research institutions and corporations abroad. Not only does this provide a way to access emerging technology, financial resources and physical capital, but it also facilitates collaboration between individuals and institutions from both advanced and developing countries. Methods to seed and foster these expatriate initiated collaborations are seen as a highly effective means to develop capacity. Strengthening links with expatriate scientists and engineers should therefore be given a high priority. In this way, the decision of an individual scientist to reside abroad should not be seen as a total loss for the country, but turned into a potential asset.

The benefits of international linkages for capacity building are often realised only if specific, focused attention is given from government level to the subject. The Ministry of Communication, Science and Technology should create a specific role that focuses on leveraging international research collaboration with a strong focus on researcher mobility and access to international research and development funding.

[17] The Marie Curie researcher mobility instrument of the European Union is a good example of such a strategy.

4.4 Strategies for recruitment and retention of new skills

The focus on the senior level of staff to address the growth in absorptive capacity is complemented by other activities at the entry or competence building level. In this area, the focus should be on four activities:

- attraction, development, and retention of young scientists and engineers;
- focused human capital development in Centres of Excellence;
- general S&T education and increased attractiveness of S&T careers;
- gender specific interventions.

The attraction, development, and retention of young scientists and engineers are obvious areas of intervention that need to be approached systematically. The attraction of young talent to S&T requires imaginative and compelling curricula and clear linkages to the needs of society. Retaining young talent depends not only on good education and training but on programmes for cultivating opportunity and recognition. Research leadership plays an important role in this regard. These initiatives are further enhanced by programmes, in partnership with the Ministry of Education, to ensure quality S&T education for all students, not just for scientists and engineers or tertiary education enrolments, but also to increase general S&T literacy and create awareness of S&T as an attractive career option.

The envisaged Centres of Excellence provide an excellent platform to build S&T capacity. The positive image projected by Centres of Excellence led by outstanding scientists helps to inspire high school, undergraduate and postgraduate students and serves as a challenge to mediocrity in other research institutions (Gervers, 2004). A number of key initiatives, such as structured post-graduate programmes in partnership with local and international TEIs and structured internship programmes with a strong focus on S&T should form part of the strategic plans of each of these centres.

4.5 Strategies for HRD in technology transfer

The inventory and assessment report (CSIR, 2005b) identified the need to address the low levels of R&D in the private sector and the low levels of technology transfer. In terms of HR, this indicates the need to look not only at the research, S&T part of the innovation pipeline, but to consider issues specifically addressing technology transfer. In this regard, two types of R&D can be differentiated (even though they are interlinked):

- Type 1 is the research dominated activity and its primary outcome is scientific leadership;
- Type 2 is development dominated and its primary outcome is competitiveness of industry and/or quality of life enhancement through roll-out of technology-based programmes.

In order to have the vibrant innovative industry Botswana envisions, industry needs to have the absorptive capacity to take up the results from type 1 activities in a seamless fashion. The interventions required to build type 2 human capacity centre on competitiveness, agility (to respond to changing market conditions) and a need to create

greater absorptive capacity in industry for R&D skills and outputs. The Innovation Fund as described in Section 2.5 provides the key vehicle for the development of Type 2 capacity.

This section of the Plan has outlined the strengths and weaknesses of the R&D workforce in Botswana and the future requirements to be able to deliver on the research priorities. Strategies to grow capacity through research leadership, new skills recruitment and technology transfer are outlined. The next section considers the institutional arrangements necessary to implement the Plan.

5 INSTITUTIONAL REQUIREMENTS

The priority areas for investment and their relationship with national goals as well as the human resources needed to implement the Plan have been identified in previous sections. This section outlines the key institutions that will be needed to implement the Plan. The section describes the existing institutions in Botswana before proposing the required set of institutions. The section concludes with recommendations to improve partnerships with the private sector and arrangements for improved management of intellectual property.

5.1 Existing Institutions

The Ministry of Communications, Science and Technology has responsibility for the management of three technological and scientific research institutions: the Botswana Technology Centre (BOTEC), the Rural Industries Promotions Company (Botswana) (RIPCO(B)) and its subsidiary – the Rural Industries Innovation Centre (RIIC), and the National Food Technology Research Centre (NFTRC).

The Botswana Technology Centre is engaged in research, development and technology transfer primarily on renewable energy technologies, electronic systems, sustainable architecture, energy efficiency and energy audits, waste water management, and ICT systems. The Rural Industries Promotions Company (Botswana) undertakes R&D to support industrial, entrepreneurial and socio-economic development. The National Food Technology Research Centre was established to enhance national food security and safety, national nutritional well-being, economic diversification, import substitution, economic empowerment and job creation, by adding sustainable value to local food materials through adoption, adaptation, the development and application of scientific and technological research in food and nutrition.

Arguably, the most significant parastatal organisation undertaking research in Botswana is the University of Botswana through its various departments and institutes. For example, the Harry Oppenheimer Okavango Research Centre conducts research in hydrology and water management, ecology, tourism management, and natural resources management, whilst the Department of Biological Sciences undertakes research on useful indigenous plants and animals.

Several other parastatal organisations are involved in activities relating to technological and scientific research. These include the Botswana College of Agriculture and the Botswana Institute for Development Policy Analysis which is involved in policy research. The Botswana Vaccine Institute produces vaccines primarily for Foot and Mouth Disease, but also for Rinderpest, Contagious Bovine Pleuroneumonia, Anthrax, and Black quarter.

Key non-governmental organisations which undertake research are Thusano Lefatsheng, Veld Products Research and Development, both of which are working on the commercialisation of some natural resources

Several Government departments undertake research. The Department of Agricultural

Research of the Ministry of Agriculture undertakes research on crops and livestock. The objective includes developing high yielding and drought resistant crop varieties, as well as technologies that are gender sensitive, and that physically infirm people can use. The Department of Geological Survey and the Department of Water Affairs, both of which are in the Ministry of Minerals, Energy and Water Resources undertake research work on mineral exploration and groundwater resources respectively. Within the Ministry of Environment, Wildlife and Tourism, the Department of Wildlife and Tourism play a critical part in research within their mandates. Within the Ministry of Health, research is taking place through the Botswana-Harvard AIDS Institute Partnership which undertakes research on the prevention of mother-to-child HIV transmission, the HIV-1C virus which is the most prevalent in Africa, resistance to anti-retroviral drugs, and the development of an HIV vaccine for Southern Africa.

5.2 Required Institutional Structures

The primary functions required from the institutions described in this section are the coordination of research, the funding of research and the provision of research services.

Overall management of S&T Research

The mandate of the Ministry of Communications, Science and Technology (MCST) is to ensure that there is policy, functional guidance and overall coordination of the Botswana National Research, Science and Technology Plan. The Ministry will thus ensure that the Plan is resourced and aligned with the national planning process and priorities. Further, the Ministry will provide a framework for oversight, guidance and monitoring of progress and impact of the Plan. The MCST will periodically review the Plan and ensure its continued relevance to the development needs of Botswana.

The Ministry is responsible for ensuring that there are delivery structures in place as well as an effective governance system. The Ministry will also ensure that national priorities are clarified from the perspective of its portfolio responsibility and ensure that adequate resources are available for the delivery of results.

The Ministry, as the overall accountable agent, will foster results orientation and alignment of efforts toward national priorities and Vision 2016 by ensuring that appropriate performance indicators are applied and communicated throughout the implementing system and that stakeholders are kept engaged. This will require comprehensive data and an information repository and management system. The ministry should also play an active role in creating a high level of public awareness of the importance of research, S&T by Batswana from an early age.

Funding agencies

A key requirement for the successful implementation of the Plan, is the establishment of an agency to objectively and efficiently allocate funding, monitor outputs and evaluate overall progress towards achieving the desired national outcomes. The key institution that needs to be established as a parastatal by the Ministry of Communications, Science and Technology is the Botswana Research, Science and Technology Agency (BRSTFA).

The BRSTFA Bill is being prepared. One of the primary objectives of BRSTFA will be to facilitate and coordinate the research outlined in this plan (MCST unpubl. Memo, April 2005). BRSTFA will be the agency responsible for calling for and awarding proposals for Mission-focused Programmes, Centres of Excellence and the Innovation Fund. It will also be responsible for monitoring and evaluating progress and reporting to the Ministry of Communications, Science and Technology. This process needs to be managed very carefully to ensure maximum benefit for improving research quality[18]. BRSTFA will use panels of experts to support them in these functions. BRSTFA will also provide inputs into the research strategies of line departments to ensure that possible synergies are fully exploited within the national system of innovation. The establishment of BRSTFA is the key step required and is critical to the implementation of this research plan.

Research Agencies

The existing research agencies (parastatals, tertiary education institutions, private sector and line research organisations) have been outlined in Section 5.1. They include public sector and parastatal institutions, tertiary education institutions, government line departments and private sector institutions.

To improve efficiency and effectiveness, Botswana will move away from guaranteed funding for research to a largely competitive approach to the allocation of funds. The use of a competitive funding mechanism is intended to improve the efficiency of research organizations and to ensure that the research is well considered, focused and has an impact on the national development priorities. This approach will therefore ensure healthy competition between research agencies and will necessitate delivery against agreed targets and outcomes. The ability of the existing research agencies to respond to the research priorities outlined in this plan over the next 5 year period will, to a large extent, determine their relevance and sustainability in the long term. Research agencies will need to organise and position themselves appropriately to address and respond to the priorities outlined in this plan.

