



innovation *NOUN* something newly introduced, such as a new method or device

knowledge *NOUN* the facts, feelings or experiences known by a person or group of people



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Acronyms



ASGISA	Accelerated and Shared Growth Initiative for South Africa
DST	Department of Science and Technology
GDP	Gross domestic product
GERD	Gross expenditure on research and development
ICT	Information and communication technology
NIPF	National Industrial Policy Framework
NSI	National system of innovation
OECD	Organisation for Economic Cooperation and Development
PGM	Platinum group metals
R&D	Research and development
S&T	Science and technology
SET	Science, engineering and technology
SMME	Small, medium and micro enterprise
TIA	Technology Innovation Agency

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The Department of Science and Technology's Ten-Year Innovation Plan is by far the clearest signal of our commitment to a prosperous South Africa, one in which all citizens benefit from the fruits of our investment in knowledge and its exploitation.

The South African science landscape has evolved dramatically since the dawn of democracy through government's commitment to transforming the inward-looking and embattled sector into a system that is innovative, flexible and responsive to the needs of our society.

Knowing that the level of economic growth envisaged by our country requires continual advances in technological innovation and the production of new knowledge, and in our common determination to build a better world, we are strengthening our role in the development and growth of South Africa. The country has ambitious growth targets, and we are certain to meet these with the Ten-Year Innovation Plan's renewal and deepening of our focus on innovation. The growing investment in research and development outlined in the Plan will guarantee an environment that accelerates the realisation of the country's innovation outcomes.

Equally fundamental to the Plan is its approach to innovation. As the first official innovation survey carried out by my Department shows, the considerable levels of innovation occurring in the business sector alone are at a level comparable with our international competitors.

As science is essentially forward-looking, the Plan provides strategic leadership and direction for modern science and technology in pursuit of South Africa's socioeconomic goals, while remaining at the cutting edge of both human and scientific endeavour, as well as technological advancement.

I am convinced that this Plan contains the elements we require to produce a generally innovation-literate society and workforce, thus contributing greatly to the strengthening of South Africa's competitiveness in the knowledge era and arena.

The Plan will enhance the Department of Science and Technology's leadership in the modernisation of our country's economy and society, as well as grow our knowledge economy to improve conditions for all South Africans. I therefore take great pleasure in presenting the Ten-Year Innovation Plan to the nation.

Mosibudi Mangena
Minister of Science and Technology



There is no mistaking that South Africa's entire science system is currently in the midst of extensive revitalisation, spearheaded by, among other things, this Cabinet-supported Ten-Year Innovation Plan. Chief among the Plan's objectives is to ensure that government investment in scientific research not only strengthens the effectiveness of our National System of Innovation, but also yields tangible socioeconomic benefits for our country.

The Plan charts the course for the enhancement of innovation in our country, contributing to sustained economic growth on the basis of what we are convinced are the pillars of a properly functional knowledge economy - human capital development, R&D and knowledge infrastructure.

It is crucially important to note that the Department of Science and Technology's Plan identifies bold interventions in certain critical areas, called "grand challenges". These areas offer tremendous opportunities for steering our resource-based economy towards a knowledge-based economy.

We believe that this Plan is the best possible high-level projection of what is expected of South Africa's knowledge base in 10-years time. It is a forward-looking blueprint that charts the course for growth in science, technology and innovation, and shows how we can optimally employ these for the greater prosperity of society and to improve the quality of life of all South Africans. The indicators in this plan are not absolute, but give an idea of the levels to which we envisage taking the system.

I am enormously proud to present the Ten-Year Plan for Innovation.

Dr Phil Mjwara
Director-General
Department of Science and Technology

Executive Summary



The purpose of this Ten-Year Innovation Plan is to help drive South Africa's transformation towards a knowledge-based economy, in which the production and dissemination of knowledge leads to economic benefits and enriches all fields of human endeavour.

The plan builds on previous work undertaken by the Department of Science and Technology (DST). It is not, however, a compendium of existing programmes. Instead, it is a high-level presentation of the principal challenges identified by the DST, starting not from where South Africa is today, but where we should be a decade from now. The core projections for 2018 are summarised as South Africa's "grand challenges" in science and technology.