Although the structure of the existing research agencies will, to a large extent, be maintained, two key changes will be effected:

- the Botswana Technology Centre and Rural Industries Promotions Company (Botswana) will be merged to form a new institution. The reasons for this merger are to remove obvious duplication between the two existing institutes; create

[18] Examples of how such processes are managed can be found at http://www.arc.gov.au) and http://nrfonline.nrf.ac.za.

critical mass in applied research and technology transfer; and to eliminate the discontinuity between research and its application; and,

- a task team should be established to merge the National Food Research and Technology Centre and the Department of Agricultural Research into a National Food and Agricultural Research Centre. The new institutional arrangement will ensure the integration of research on agricultural and food processing. The focus should be on improving food security, especially of the rural poor through the generation of agricultural technologies and policies that sustain livelihoods. A close working relationship with the College of Agriculture will be important in fulfilling this mandate.

Any institutional restructuring should ensure that the quality and relevance of research is maintained, scientific expertise is retained and research outputs address national priorities.

By the end of NDP10, the proportion of research funding directly allocated to line departments will be reduced and progressively replaced with competitive funds. Some of the research currently undertaken in the line departments may, with time, shift to Centres of Excellence, Mission-focussed Programmes and the Innovation fund.

Key funding mechanisms

The four funding mechanisms (see Section 2 for detailed discussion) and their key attributes are listed below:

1) **Line Research.** Funding for R&D activities through line departments should be based on a performance-based block funding mechanism. This means that the annual budgets will be influenced by performance and strategic targets. In this way, the Government can, over time, either grow or phase out research in certain areas depending on its impact and strategic relevance.
2) **Mission-focussed Programmes.** The introduction of an open and competitive funding mechanism whose goals are clearly defined provides an ideal way to rapidly develop the overall competency within a National System of Innovation (NSI), especially in its ability to generate new knowledge, within the identified strategic priorities of the Government. Any part of the NSI should be able to apply and preference should be given to proposals that are multi-organisation and multi-disciplinary. Projects should be approved for a three year period, subject to interim reviews.
3) **Centres of Excellence.** Mission-focussed funding is typically not successful at establishing globally recognised Centres of Excellence within a NSI since it funds projects, not portfolios and does not provide the longer term security. A Centre of Excellence programme is a mechanism to identify real areas of strength within a NSI, that can act as a hub for research, human capital development and innovation, and attract global or international interest.[19]
4) **Innovation Fund.** None of the above caters adequately for the translation of

[19] There are many excellent examples of Centres of Excellence, including the Scripps Research Institute in San Diego, USA.

research output to innovative products and services; this is the job of the Innovation Fund. Its primary role is to ensure that any knowledge that is generated within a country is indeed transferred and results in wealth creation or contributes to the greater public good.

Flow of funds

Figure 5.1 provides a schematic representation of the major flows of funds from the national budget into the National System of Innovation. The Government departments that currently undertake research will continue to do so and will be supported through current budget allocations. The Ministry of Communications, Science and Technology, through BRSTFA will provide support in the development of the research plans of the line ministries to ensure that they are consistent with the National Research, Science and Technology Plan. Where appropriate, line departments should contract other research organisations to undertake research on their behalf. It would also be appropriate, in certain instances, for researchers from line departments to collaborate in Mission-focussed Programmes and Centres of Excellence. It is envisaged that, with time, all Botswana's national R&D funds (i.e., including that allocated to the line ministries) will be administered through BRSTFA.

Mission-focussed Programmes should promote multi-institutional collaboration in the form of consortia of research agencies, drawn from across the various institutions. The Centres of Excellence will primarily be based in the existing institutions which are currently undertaking related research. The location of the centres will depend on which existing institutions are successful in bidding to host them. BRSTFA will develop criteria for selection. In areas where research is currently not being done, new Centres of Excellence will be established.

The relationship between funding mechanisms and existing institutions

Figure 5.2 shows the possible linkages between institutions (research agencies) and the various funding mechanisms. Mission-focussed Programmes should promote multi-institutional collaboration through the establishment of consortia of research teams, drawn from the various institutions. The degree of overlap will depend on the needs within the particular mission-focussed programme. The Centres of Excellence will primarily be based in the existing institutions which are currently undertaking related research. Centres of Excellence could, in certain cases link in with Mission-focussed programmes (e.g. COE 3 in Figure 5.2). The location of the Centres of Excellence will depend on which existing institutions are successful in bidding to host them. BRSTFA will develop criteria for selection of the Centres. In areas where research is currently not being done, new Centres of Excellence will be established (e.g. COE 2 in Figure 5.2). The Plan does not prescribe the location of the Centres or Mission-focussed programmes to particular institutions this would detract from the principle of competitive bidding. Figure 5.2 illustrates the integrative function of the proposed policy interventions, encouraging increased interdisciplinary and institutional collaboration, maximising efficient use of Botswana's National System of Innovation (Figure 5.2)

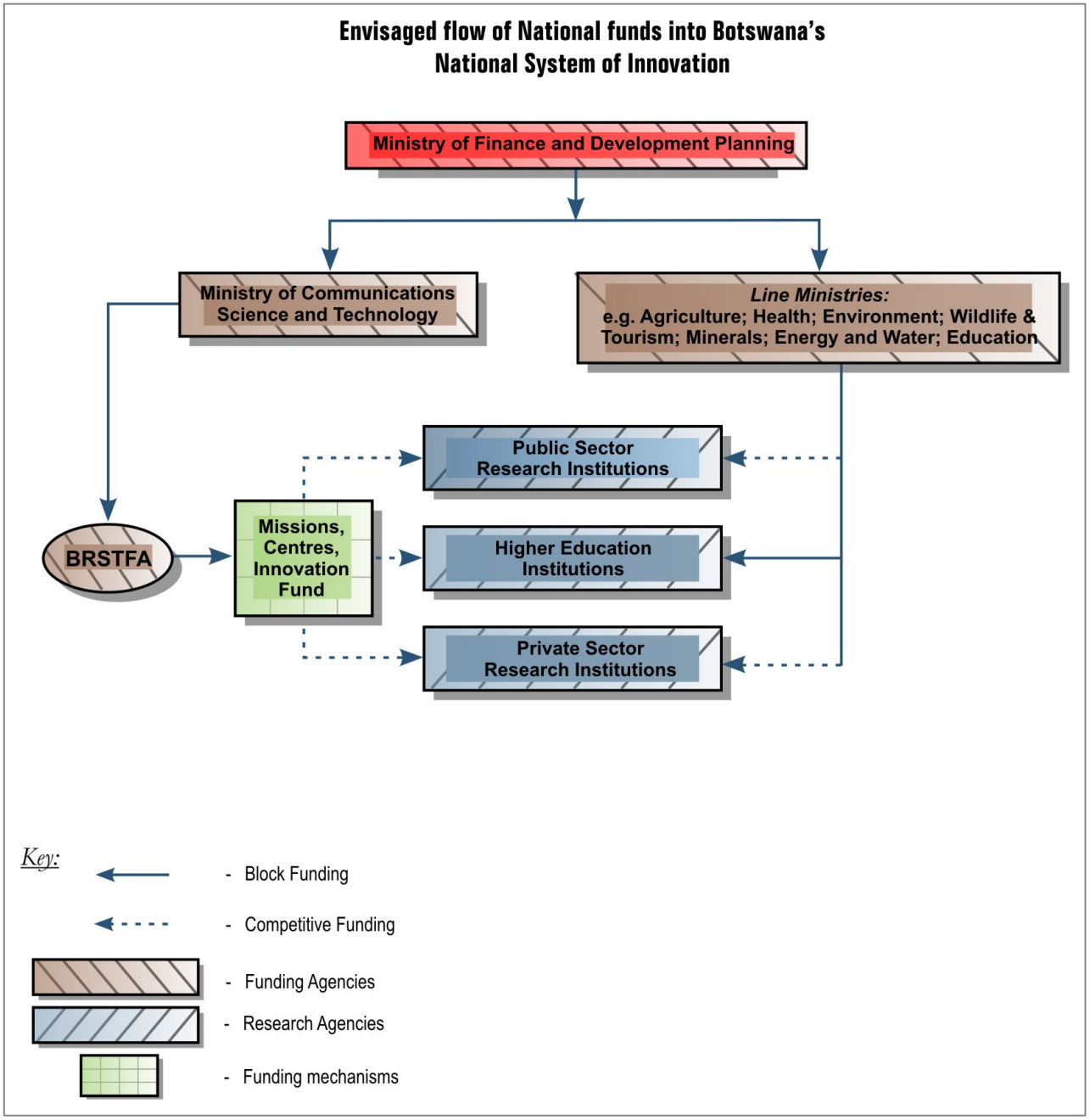

Figure 5.1: Envisaged flow of national funds into Botswana's National System of Innovation