The plan proceeds from government's broad socioeconomic mandate – particularly the need to accelerate and sustain economic growth – and is built on the foundation of the national system of innovation (NSI). It recognises that while the country's science and technology system has taken important strides forward, there is a tremendous gap between South Africa and those countries identified as knowledge-driven economies. To close this gap, the NSI must become more focused on long-range objectives, including urgently confronting South Africa's failure to commercialise the results of scientific research, and our inadequate production (in both a qualitative and quantitative sense) of knowledge workers capable of building a globally competitive economy.

The title of this report emphasises innovation – but not innovation for its own sake. South Africa's prospects for improved competitiveness and economic growth rely, to a great degree, on science and technology. The government's broad developmental mandate can ultimately be achieved only if South Africa takes further steps on the road to becoming a knowledge-based economy. Transformation in this direction will necessarily shift the proportion of national income derived from knowledge-based industries, the percentage of the workforce employed in knowledge-based jobs and the ratio of firms using technology to innovate.

Progress towards a knowledge-based economy will be driven by four elements:

- Human capital development
- Knowledge generation and exploitation (R&D)
- Knowledge infrastructure
- Enablers to address the "innovation chasm" between research results and socioeconomic outcomes

The grand challenges outlined in this plan address an array of social, economic, political, scientific, and technological benefits. They are designed to stimulate multidisciplinary thinking and to challenge our country's researchers to answer existing questions, create new disciplines and develop new technologies.

The grand challenge areas are:

- The “Farmer to Pharma” value chain to strengthen the bio-economy – over the next decade South Africa must become a world leader in biotechnology and the pharmaceuticals, based on the nation's indigenous resources and expanding knowledge base.
- Space science and technology – South Africa should become a key contributor to global space science and technology, with a National Space Agency, a growing satellite industry, and a range of innovations in space sciences, earth observation, communications, navigation and engineering.
- Energy security – the race is on for safe, clean, affordable and reliable energy supply, and South Africa must meet its medium-term energy supply requirements while innovating for the long term in clean coal technologies, nuclear energy, renewable energy and the promise of the “hydrogen economy”.
- Global change science with a focus on climate change – South Africa's geographic position enables us to play a leading role in climate change science.
- Human and social dynamics – as a leading voice among developing countries, South Africa should contribute to a greater global understanding of shifting social dynamics, and the role of science in stimulating growth and development.

With these challenging goals before us, the government must address the “innovation chasm”, which means improving access to finance, creating an innovation-friendly regulatory environment and strengthening the NSI. This 10-year innovation plan also recognises that a significant strengthening of the production of human capital and the institutional environment for knowledge generation is necessary, in collaboration with international partners.

Finally, this bold innovation strategy will require policy leadership from the DST and other government departments, and strengthened cooperation in all matters of science and technology.





1 Introduction

This Ten-Year Innovation Plan proposes to help drive South Africa's transformation towards a knowledge-based economy, in which economic growth is led by the production and dissemination of knowledge for the enrichment of all fields of human endeavour.

Success in this regard will be measured by the degree to which science and technology play a driving role in enhancing productivity, economic growth and socioeconomic development.

This plan is a high-level presentation of the principal challenges identified by the Department of Science and Technology (DST), starting not from where South Africa is today, but where we should be a decade from now. The core projections for 2018 are summarised as South Africa's "grand challenges" in science and technology.

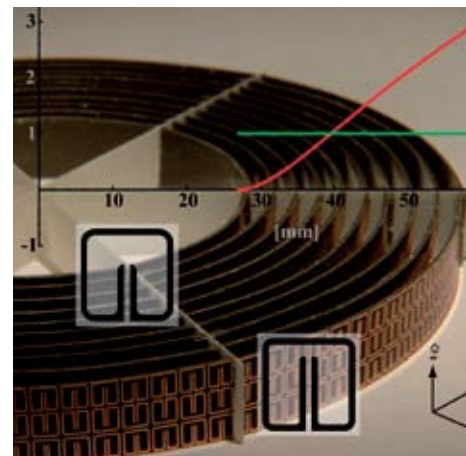
Innovation is, of course, the key to scientific and technological progress, but our starting point is not innovation for its own sake. South Africa's innovation revolution must help solve our society's deep and pressing socioeconomic challenges. This is the government's broad mandate, and the grand challenges of science and technology are in sync with the needs of our society.

For more than a decade South Africa's democratic government has been developing the national system of innovation (NSI). This plan builds on the foundation of the NSI, and its multiplicity of institutional structures and relationships. It is specifically not the intention of this plan to review the entire NSI, or other critical elements of the science and technology system (the need for advanced facilities and equipment, modern laboratories, research support, expanded international cooperation) that are integral to our progress. All these elements of the science and technology system, and the challenges specific to them, are discussed thoroughly elsewhere, and this plan is built on the assumption that we must continue to make progress in all these areas as we implement the Ten-Year Innovation Plan.¹

Policy background

The NSI is an enabling framework for science and technology, and is central to the country's prospects for continued economic growth and socioeconomic development.

¹ See, for example, the White Paper on Science and Technology (1996); the National Research and Technology Foresight (1999); and the National Research and Development Strategy (2002)





The DST and the Cabinet laid the foundations for the NSI with a series of strategic documents, beginning with the 1996 White Paper on Science and Technology, and followed by the National Research and Technology Foresight (1999) and the National Research and Development Strategy (2002). The latter emphasised the need to strengthen the place of research and development (R&D) in the economy, proposing an investment target of 1 percent of gross expenditure on R&D as a percentage of gross domestic product (GERD/GDP) for 2008.

These direction-setting initiatives have yielded measurable progress throughout the NSI and the economy, where GERD/GDP reached 0.92 percent in 2005/06. Yet for South Africa to rise to the global challenge, the NSI must become more focused on long-term objectives. In particular, the government must urgently confront the failure of the NSI to commercialise the results of scientific research. The DST's conclusions in this regard are mirrored in a peer review conducted by the Organisation for Economic Cooperation and Development (OECD).²

The economic cluster of government departments, which includes the DST, has identified a number of key national targets to meet over the decade leading up to 2018. These include achieving 6 percent economic growth by 2010 – a core target of the Accelerated and Shared Growth Initiative for South Africa (ASGISA)³ – and halving poverty and unemployment by 2014. The Ten-Year Innovation Plan helps to map this critical trajectory and supports the National Industrial Policy Framework (NIPF)⁴ by encouraging sectoral growth to enhance the competitiveness of the economy.

Towards a knowledge-based economy

South Africa's prospects for improved competitiveness and economic growth rely, to a great degree, on science and technology. The government's broad developmental mandate can ultimately be achieved only if South Africa takes further steps on the road to becoming a knowledge-based economy, in which science and technology, information, and learning move to the centre of economic activity.

The knowledge-based economy rests on four interconnected, interdependent pillars:

- Innovation
- Economic and institutional infrastructure
- Information infrastructure
- Education

² OECD Review Report on South Africa (2006)

³ Accelerated and Shared Growth Initiative for South Africa (2005)

⁴ Draft National Industrial Policy Framework (2006)

1 Introduction – continued

South Africa, which has historically been a resource-based economy, has some distance to travel to become a knowledge-based economy.

Today, new “frontier” technologies are transforming and expanding many economies in the same way that earlier industrial and technological revolutions changed the course of history.⁵ Just as the steam age and the information technology age, for example, went through various stages of development, so too will the technologies considered to be at the frontiers of knowledge today. Figure 1 below depicts typical patterns of technological development linked to economic activity.

South Africa must seize the opportunities now available in areas such as biotechnology, nanotechnology and the “hydrogen economy” to establish capabilities that will provide long-term, sustainable solutions in national priority areas such as health and energy, while boosting economic growth.