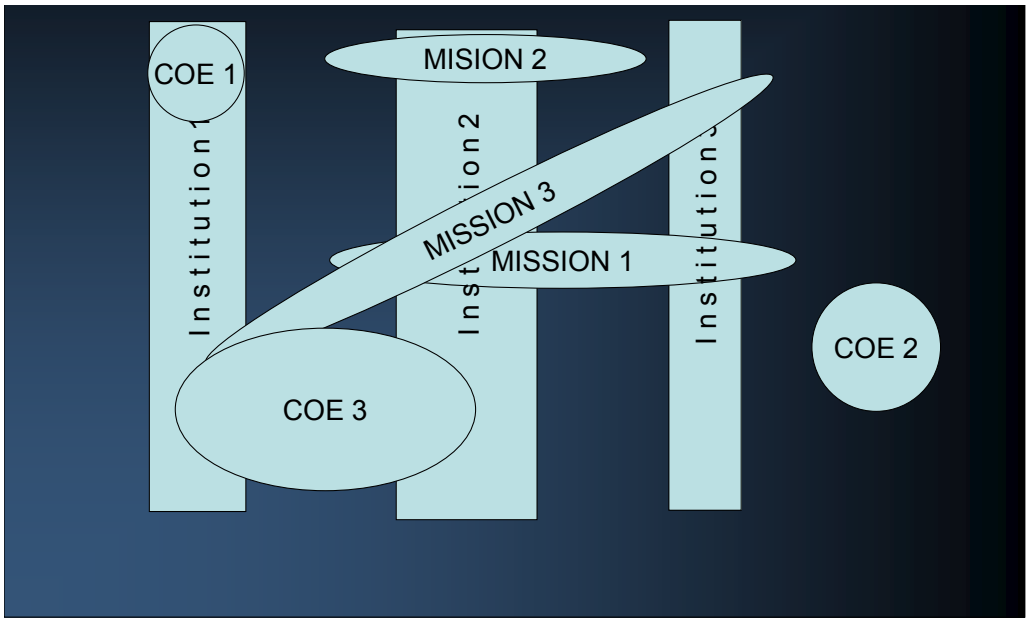

Figure 5.2: Schematic representation of the relationship between funding mechanisms and existing institutions

5.3 Partnerships

Partnerships for S&T development are important for building capacity to innovate. Terms of Reference for BRSTFA-funded research should encourage the creation of meaningful partnerships with:

i. Private industry: If Botswana is to be successful in building the capacity of small industries and increase productivity, it will need to create links with private industries. Innovation is strengthened when S&T flows out of the science base into the market. Fiscal incentives in the form of as tax concessions and rebates should be introduced to increase private sector involvement in S&T (see 7.3).

ii. Regional R&D institutions: Such partnerships are particularly important for building and strengthening S&T capacity in a systems sense (Oyelaran, 2005). The notion of capacity development in a systems sense entails “building up the collective capacity of networks or systems of actors interactively linked with a view to innovate”.

iii. Other national institutions: Partnerships that enhance knowledge exchange are more effective in building a culture of innovation and generating multi-faceted solutions. Where research areas over-lap, institutions will need to cooperate, debate and resolve competing priorities and mobilise resources.

iv. International Funding Organisations: Botswana needs to continue to demonstrate a strong governance system and result driven character to attract support from

international agencies. The national S&T strategy should determine the funding priorities and should not be driven by donor funding.

For these partnerships to be effective:

i. The Government should review policies with regard to the extent to which they encourage or inhibit partnering. Policies should support research collaboration; foster contacts between researchers and remove any obstacles to the free flow of information.
ii. Appropriate incentives should be provided. Incentives can include substantial funding for collaborative research; grants for equipment purchases and post-graduate training; recognition and monetary awards for the generation of intellectual property and other significant R&D output; support for inter-institutional exchanges, especially where international institutions are involved in local consortia. The outcomes of such incentives need to be closely monitored to ensure that the desired impact is achieved and negative behaviour is minimised.
iii. Institutions need to ensure that their governance and administrative systems and guiding principles make it conducive for other organisations to partner with them.
iv. From a strategic position, institutions need to critically review the value addition of existing partnerships and plan ahead for strategic partnerships that will help them to deliver on their mandate.
v. The quality of research and researchers needs to be of a calibre that encourages and attracts research collaboration.
vi. International collaborations and exchanges are required to provide training and capacity building opportunities.
vii. Strategies to raise awareness across the world of Botswana's opportunities in S&T should be developed. One way to achieve this is to establish a strong relationship with the Ministry of Foreign Affairs and International Cooperation.

In addition to the above guidelines, a portion of the national research budget will be allocated by BRSTFA through an Innovation Fund designed to foster private-public research partnerships (see Section 2.5). Tax incentives as recommended in sections 2.5 and 7.3 provide a further mechanism for increasing private sector investment in R&D.

5.4 Management of Intellectual Property

Botswana has an Industrial Property Act and a Copyrights and Neighbouring Rights Act. The Industrial Property Act provides for the registration of patents, trademarks, designs and utility models while the Copyrights and Neighbouring Rights Act details the rights of authors with respect to the expression of literary, artistic, broadcasting, cinematographic and computer programming works. Both Acts offer internationally accepted standards of protection and provide the Government with the means to regulate the Intellectual Property Rights protection system and penalise against infringement.

However, Botswana is not a major player in the intellectual property domain and IP protection is largely inward where protection is sought in Botswana for IP that originates from elsewhere (see CSIR, 2005b). The situation needs redress. Comprehensive support to S&T institutions is required to encourage institutions to exploit the results of their work and to ensure that they receive recognition and reward for doing so. This includes:

i. Developing an Intellectual Property (IP) Policy to provide guidance for the management and exploitation of IP and establishing a legislative and/or regulatory framework to ensure better practice and returns from IP.

ii. Developing an Indigenous Knowledge Systems (IKS) policy that will:

- recognise and promote IKS research;
- provide for a policy and legislative regulatory framework that ensures good practice; and,
- give consideration to an institutional framework.

A great proportion of scientific research of indigenous knowledge is in the area of biodiversity where scientists are involved in activities such as bioprospecting, taxonomy, conservation, data-capturing and storage. The Convention on Biological Diversity (CBD) and the agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) provide a framework for countries to create access to genetic resources, based on prior informed consent for environmentally sound use; ensure fair and equitable sharing of benefits and to promote the effective transfer of technology. In planning for IKS policy, Botswana should take cognisance of international experience.[20]

iii. Providing funding to build institutional capacity to transfer knowledge. Such funding can be used to pay IP protection costs; promote increased network between institutions and across sectors; support large scale funding and ensure that S&T addresses national priority needs.

iv. Providing specialised IP and commercialisation support including:

- offering access to a facility that will link S&T institutions with business, marketing and finance expertise that is necessary to develop new products and processes; and,

[20] For example:
- Decision 391, The Common System on Access to Genetic Resources – Andean Community, http://www.wipo.int/clea/docs_new/en/ac/ac004en.html
- Model Legislation for the Recognition and Protection of the Rights of Local Communities, Farmers and Breeders and for the Regulation of Access to Biological Resources – Organization of African Unity, http://www.grain.org/publications/oau-model-law-en.cfm
- Biological Diversity Law, Law 7788 – Costa Rica, http://eelink.net/~asilwildlife/costa.pdf
- Genetic resources: draft intellectual property guidelines for access and benefit-sharing contracts – WIPO, http://www.wipo.int/documents/en/meetings/2004/igc/doc/grtkf_ic_6_5.doc
- No. 10 of 2004: National Environmental Management: Biodiversity Act, 2004, Republic of South Africa,
- Indigenous Knowledge Policy, Department of Science and Technology, Republic of South Africa, December 2004.

- offering access to internet based intellectual property portals that contain a full range of IP information.

v. Developing a capacity building programme that will develop competencies in IP management, licensing and commercialisation. Such programmes should be designed to promote guidance for the private sector and spread best practice.

This section has outlined the institutional requirements for funding and undertaking research and for ensuring that intellectual property in Botswana enjoys necessary protection. The next section outlines the key activities necessary for the implementation of the Botswana National Science and Technology Plan.

6 PLAN FOR IMPLEMENTATION

Previous sections have discussed human resources and institutional arrangements necessary for undertaking the research prioritised in Section 2. This section outlines the key actions and deliverables for the implementation of the Plan.

6.1 Key actions and milestones

Several actions are necessary to undertake the research identified in Section 2. These include the establishment of new institutions or the re-tooling of existing ones, the establishment of a process for soliciting and funding proposals, as well as the establishment of review mechanisms to ensure that the desired results of research are achieved. Table 6.1 presents the key actions and milestones that are envisaged for the first five years of the Plan.

Financial year 2005/6

The main actions required in the financial year 2005/6 are the establishment of BRSTFA by the Ministry of Communications, Science and Technology and the first national survey of the state of research S&T in Botswana.

Financial Year 2006/7

The main actions for this financial year will be the

- approval of funding for research by the Ministry of Finance and Development Planning;
- development of criteria for awarding Mission-focussed Programme funding and selection of Centres of Excellence by BRSTFA;
- establishment by BRSTFA of independent expert panels which will review proposals for funding;
- calls for proposals for Mission-focussed Programme funding, for the Innovation Fund, and for hosting the Centres of Excellence;
- adjudication of the proposals, development of guidelines for ministry research strategies;
- development of ministry research strategies which will involve the ministries indicated in Section 2 (Ministry of Health; Energy and Water Resources; Wildlife, Environment and Tourism; Communications, Science and Technology; Agriculture);
- development of National Researcher ranking and recognition system;
- development of a model of the human resources pool;
- interim progress reviews by BRSTFA, and,
- the submission of annual reports from the recipients of research funding.