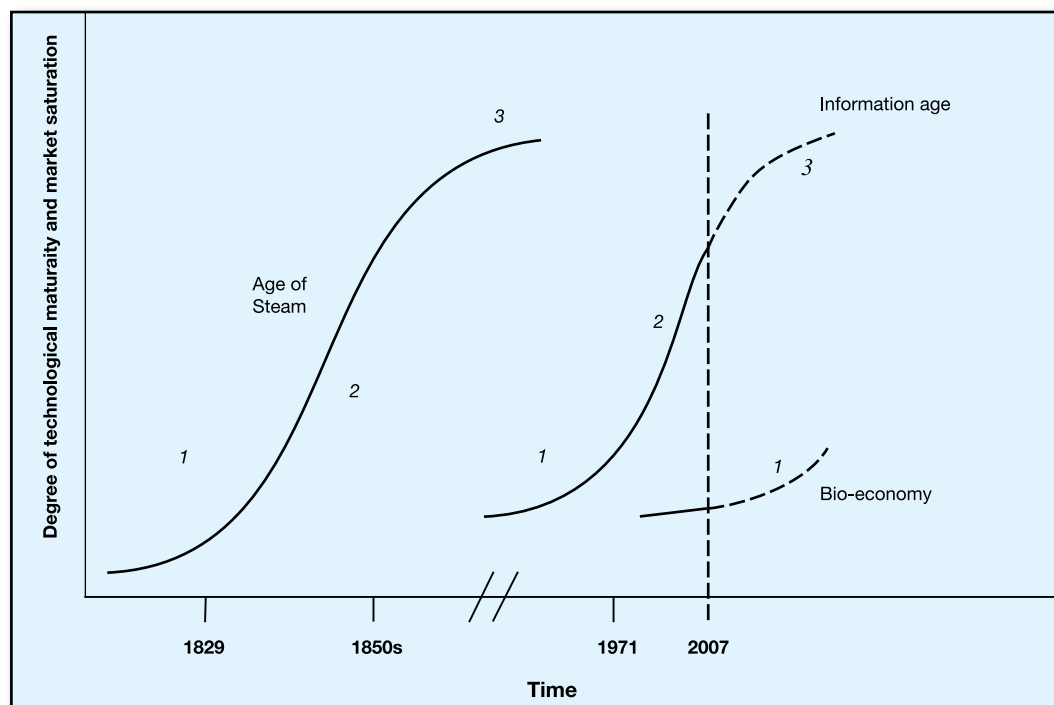


Figure 1: Technological development phases linked to economic activity over a time period⁶

⁵ Adapted from: Great surges of development and alternative forms of globalization, Perez C, Universities of Cambridge and Sussex, U.K. and Technological University of Tallinn, Estonia, 2007

⁶ Adapted from Perez (2007)

Today, a growing percentage of wealth in the world's largest economies is created by knowledge-based industries that rely heavily on human capital and technological innovation. The DST supported by other government departments, aims to lead a programme of interventions over the next decade to drive South Africa's transformation towards a knowledge-based economy. Innovation must become the watchword.

A vision for 2018

The key objective of this plan is to articulate a national path of innovation, building on the NSI, in support of the transformation to a knowledge-based economy. It describes a future in which South African innovations in science and technology are combating the negative effects of climate change in Africa; fighting crime; producing drugs to combat disease; developing sustainable energy solutions; introducing drought-tolerant, disease-resistant crops; devising “intelligent” materials and manufacturing processes; revolutionising our communications; and changing the work we do and the way we do it.

In contrast to many short- and medium-term plans, which amount to an aggregation of current activities, this Ten-Year Innovation Plan has a different starting point: it begins with where South Africa needs to be a decade from now – an agreement on what we will have accomplished by 2018. These strategic outcomes are identified as the “grand challenges”, and we are confident that the nation, and our entire science and technology system, will rise to the occasion. A concise set of indicators anticipated to be achieved by 2018 is presented with each of the grand challenges.

Our vision for South Africa in 2018 includes:

- Being one of the top three emerging economies in the global pharmaceutical industry, based on an expansive innovation system using the nation's indigenous knowledge and rich biodiversity
- Deploying satellites that provide a range of scientific, security and specialised services for the government, the public and the private sector
- A diversified, supply secured sustainable energy sector
- Achieving a 25-percent share of the global hydrogen and fuel cell catalysts market with novel platinum group metal (PGM) catalysts
- Being a world leader in climate science and the response to climate change
- Having met the 2014 Millennium Development Goals to halve poverty

In summary, we envisage a society that uses its knowledge systems and human capital to solve problems in our country and on our continent, while exploiting economic opportunity in a sustainable way. With increased R&D investment by the private and public sectors, an opportunity exists for bold interventions that will secure a greater share of global markets. South Africa can exploit its natural resource base and intensify knowledge-generation activities to

produce competitive technologies in fields that are still at the development phase. At the same time large, targeted R&D programmes can build scientific, engineering and management capacity over the long term. For example, research on fuel cell technologies will have important spin-offs in the chemicals, plastics and manufacturing sectors. In other words, appropriately targeted R&D can provide a broad impetus for innovation and growth.

Key principles

This long-term plan presents a range of strategic objectives that cannot be simply extrapolated from existing projects and technologies. Instead, it is based on a set of broad principles that should inform the government's investment decisions.

This does not mean picking individual winners and losers – but it does mean being selective, alert and flexible. Today, South Africa may need to invest heavily in areas on which we all agree; tomorrow, we may need to disengage from some sectors as their importance declines, while keeping our options open elsewhere. Ultimately, we must keep our eyes on the prize: building a knowledge-based economy.

This plan is built on the assumption that South Africa must continue to make more rapid progress in critical related areas of societal transformation. This includes the crucial need to expand the numbers of black and women scientists, engineers and technology experts; and more broadly, that the government's investments in science and technology also help to eliminate poverty.

This Ten-Year Innovation Plan is based on the following key principles:

1. Strategic decision: South Africa is failing to convert ideas into economic growth. While the government must invest throughout the entire innovation chain, strategic choices must be made.
2. Competitive advantage: the government should invest in areas of the highest socioeconomic return, i.e. Grand Challenges.
3. Critical mass: investment in key research must be made at a critical mass.
4. Sustainable capacity: the R&D scale-up must be consistent for the system to have the appropriate absorptive capacity, with each element (e.g. skills, capital spend) relying on others for the system to work.
5. Life-cycle planning: R&D infrastructure must be considered over the long term, including depreciation, skills needs and running costs.

With these principles in mind the Ten-Year Innovation plan proceeds to outline the core projections for 2018. At the heart of the plan is transformation towards a knowledge-based economy, which is discussed in Section 2 below.

2 Transformation towards a Knowledge-based Economy

Long-term transformation in the structure of South Africa's economic life requires strategic leadership and policy direction by the government. Over the past decade there has been a growing recognition of the place of knowledge and technology in economic development, and a concomitant shift in economic theory. This shift acknowledges that not only labour and capital are factors of production, but that technology and the knowledge to exploit it are also crucial.⁷

The knowledge-based economy has four pillars: innovation, education, the economic and institutional regime, and information infrastructure.⁸ The DST, in collaboration with other government departments, aims to boost innovation through a series of directed interventions in strategic areas. Today's explosive growth in innovation, new products and services can be ascribed to earlier investments in developing knowledge in areas such as chemistry, biology, earth sciences and nuclear sciences, coupled with phenomenal advances in information technology.

Economic growth is accelerated with the right mix of investment in knowledge stocks and knowledge infrastructure. "Stocks" of knowledge form part of the intellectual capital held by private companies, or within countries. Such stocks can profitably be invested by both the public and private sectors. Both the public and private sectors can profitably invest such stocks.

Transformation towards a knowledge-based economy will necessarily shift the proportion and growth of national income derived from knowledge-based industries, the percentage of the workforce employed in knowledge-based jobs and the ratio of firms using technology to innovate. South Africa has a long way to go in this regard. According to the World Bank's 2006 Knowledge-based Economy Index, South Africa ranked 58 out of 132 countries, down from 52nd in 1995.

Progress towards a knowledge-based economy will be driven by four elements:

- Human capital development
- Knowledge generation and exploitation (R&D)
- Knowledge infrastructure
- Enablers to address the "innovation chasm" between research results and socioeconomic outcomes

Increased investment in these four areas will certainly have an impact. International experience, however, suggests that an incremental approach will not work. Nations that have achieved accelerated growth in outputs and capabilities have acted decisively, targeting investments in areas of strategic opportunity.

⁷ Romer, P. M., "Endogenous Technological Change," *Journal of Political Economy*, Vol. 98, No. 5, "Part 2: The Problem of Development: A Conference on the Institute for the Study of Free Enterprise Systems." (1990), pp. S71-102.

⁸ World Bank Institute

2 Transformation towards a Knowledge-based Economy – *continued*

This plan outlines such a bold stance, targeting specific outcomes for 2018. Success depends on a vibrant NSI. This will require certain reforms of the NSI's institutional fabric – including actions to forge working partnerships between intellectual property holders and industry. In support of this, the government will create mechanisms to develop and harvest research outputs for commercialisation, such as the Technology Innovation Agency.