The progress reports will reflect performance against the agreed indicators of both progress and results as well as any significant problems experienced. Specific attention will be paid to ensuring alignment of research with the Research, Science and Technology Plan.

Table 6.1: Implementation Plan and Indicators for the Botswana National Science and Technology Plan.

ACTION	RESPONSIBILITY	TIMING	MILESTONES
Establish BRSTFA	Ministry of Communications, Science and Technology (MCST)	November 2005	BRSTFA constituted and functioning
Approve funding for research	Ministry of Finance and Development Planning	April 2006	Budget allocated
Develop criteria for awarding Mission-focussed Programme funding and selection of Centres of Excellence	Botswana Research, Science and Technology Funding Agency (BRSTFA)	April 2006	Criteria for selecting research projects and establishing centres including expected outputs (publications, patents etc)
Appoint review panels	BRSTFA	April 2006, thereafter as required	Panels appointed
First call for proposals for Mission-focussed Programme funding	BRSTFA	June 2006, thereafter annually	Calls for proposals published
Call for proposal for establishment of centres	BRSTFA	June 2006, thereafter as and when required	Calls for proposals published
First call for Innovation Fund proposals	BRSTFA	June 2006, thereafter annually	Calls for proposals published
Adjudication of Mission-focussed Programme proposals	BRSTFA through Review panels	September 2006, thereafter as and when required	Thematic proposals to value indicated in budget approved
Adjudication of Centre of Excellence proposals	BRSTFA through Review panels	September 2006	Approval for establishment of 5 COE
National Survey of the State of Research, Science and Technology in Botswana	MCST using based in OECD questionnaire (4)	Annually in November, first survey (2005) to cover financial year 2004/2005	Publication of “High Level Research, Science and Technology” results for Botswana Feb each year
Develop guidelines for line ministry research strategies	MCST in collaboration with BRSTFA	November 2006	Guidelines distributed to appropriate ministries
Development of research strategies in line with NDP time frames	Line Departments in collaboration with BRSTFA	November 2006 thereafter every five years	Ministry research strategy approved
Interim progress reviews: Mission-focussed Programmes Centres of Excellence Innovation Fund	BRSTFA to visit researchers	September each year	Successful progress against approved plans

ACTION	RESPONSIBILITY	TIMING	MILESTONES
Development of National Researcher ranking and recognition system	MCST	February 2007	National Researcher ranking and recognition system
Development of a model of the human resources pool	MCST	February 2007	Model of the human resources pool
Annual reviews: Mission-focussed Programmes Centres of Excellence Innovation Fund	BRSTFA to review annual reports from researchers	February each year	BRSTFA – approved annual report
External review of BNRSTP	MCST appointed panel	Every 5 years	Revised BNRSTP
External review of BRSTFA performance	MCST appointed panel	Every 5 years	New BRSTFA members appointed and functioning

Financial Year 2010/11

An external review of the National Research, Science and Technology Plan will be undertaken so that it can provide input into the NDP 10 process. Thereafter, this review will be undertaken every five years so that it can better inform the national development planning process. The key purpose of the review will be to ensure that the National Science and Technology Plan is aligned to national priorities which will change over time.

Table 6.2 provides guidelines that can be used for the development of output indicators for the research institutions in Botswana. The indicators are based on the sources indicated as well as on *ab initio* research in a number of institutions including the Scripps Institute, other science councils and private sector organisations. The targets are not stretch targets in the productive R&D economies of the world, such as China, India, USA, Finland and UK. They are, however, stretch targets for countries like Botswana and South Africa. (For example, on average, the performance of the CSIR in South Africa against the targets has been about 60% over the last five years).

Measures are calculated as a proportion of the total R&D expenditure, not as a proportion of directly targeted portions of the R&D expenditure. Although there is a tendency to move toward the use of journal impact scores and citation analyses, this is not recommend in the early stages of the implementation of the Plan where the emphasis should be on getting research results into the peer-reviewed domain and building citation frequency. The indicators suggested are, to a large extent, output-based (as opposed to outcome or impact-based). Although there are various attempts to develop outcome-based measures, many of these are non-descript and difficult to quantify. Ascribing cause and effect over the full innovation life-cycle is also extremely difficult due to the variety of factors and the long periods of time involved.

The specific deliverables and performance indicators appropriate to each of the BRSTFA programmes (Centres of Excellence, projects funded through Mission-focused Programmes, Innovation Fund projects) should be developed to monitor performance and ensure the effective use of resources.

Table 6.2: Guidelines for benchmarking performance of institutions

PERFORMANCE INDICATOR	UNITS PER YEAR	TYPE OF INSTITUTION		
		HEI (universities and CoEs, etc)	Parastatal Research and Technology Organisation	Private Sector Research Department
Peer reviewed publication equivalents [21]	Equivalent per researcher	1	0.5	0.1
Other publications (conference papers, non peer reviewed articles, internal reports, etc)	Number per researcher	2	2	2
Registered Patents	Million Pula R&D expenditure per registered patent	10	5	5
Licensed Patents	Million Pula R&D expenditure per licensed patent	50	25	15
Royalty income	Royalty income/total R&D expenditure	2%	4%	5%
Return on investment	New product profit/research expenditure	N/A	N/A	15%
Spin Outs[22]	Million Pula R&D expenditure per spin out	50	25	10
Graduation of Qualified Persons	Million Pula R&D expenditure per PhD	2	25	50
Minimum contract research income[23]	% of total research expenditure	20	40	10 (recommended)

Source: (based on own research, AUTM, 2002 , Bunting and Cloete, 2004 and Heher, 2004).

[21] One research equivalent is defined as a single peer reviewed publication with a single author; joint publications are divided by the number of authors and a book is counted as five equivalents.

[22] Refers to the establishment of a entity based on the commercialisation of the parent institution's intellectual property.

[23] Refers to income sources other than block funding.

7 FINANCIAL COSTS

7.1 Current Investment in S&T Research

The R&D survey, completed during the preparation of this Plan, revealed that the gross expenditure on R&D for Botswana as a percentage of GDP (referred to as GERD) was approximately 0.43% in 2003/4 (CSIR, 2005b). The survey also established that the Government is both the dominant performer and funder of R&D, contributing about 84% of the total funding in 2003/4 (see Figure 7.1). In contrast, business contributed only 3%, NGOs 5% and foreign sources 6%.

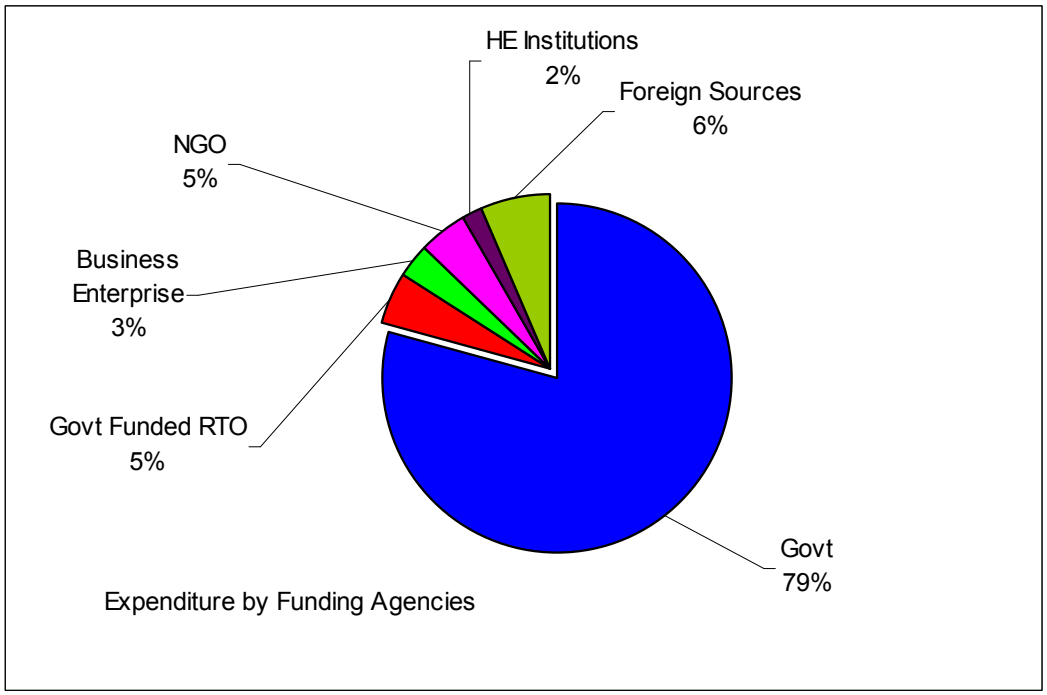

Figure 7.1: Expenditure by funding agencies.
Source: CSIR, 2005b

7.2 International benchmarks for research funding

The leading and innovative economies such as Australia, Canada, Japan, the United States and northern and western Europe all spend between 1.5 percent and 3.9 percent of their GDP on R&D. Other countries such as South Korea and Singapore spend over 2% of GDP on R&D, while Botswana's expenditure on R&D as a percentage of GDP is 0.43 percent (See Figure 7.2).

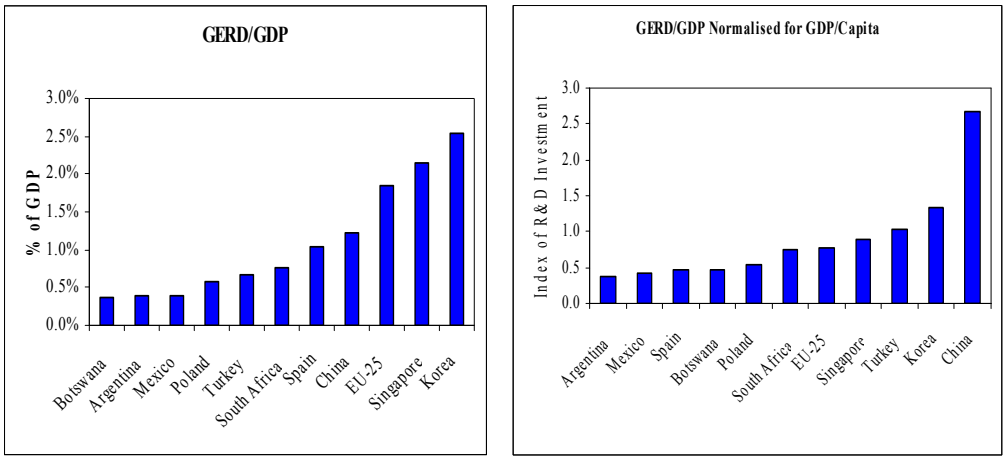

Figure 7.2: Country comparison of percentage of GDP invested in R&D (GERD) as a percentage of GDP (2002 data) and GERD/GDP normalised for GDP/capita

The InterAcademy Council recommends that "…national governments in developing nations should increase their spending considerably certainly above 1 percent of GDP and preferably closer to 1.5 percent if there is to be any hope of not falling farther behind the industrialised states" (IAC, 2004, p2). South Africa spends more than 0.8% of GDP on R&D while Singapore and Korea spend over 2% of GDP. In terms of GERD, Botswana was clearly lagging behind these countries in 2003/4.

Further, in high performance economies private sector funding represents over 70% of total expenditure on R&D (e.g. in Korea) which contrasts markedly to the situation in Botswana. The extent of private sector participation in the funding of R&D is critical since it is business that plays a key role in the commercialisation of research.

The desired objective in terms of research funding in Botswana is to increase expenditure on R&D to at least 1% of GDP. This will have the effect of more than doubling expenditure on research and bringing the country in line with the leading medium income countries such as South Africa. However, if the country hopes to come to the current level of countries such as Singapore and Korea it will have to increase its expenditure on R&D to at least 2% of GDP, possibly during NDP10 or the next plan period. According to NDP9, GDP is projected to grow to P25.342 billion in 1993/94 prices by the end of the

development plan period in 2008/09. An expenditure of 1% of GDP will therefore amount to over P250 million in real 1993/94 prices. In nominal GDP terms the equivalent figures are P67.7 billion and P677 million respectively.

7.3 Budget considerations

In common with the practice in the high performing economies, measures should be put in place to increase private sector funding for R&D. Little can be achieved by trying to increase the participation of the private sector in the existing research programmes. The strategy will be to provide incentives to attract private sector participation in the new areas of R&D (See 2.1.4). An Innovation Fund which will promote public-private research partnerships will be established.

In line with the objective of promoting greater private sector participation, the bulk of the Innovation Fund will go toward the provision of matching funds, and other funding mechanisms aimed at catalysing the flow of non-public funding into R&D. The private sector in Botswana is, presently, not sufficiently developed to provide high levels of funding nor to react in any meaningful way to the proposed incentives. A significant part of the research by a few major private sector companies currently takes place outside the country and subject to meeting policy objectives, such funding could be attracted into the country through appropriate incentives. In addition to the proposal for the establishment of an Innovation Fund which will provide matching funding for private sector expenditure on R&D, use should also be made of tax concessions or credits[24]. Such incentives will help attract the multinationals which operate in Botswana but undertake their R&D elsewhere to relocate at least some of their research activities in the country. Other new companies could similarly be attracted to locate their R&D activities in Botswana.

The envisaged increase of expenditure on R&D will require a commensurate increase in absorptive institutional capacity. There will therefore be a need to concurrently build the capacity to manage and productively use such funds over the next five years (see Section 5). Alternatively and in the short term, the required capacity can be created quickly through the importation of the required skills in a proactive immigration policy akin to that in the leading economies of the world, or by attracting back the significant number of qualified Batswana now working outside the country.

Other key assumptions regarding the budget are:

[24] The Australian R&D tax concession is reported to be one of the most successful in attracting private sector funding for R&D. As a benchmark Australia has an R&D tax concession with the following key elements:

1) it is intended to increase the level of R &D conducted by Australian companies;
2) it is broad-based as opposed to industry specific and market driven with the applicant deciding on the scope and timing of R&D;
3) companies are eligible to deduct up 125% of eligible expenditure on R&D. Plant or infrastructure related expenditure is ineligible;
4) an additional 50% deduction may be available to companies that increase their eligible level of R&D expenditure relative to their average for the previous three years; and
5) an R&D tax offset, equivalent to the value of the R&D tax concession is available to SMMEs which can elect to receive the offset at the rate of 30 cents for each Australian Dollar that would have been claimable under the deduction.

- The desire that competitive funding and non-competitive performance-based block funding (to RTOs and line ministries) should reach the target of 1% of GDP by the end of NDP 9.
- An appropriate initial distribution of funds between the various funding mechanisms (Mission-focussed: Centres: Line: Innovation Fund) is 10: 20: 65: 5 (see Figure 7.2). This assumption is based on a combination of the current estimate of distribution between line functions and other research agencies and a desire to limit disruption during the transition to competitive funding mechanisms, as well as the following observations regarding the three non-line funding mechanisms:
    - Five Mission-focussed Programmes receiving on average P 5 million per year. Each Mission-focussed Programme will comprise a suite of 3-5 year projects.
    - Five Centres of Excellence to be established by the end of NDP 9 at an average annual cost once established of P10 million per centre in current 2005/06 prices.
    - Innovation Fund is initially budgeted at 5% of the national R&D expenditure, and will increase to 15% by 2011/2012.

- There will be a progressive real growth in competitive funding and private sector funding (from 35% to 60%) as a proportion of the total R&D budget and a concomitant decrease in the proportion of non-competitive block-funding (from 65% to 40%) during the funding period (Figure 7.2).
- As a general benchmark[25], the deployment of funds on manpower and running should be at a ratio of 55:45 in the following proportions:
    - Direct manpower costs (i.e. those directly associated with research activities and appearing as line items in project budgets) – 30%.
    - Direct running costs – 25%.
    - Indirect manpower costs (i.e. those that support research) – 25%.
    - Indirect running costs (i.e. those that support research (including depreciation and infrastructure)) – 20%.

[25] Based largely on CSIR experience which is globally benchmarked.

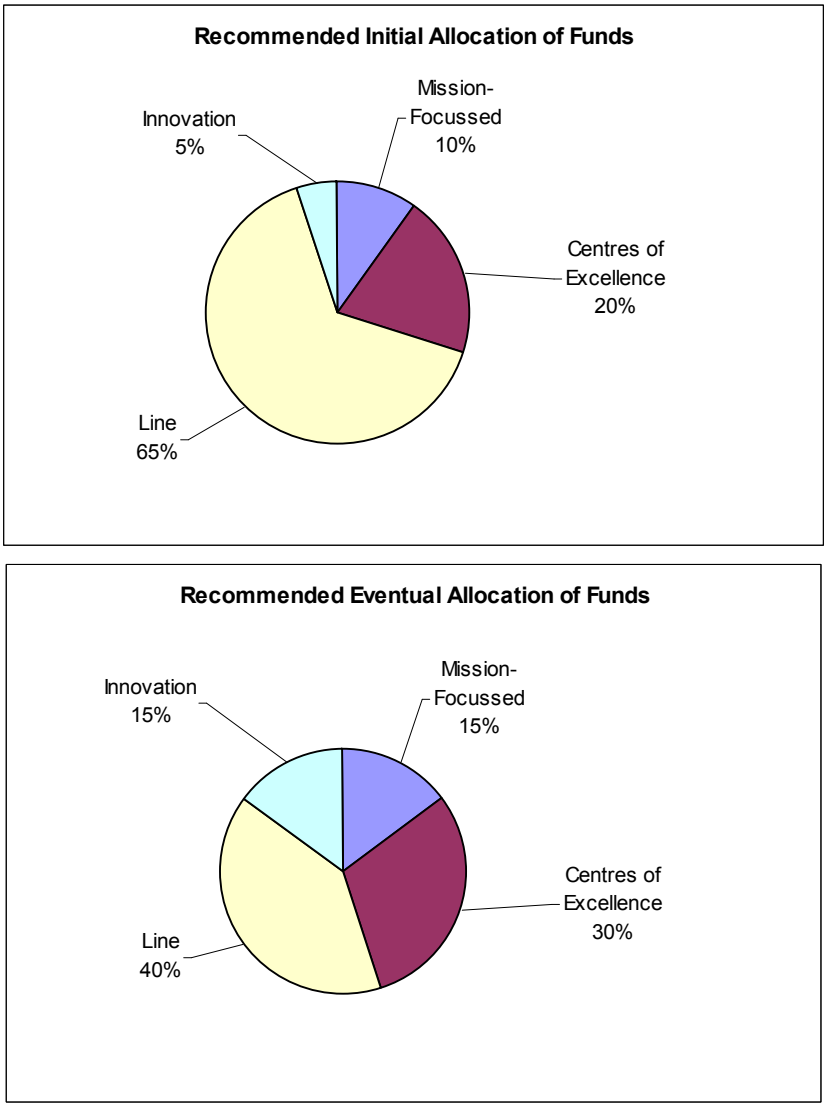

Figure 7.2: Recommended proportions of initial (2006/7) and eventual (2011/12) total allocation from the Botswana Government.