Figure 2: Link between citation and wealth intensities (Sources: King, D.A., *Nature*, 2004)

Figure 2 demonstrates the correlation between the economic wealth of nations and their “citation intensity”. The graph shows the ratio of citations per unit (person) versus per capita GDP for the 31 nations in the comparator group. Wealth intensity is given in thousands of US dollars at 1995 purchasing-power parity.

2 Transformation towards a Knowledge-based Economy – *continued*

South Africa is clustered with countries such as Poland, Russia and Brazil. The implication is clear: for South Africa to join the ranks of wealthier countries, it needs to increase its knowledge output substantially. This will require an increase in R&D expenditure. For example, while average R&D spend by the OECD countries in 2004 was 2.3 percent of GDP, and China's was 1.35 percent that year, South Africa invests a mere 0.91 percent of GDP on R&D.⁹

This plan is based on the premise that the government's growth targets require a significant investment in innovation, balanced and targeted in accordance with the full range of national priorities. Ultimately, such investment will contribute to more rapid economic and social transformation. By committing to growing the base of scientists and engineers, both in general and in areas offering the most economic potential over the long term, South Africa is investing in human capital that will serve its needs well into the future. By targeting development and new global industries, the country can reduce its dependence on imported technology, and become more self-sufficient in such basic commodities as energy and food.

The Ten-Year Innovation Plan presents a framework of indicators drawn up by DST in collaboration with other partners. These indicators should guide the direction of investments and actions over the next decade. The first table of indicators is presented below.

Innovation towards a knowledge-based economy: the transformation

Indicator	Measure	2018
SA positioned as knowledge-based economy	Economic growth attributable to technical progress (10% in 2002)	30%
	National income derived from knowledge-based industries	>50%
	Proportion of workforce employed in knowledge-based jobs	>50%
	Proportion of firms using technology to innovate	>50%
	GERD/GDP (0.92 in 2005; short-term 2008 target was 1%)	2%
	Global share of research outputs (0.5% in 2002)	1%
	High- and medium-tech exports/services as a percentage of all exports/services (30% in 2002)	55%
	Number of South African-originated US patents (100 in 2002)	250
Research and technology enablers	Matriculants with university exemption in maths and science (5.2% maths and 5.9% science in 2005)	10%
	SET graduates as percentage of all students in public higher education institutions (28% in 2005)	35%
	Number of SET PhD graduates per year (561 in 2005)	3 000
	Number of full-time equivalent researchers (was 11 439 in 2005)	20 000
	FTE researchers per 1 000 workforce employed (1.5 in 2005)	2.6

⁹ DST (2007) National R&D survey, 2005/06

3 The Grand Challenges

With these broad goals in mind, section 3 presents the grand challenges facing the science and technology system over the next decade. The grand challenges outlined in this plan address an array of social, economic, political, scientific, and technological benefits. They are designed to stimulate multidisciplinary thinking and to challenge our country's researchers to tackle existing questions, create new disciplines and develop new technologies. This bold innovation strategy will require policy leadership by the DST and strengthened cooperation across government.

The grand challenge areas are:

- The Farmer to Pharma value chain to strengthen the bio-economy
- Space science and technology
- Energy security
- Global-change science with a focus on climate change
- Human and social dynamics

Progress in all these areas will be based on the three foundations: technology development and innovation, human capital and knowledge infrastructure (including the research institutions mandated to promote sector research). Figure 3 illustrates the interconnections between these foundations and the grand challenge programmes. While the latter are structured within a national context, international collaboration and partnerships will be essential to success.