7.4 Preliminary Budget Implications of the Research S&T Plan

The following budget (Table 7.1) assumes that Botswana commits to increasing GERD to 1% by 2010/2011. As described in section 1.2, this would be in line with comparative countries, but still behind that invested by highly competitive countries. The budget allows for a growth in the Innovation Fund to 15%, Line funding reducing from 65% to 40% and competitive funds allocated to Centres of Excellence and Mission-focused Programmes growing from 30% to 45% of the government allocation over a 6 year period.

Table 7.1: Estimate of total government expenditure on R&D in current prices and thousands of Pula for 2006/07 to 2010/11.

	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/12	Totals
Mission	28049	40531	56902	73063	93162	116435	408142
Centres	56099	81062	113804	146127	186324	232869	816285
Line[26]	182321	221077	260801	281013	299449	310492	1555153
Innovation	14025	25792	42676	61822	86508	116434	347257
Total	**280494**	**368462**	**474183**	**562025**	**665443**	**776230**	**3126837**
GDP[27]	**56098880**	**61410230**	**67740400**	**70253210**	**73938150**	**77623079**	**407063949**
GERD	**0.50%**	**0.60%**	**0.70%**	**0.80%**	**0.90%**	**1.0%**	

The budget reflects minimum total investment numbers as it does not consider non-government contributions to GERD (currently at 14%) which will grow with the introduction of various incentives outlined in this report. For example, assuming a 50% matching through the Innovation Fund, an additional P347 million can be expected from the private sector during the funding period until 2011/2012.

The target distribution of funds within the various funding streams is also shown in Figure 7.2 (Recommended Eventual Allocation of Funds). While every effort should be made to refocus and reallocate line ministry funding in the context of the Plan, this will take time. In the interim, line ministry funding should be reorganised to bring about greater competition through such measures as outsourcing and contracting out some of the line ministry activities. In this context, much of the funding for the non-line ministry research will have to be new funding, particularly in the early years as the whole national R&D infrastructure undergoes reorganisation. Mission-focussed Programmes, Centres of Excellence and the Innovation Fund which are well designed and subject to good governance will attract international researchers and funding which, with time, will have the effect of easing the national budgetary constraints and shortening the time required to build an indigenous research capacity. Care should be taken, however, to ensure that such financial assistance operates within the National Research, Science and Technology Plan and contributes to the strengthening of the national R&D capability.

8 CONCLUSIONS

This Plan responds to several socio-economic challenges presently facing Botswana, including economic diversification, poverty and unemployment, HIV/AIDS and the sustainable use of natural resources. The Plan contains four main policy interventions, namely the introduction of a Mission-focussed Programme, the establishment of Centres of Excellence, the stimulation of private sector research through the introduction of an Innovation Fund and research tax incentives, and the improved integration of Line Function research within the overall National System of Innovation. These interventions will focus research efforts in a number of key priority areas.

[26] Includes non-competitive Block funding to RTOs and line ministries.

[27] Nominal Pula or estimates in current prices.

The proposed areas of R&D that will be supported during the remainder of NDP9 as well as during NDP 10 cover several sectors including health; the service industry; eco and cultural tourism; the software industry; manufacturing; mining; water; energy; agriculture; media, education and human resource development; housing and construction; as well as transport and logistics.

The Mission-focussed Programme will typically support long term and multi-disciplinary research within the themes of ecosystems; processing and mining; manufacturing, engineering and infrastructure; geomatics; and biosciences. The Centres of Excellence will focus expertise from existing research institutions into key focus areas including energy for the future; infectious diseases; indigenous knowledge and technology systems; Information and Communication Technology; and human sciences and policy research. Support for the R&D activities will continue to be provided to existing public sector line ministries including the Ministries of Agriculture; Minerals, Energy and Water Resources; Wildlife, Environment and Tourism; Health; and, Communications, Science and Technology.

The institutional changes required are the establishment of the Botswana Research Science and Technology Funding Agency as a mechanism to manage competitive funding and the merger of Botswana Technology Centre and Rural Industries Promotions Company (Botswana) to form a new institution. In addition a task team should be established to merge the National Food Research and Technology Centre and the Department of Agricultural Research into a National and Agricultural Research Centre.

The strategies for improving human resource capacity in S&T include postgraduate training in some areas in order to attract, develop and retain engineers and scientists in the National System of Innovation, the strengthening of research leadership including international recruitment, the establishment of research partnerships with international organisations and the establishment of mechanisms for recognising and rewarding researchers.

The Plan also specifies a programme of implementation. The programme includes the establishment of new institutions or the re-tooling of existing ones, the establishment of a process for soliciting and funding proposals, as well as the establishment of review mechanisms to ensure that the desired results of research are achieved.

The Government will continue to play a key role in funding research. Over a period of six years, the level of funding will increase from the current estimated 0.43 to 1% of GDP, bringing Botswana in line with practice in innovative economies elsewhere.

Focussed investment in the identified research areas through the implementation of this research, science and technology plan will enable Botswana's research community to make a meaningful contribution to the attainment of the Vision 2016 objectives, namely that of an educated, informed nation; a prosperous, productive and innovative nation; and a compassionate, just and caring nation and generally improve the welfare of Batswana.

9 RECOMMENDATIONS

The Plan recommends actions relating to funding, institutional arrangements, human resource capacity development, monitoring, partnerships and intellectual property that are essential to achieve the desired outcomes stated in Section 1.3:

Funding

1) The Government should commit to a research expenditure of 1% of Gross Domestic Product, which is the minimum level for emerging innovative economies (Sections 7.2 and 7.4).

2) Over the next 6 years, competitive funding (including the private sector contribution) should be increased from 35% to 60% and non-competitive block funding should be decreased from 65% to 40% of the total national R&D budget (Section 7.3 and 7.4).

3) To improve the efficiency of research and its impact on national development priorities, Botswana will move away from guaranteed funding to a largely competitive approach to the allocation of research funds. This approach will ensure healthy competition between research agencies and will necessitate delivery against agreed targets and outcomes (Section 5.2).

4) A tax concession to increase the level of R&D being conducted by Botswana companies should be instituted (Section 2.5).

Institutions

5) The Botswana Research, Science and Technology Funding Agency should be established as a mechanism to objectively and efficiently allocate funding, monitor outputs and evaluate overall progress towards achieving the desired national outcomes (Section 5.2).

6) Four competitive funding mechanisms are recommended (Sections 2 and 5.2):

    a. Mission-focussed Programmes focusing on: ecosystems; manufacturing, engineering and infrastructure; processing and mining; geomatics; and, biosciences;

    b. Centres of Excellence in: energy for the future; infectious diseases; indigenous knowledge and technology systems; information and communications technology; and, human sciences and policy research;

    c. Line Research in: agriculture; minerals; water; environmental management; health; and, communications; and,

    d. An Innovation Fund and tax incentives to encourage increased private sector participation.

7) A task team should be established to merge the National Food Research and Technology Centre and the Department of Agricultural Research into a National Food and Agricultural Research Centre (Section 5.2).

8) The Botswana Technology Centre and Rural Industries Promotions Company (Botswana) should be merged to form a new institution (Section 5.2).

9) The objectives of the Plan should be incorporated into the institutional plans of all government-funded research entities in order to ensure full alignment within the National System of Innovation (Section 6.1).

Monitoring

10) In order to monitor both the implementation of this Plan and the impact of Government-funded research, specific output- (Table 6.2) and outcomes- (section 1.3) based performance indicators based on the generic models outlined in this plan should be developed as an integral part of all research proposals.

11) Undertake a national survey of the State of Research, Science and Technology in Botswana to provide information for appropriate policy responses (Section 6.1).

12) BRSTFA should undertake annual reviews of the Missions, Centres and the Innovation Fund in order to ensure that they perform according to agreed indicators (Section 6.1).

13) An external review of BRSTFA and the BNRSTP should be done every five years with the purpose of ensuring that the National Science and Technology Plan remains aligned to national priorities (Section 6.1).

Human resource development and capacity

14) The University and the Centres of Excellence must play a key role in training highly specialised post-graduate researchers who will be required to lead the research within the identified priority areas (Section 4).

15) The Department of Research, Science and Technology, in partnership with the Ministry of Education, the Ministry of Finance and Development Planning, the Ministry of Labour and Home Affairs and the Ministry of Trade and Industry, should establish and continuously update a systems model of the S&T HR pool and associated data sources (Section 4.2).

16) A detailed assessment of research staff, research infrastructure and access to knowledge resources should be undertaken to highlight areas for intervention that may impact positively on the research environment, influencing the ability to attract and retain senior level skills in the system (Section 4).

17) A national researcher ranking and recognition framework should be established in order to enable the benchmarking of individual researchers and their institutions (Section 4.3).

18) Policies addressing the brain drain and researcher mobility should be created and managed in a holistic fashion to address key issues within the NSI in order to retain and attract skilled citizens (Section 4.3).

19) Formal mechanisms for strengthening researcher mobility, such as joint appointments between academic institutions and Research and Technology Organisations, should be supported to assist in leveraging scarce national resources more effectively (Section 4.3).

20) The Ministry of Communication, Science and Technology should focus on leveraging international research collaboration with a strong focus on researcher mobility and access to international research and development funding (Section 4.3).

21) The current and planned programmes that support upgrading of the qualifications of existing researchers and employees within S&T institutions to PhD and MSc level should be strengthened both from a dedicated funding and measurement and reward perspective (Section 4.3).

22) Where appropriate human resource capacity should be grown through the use of retired researchers for mentorship, structured post-graduate as link to HEI and structured internships as link to industry (Section 4.3).

23) There should be a strong focus on succession planning, utilising skills available in other countries to build Botswana's own resources (Section 4.3).

24) Strengthening links with Botswana scientists and engineers living outside the country should be given a high priority as they are an important resource (Section 4.3).

25) Imaginative and compelling curricula with clear linkages to the needs of society should be developed in order to attract talent (Section 4.4).

Partnerships

26) Links between Research and Technology Organisations and private industries should be created in order to build the capacity of the private sector and increase productivity (Section 5.3).

27) The Government should review policies with regard to the extent to which they encourage or inhibit partnering (Section 5.3).

28) Appropriate incentives such as funding for collaborative research; grants for equipment purchases and post-graduate training; recognition and monetary awards for the generation of intellectual property and other significant R&D output; should be provided to encourage innovation (Section 5.3).

29) Strategies to raise awareness across the world of Botswana's opportunities in S&T should be developed including through the Ministry of Foreign Affairs and International Cooperation (Section 5.3).

Intellectual Property

30) An Intellectual Property (IP) Policy should be developed to provide guidance for the management and exploitation of IP and the establishment of a legislative and/or regulatory framework to ensure better practice and returns from IP (Section 5.4).

31) A policy on Indigenous Knowledge Systems (IKS) should be developed to recognise and promote IKS research (Section 5.4).

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APPENDIX 1: DEFINITIONS OF RESEARCH[28]

Pure Basic Research

- Work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without a specific application in view.
- Analyses of properties, structures, and relationships with a view to formulating and testing hypotheses, theories or laws.
- The results of basic research are not generally sold but are usually published in scientific journals or circulated to interested colleagues.
- Work carried out without looking for long-term economic or social benefits other than the advancement of knowledge.

Strategic Basic Research

- Basic research directed into specific broad areas in expectation of useful discoveries.
- Basic research providing the broad base of knowledge necessary for the solution of recognised practical problems

Applied Research

- Original investigation to acquire new knowledge with a specific application in view.
- To determine the possible uses for the findings of basic research.
- To determine new methods or ways of achieving specific and pre-determined objectives.
- The results of applied research are intended primarily to be valid for a single or limited number of products, operations, methods, or systems.
- Applied research develops ideas into operational form.
- The knowledge or information derived from it is often patented but may also be kept secret.

Experimental Development

- Systematic work using existing knowledge gained from research and/or practical experience for the purpose of creating new or improved materials, products, processes or services, or improving substantially those already produced or installed.

[28] OECD,2002

APPENDIX 2: S& T QUALIFICATIONS OBTAINED ABROAD BY GOVERNMENT-SPONSORED STUDENTS(2000 – 2005)[29]

	2000	2001	2002	2003	2004	2005	TOTAL
Acturial science	6	6	21	3	4	5	45
Aeronautical engineering	1			1			2
Aerospace electronics				1			1
Agriculture		9	23	2	20	42	96
Aircraft maintenance	3	2		1	2	1	9
Animal science		6	6	4	13	74	103
Applied chemistry		1					1
Applied computing			1				1
Applied human nutrition		2					2
Applied maths		1			2	1	4
Applied physics			1				1
Architectural design and technology					1		1
Architectural engineering technology		3	4		7		14
Architecture	3	5	10	9	6	7	40
Automobile engineering			2				2
Aviation maintenance technician		1					1
Aviation management	1				1		2
Avionics engineering technology						1	1
Biological studies						1	1
Biology			4			3	7
Biology and chemistry					2	1	3
Biomedical engineering	3	2	2	10	5		22
Biomedical science	1		1	3	2	3	10
Biomedical technology			1	1		4	6
Building construction technology			1			1	2
Building engineering			1				1
Building surveying		1	3				4
Chemical engineering	1	3	3		6	2	15
Chemistry						2	2
Civil engineering	1	1	4	5	9	13	33
Civil engineering and environment	1	1	1		1		4
Computer and information science	1	1	3	2	1		8
Computer engineering & engineering	3	4	4	9	9	3	32
Computer networking and communication				3			3
Computer science		3	12	5	7	7	34
Computer systems					1	3	4
Computer systems design				2	2	1	5
Computer systems engineering				2	1		3
Computer technology			1				1
Computers	1		1		3	1	6
Construction management	1	2	3			1	7
Construction studies					1	2	3
Control systems		1					1

[29] Source obtained from Ministry of Education Department of student welfare and placement.

	2000	2001	2002	2003	2004	2005	TOTAL
Control systems engineering				1			1
Crop production				2	5	6	13
Dental technology			2		3		5
Dental therapy						2	2
Dentistry	2	2	2	2	6		14
Dietectics and nutrition	2	3	2		2	3	12
Electrical and computer engineer				1	2		3
Electrical and electronic	2	1	1	2	3		9
Electrical engineering		5	2	6	5	11	29
Electronics			1	1		4	6
Engineering	2	1	1	6	10	2	22
Engineering (computer)	1	1		1	2	2	7
Engineering (geophysics)	1						1
Engineering management				1			1
Environmental health programme				2	1	1	4
Environmental science				1		1	2
Environmental design studies program					1		1
Environmental eng	1	3		3	2	1	10
Environmental health		1	3		6	8	18
Environmental sciences		1	1	1			3
Food and nutrition			1	3	3	1	8
Food science & technology		1	1	1	1		4
Food science and engineering				1			1
Food technology		1	2	2	1	2	8
Forestry	2					1	3
Geographical & environmental management				1			1
Geographical information systems		1		2	3		6
Geology			1		2	1	4
Graphics and web development				1			1
Health information tech.		1					1
Health services					1		1
Heavy equipment		1					1
Human biology						1	1
Hydrology	1						1
Industrial engineering	2	2	1	9		2	16
Industrial safety management			1				1
Industrial/product design					1	2	3
Informatics		1	1		2	8	12
Information science		1	4				5
Information systems	8	11	23	16	22	9	89
Information systems(info mgt)					1		1
Information technology	2	4	19	16	40	28	109
Instrumentation engineer			2				2
Land surveying			4	1		4	9
Leather technology		1					1
Life science				1			1
Management information systems	1	6	11	6	2	5	31
Manufacturing engineering			8	4	2		14
Material engineering				1			1
Mathematics			2		1	1	4
Mechanical and manufacturing					1		1
Mechanical engineering	1	2	2	6	8	7	26
Medical lab technology	4	1	1		1		7
Medicine	11	15	13	27	29	12	107
Metallurgical engineering	3	1		1		1	6
Meteorology	3				2		5
Microbiology		1		3	2		6

	2000	2001	2002	2003	2004	2005	TOTAL
Microsoft certified system engineer				1	1		2
Mineral engineering		1		2			3
Mineral processing	1	2					3
Minerals surveying management					1		1
Mining engineering		3	2	2	1		8
Nuclear medicine technology		1					1
Nutrition and dietetics		2			1		3
Occupational health and safety			1	1		1	3
Optometry				1			1
Pharmaceutical chemistry		1					1
Pharmacy	7	3	3	4	11	1	29
Physics			1			1	2
Physiotherapy	1			3	1		5
Poultry science				1			1
Power engineering			1	1			2
Quantity surveying	4	6	13	3	13	3	42
Radiography	4	1	6	2			13
Science	1	12	11	10	12	22	68
Science and maths					3	7	10
Science education	1				1	1	3
Science geophysics	1	1	1		2	1	6
Sewage and water engineering			1	2	2		5
Software engineering				1		1	2
Soil science				1			1
Sound engineering						1	1
Surveying			1				1
Surveying and mapping sciences	3	1	1		1		6
Systems analysis			1	1			2
Systems engineering		1	1	1			3
Telecommunication engineering					2		2
Telecommunications eng.			1				1
Textile design		1	1				2
Textile manufacturing				1			1
Transport				1	1		2
Transport engineering	3						3
Veterinary medicine	1	2	2	2	1		8
Wildlife management		1					1
Zoology		1		3	3		7
	103	164	273	239	337	344	1459

APPENDIX 3: CRITERIA FOR PRIORITISING RESEARCH AREAS

Value addition is an important result of innovation and a key contributor to income and employment. Botswana needs to invest in areas where value chains based on its natural capital can be repatriated thus adding wealth and creating employment opportunities.

Economic diversification: The country's economy is based on a few resources which makes it vulnerable to changes in trade or to the demand for those resources. Diversification is an important vehicle for increasing and ensuring the sustainability of employment and income opportunities.

Comparative advantage and disadvantage:

- The country should invest in those areas in which it has comparative advantage in order to be better positioned in relation to its competitors in terms of access to markets (e.g. Minerals, natural ecosystems, and human resource base).
- There are also certain crucial areas where the country has a distinct disadvantage which require investment in research to ease the constraints that these areas impose on the economy and to mitigate the burden that they impose on its natural resources and fragile environment (e.g. access to water and energy).

The potential for market and private sector uptake is important because developed technologies need to be translated into services and manufactured products so that they can contribute to employment and incomes. Innovative economies show a far higher degree of technology uptake than is currently evident in Botswana (CSIR, 2005c)

Poverty alleviation: Poverty, especially among female headed households and in certain parts of the country is a major concern. It is now accepted that there is a relationship between poverty and the degradation of the environment such as the felling of trees for fuel wood and between poverty and the spread of HIV/AIDS. It is important that the research that is supported contributes to its reduction.

Job creation: Unemployment, especially among the young is a major national concern and it is expected that the nation's investment in research should have positive spin-offs in terms of job creation.

HIV/AIDS: Botswana suffers from one of the highest rates of HIV infection in the world. Reducing the impact of HIV/AIDS will help to maintain knowledge and capacity of the country.

Institutional and Human resource development (HRD) is not only important for the

maintenance of capacity to undertake research and to be innovative but also as a means to provide better service delivery, create jobs and reduce unemployment. This is particularly important for creating opportunities for women and the youth.

Sustainable use of natural resources: Natural resources are the basis for economic development and life in general. Many natural resources in Botswana are under pressure[1]. Access to and the sustainable use of natural resources goes hand in hand with sustainable economic growth and social justice. The minimisation of waste and pollution control are important components of sustainable resource use.

Environmental health: Research should contribute towards ensuring sustained ecosystems' functioning as a key livelihood support mechanism.

Beneficial use of natural resources: Botswana has a vast natural resource base. There are a variety of natural resources which remain unexploited and undiscovered. Research aimed at unlocking this natural capital for the nation's benefit should be encouraged.

Link to regional and international initiatives: a recurrent theme in initial stakeholder meetings was the need for Botswana to form regional partnerships as this would ensure optimal use of the resources and facilities available in the region thus reducing the investment required in people and equipment and encouraging knowledge sharing. With the rapid globalisation of the knowledge economy, international linkages and collaboration are also important.

Potential to convert intellectual capital into other forms of capital. The survey undertaken as part of the Inventory and Assessment Report showed a low conversion of intellectual capital in comparison to other countries (CSIR, 2005c).

Scientific merit and ethics: It is important that only proposed research ideas that have scientific merit are supported and, for example, that investment is not made in areas where the knowledge can be acquired off the shelf at a lower cost. It is also important that Botswana avoids supporting research into ethically questionable areas.

Development of indigenous knowledge: Indigenous knowledge is recognised throughout the world as having the potential to contribute to human welfare. Botswana needs to protect its indigenous knowledge and harness it to the benefit of its citizens.

Alignment with policy: The research priorities and effort should not only be aligned to the country's policies but also inform its future policy choices.

APPENDIX 4: GLOBAL TECHNOLOGY TRENDS

Table 1 summarises emerging technologies as identified by various organisations globally (CSIR, 2005d[30]). The organisations were selected on the basis of:

- the reputation of the organisations that generated them;
- the breadth of technologies covered; and,
- the publication date (generally within the past 1-3 years).

Not surprisingly, technology is interpreted and presented quite differently by the different organisations. In some cases technologies are described as areas of know-how with a variety of potential applications (such as the Batelle and MIT lists), while in others technologies are described in more specific application terms (such as the CNN and Healthcare Informatics lists). Although the table provides a useful indication of trends in the global research arena, many of which find resonance in areas identified in the Botswana process, the organisations represented in the survey are from highly developed countries at the cutting edge of technology development and perhaps not directly applicable in the Southern African context.

The South African Department of Trade and Industry, recently commissioned a study on global technology developments as an input to the identification of areas where business growth through foreign currency earning exports could be encouraged[31]. There is a fairly close correlation between the recommendations in this report and those from the Botswana prioritisation process. Table 2 highlights some of the technologies of relevance to Botswana listed in the South African report.

[30] CSIR,2005: Top emerging technologies: desktop study. Unpublished report to the Strategic Research Committee of the CSIR. Pretoria. . For the purposes of this project, an emerging technology is defined as "a new evolving area of know-how with potential to start changing our world in the next 5 -10 years".

[31] Bluepeter/AMI, 2004: Benchmarking of technology trends and technology developments. Report to the South African Department of Trade and Industry. Pretoria.

Table 1: Top emerging technologies identified by various organisations (CSIR,2005d[32])

Batelle (2002)	AICPA (2004)	CNN Top 10	Genome Canada	MIT Technology Review (2005)	MIT Technology Review (2004)	MIT Technology Review (2003)	Healthcare Informatics (2004)
Genetic-based Medical and Health Care High-power energy packages Green Integrated Technology Omnipresent Computing Nanomachines Personalised Public Transportation Designer Foods and Crops Intelligent Goods and Appliances Worldwide Inexpensive and Safe Water Super Senses	ID authentication Radio Frequency Identification (RFID) 3G Wireless Simple Object Access Protocol (SOAP) Autonomic Computers	Ultra-wideband RFID Wireless broadband Micro fuel cells Gecko tape Antispam software OLEDs LED lightbulbs MRAM Bioinformatics	Molecular diagnostics Recombinant vaccines Vaccine and drug delivery Bioremediation Sequencing pathogen genomes Female-controlled protection against STIs Bioinformatics Nutritionally enriched genetically modified crops Recombinant drugs Combinatorial chemistry	Airborne networks Quantum wires Silicon photonics Metabolomics Magnetic-resonance force microscopy Nanotube based universal memory Bacterial factories Enviromatics Cell-phone viruses Biomechatronics	Universal Translation Synthetic biology Nanowires Bayesian machine learning T-Rays Distributed storage RNAi therapy Power grid control Microfluidic optical fibres Personal genomics	Wireless Sensor Networks Injectable Tissue Engineering Nano Solar Cells Mechatronics Grid Computing Molecular Imaging Nanoimprint Lithography Software Assurance Glycomics Quantum Cryptography	Semantic Web Smart bandages Contamination detection RFID Intelligent agents 3-D computer imaging Artificial intelligence Personal monitoring networks Email protocol Radiosurgery Smart cards Data storage

[32] CSIR,2005: Top emerging technologies: desktop study. Unpublished report to the Strategic Research Committee of the CSIR.

Table 2: Selected technology areas and research needs identified for South Africa[33].

Sector	Technology needs/research areas
ICT The future ICT landscape – unobtrusive hardware, seamless communications infrastructure, distributed networks, natural feeling human interfaces, secure ubiquitous environment.	▪ Mobile technologies and services ▪ Wireless network technologies ▪ Human language technologies ▪ Open source software ▪ Telemedicine ▪ Geomatics ▪ Manufacturing technologies
Tourism Needs clean, safe and healthy environment, marketing to rest of world and participation locally.	▪ ICT to improve productivity and reach broader client base ▪ Environmental (fuel efficiency, cleaner production) ▪ Renewable resources ▪ Cultural heritage
Cultural sector Large global industry – job creation potential and opportunity to develop less favored regions. Complex and fragmented sector	▪ Not from new technologies but from creativity, skills and traditional materials. ▪ Enabling communication technologies ▪ Product improvement technologies ▪ Links to end consumer
Agro-processing Declining profits leads producers to develop new products with higher margins and functions, new uses for old products and waste streams, incorporating cutting-edge technology. Consumers consumption shift to organic products and functional foods. Food processing for improved shelf-life, availability and safety.	▪ Real-time detection of microorganisms ▪ Monitoring sensors in food processing ▪ Neutraceutical intake levels ▪ Technologies to inactivate food microorganisms for greater shelf life ▪ Food traceability technologies ▪ Edible food packaging films ▪ Minimise food wasteage through ICT and process solutions and increased shelflife
Biotechnology Bioeconomy of South Africa is still small – used in food, beverage, waste and water treatment. Emphasis mostly at R&D level.	▪ Recombinant therapeutic products ▪ Vaccines – eg, HIV/AIDS, TB, malaria ▪ Diagnostics – instruments, reagents for screening. ▪ Commodity chemicals from Biomass ▪ Energy from renewable resources ▪ Biocatalysts
Other	▪ Extraction of minerals from coal ash and low value slag ▪ Improved minerals recovery in mining ▪ Value addition to natural products and unique biodiversity ▪ Improvements to metals value chain processes ▪ Improved minerals reduction and extraction techniques ▪ Energy efficiency

[33] Bluepeter/AMI, 2004: Benchmarking of technology trends and technology developments. Report to the South African Department of Trade and Industry. Pretoria.