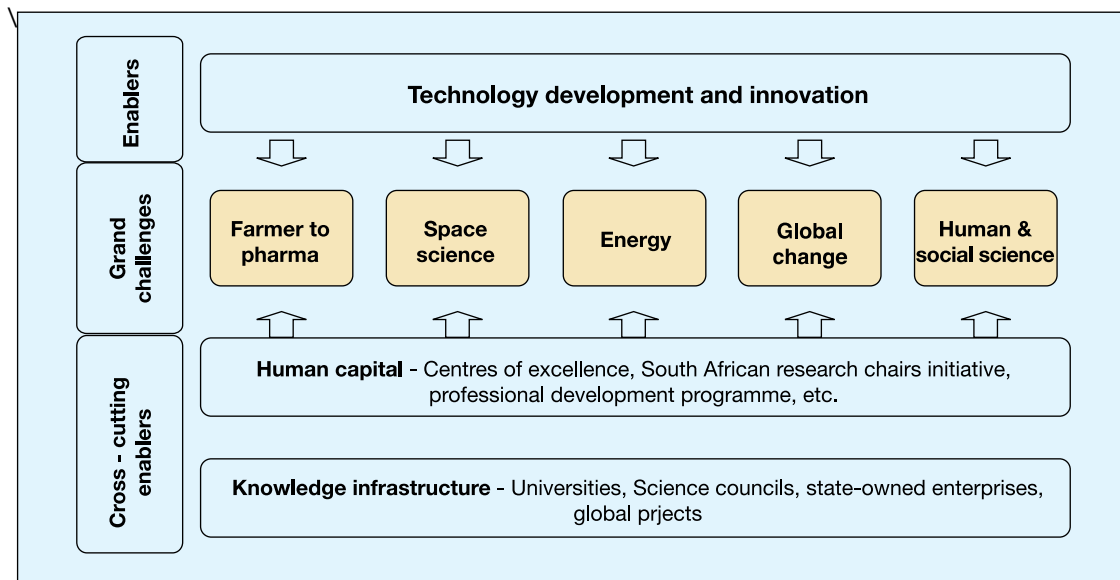


Figure 3: Grand challenges and enablers of the ten-year plan

3.1 From Farmer to Pharma: life sciences and health

Over the next decade South Africa must work to become a world leader in biotechnology. Since the introduction of the first commercial genetically modified crops in 1995, more than 400-million hectares have been planted, 40 percent of which are grown in the developing world. And it is in the developing world where the need for biotechnological innovation to solve basic problems, from health care to industrial applications, is most apparent.

There is tremendous yet untapped potential to develop the biotechnology industry. South Africa has the world's third-largest biodiversity resource base, a solid foundation of human capital and a large store of indigenous knowledge, along with a strong industrial base. The government has invested more than R450 million in biotechnology over the past three years, and a number of innovation centres and other facilities have strengthened the R&D base. There is, however, concern that given the breadth of opportunities, current efforts and expenditure are thinly spread.

At the time of the National Biotech Survey (2003) there were 106 biotechnology companies in South Africa. The local industry is still in a developmental phase. The sector is made up almost exclusively of private companies, most of which fall into the SMME category, with 10 or fewer researchers.¹⁰ Only 10 percent of these companies are estimated to be conducting innovative, cutting-edge R&D, with the majority involved in new applications of low-tech modern biotechnology. Support for start-up firms needs to be improved. Initial funding is typically obtained through a state agency because start-ups generally have higher R&D costs. But the lack of second- and third-round funding forces many start-ups to take a short-term view. Table 1 presents data drawn from 26 biotech firms.

	Total Sample	No.	Start-ups created since 2001	No.
Total Sample	R388.36 million	20	R14.4 million	6
Total R&D Expenditure	R38.32 million	20	R7.17 million	6
R&D as a % of Revenue	9.87	20	48.80	6
Total Profit / Loss	(R47.31 million)	18	(R1.04 million)	5
Revenue Growth	-14.59	20	138.25	6
R&D Expenditure	13.67	20	76.21	6

Table 1: Biotech start-ups since 2001 vs. "old" biotech firms¹¹

¹⁰ Trends in Biotechnology, Cloete et al

¹¹ Ernst & Young, 2008 Biotech Review

3 The Grand Challenges – *continued*

For South Africa's biotechnology industry to grow, a number of critical factors need to be satisfied, including:

- Greater networking and collaboration (domestic and international) across all sectors (academia, science councils, industry and government)
- The development of business skills to help identify viable projects
- A clearer strategic focus on selected platforms and markets
- Improved funding mechanisms to close the gap between basic research and commercialisation; and shorter turnaround times between application and receipt of funding
- Investment in platforms (including infrastructure) to bridge the gap between research and commercial implementation

South Africa has a range of natural advantages that it can exploit. In combination with a supportive policy environment, the country is well positioned to derive strong socioeconomic benefits from developing these advantages. Bio-prospecting, high-throughput sequencing, bioinformatics and genomics, together with a fully functioning innovation chain, can position South Africa as a major producer in the pharmaceutical, nutraceutical, flavour, fragrance and bio-pesticide industries.

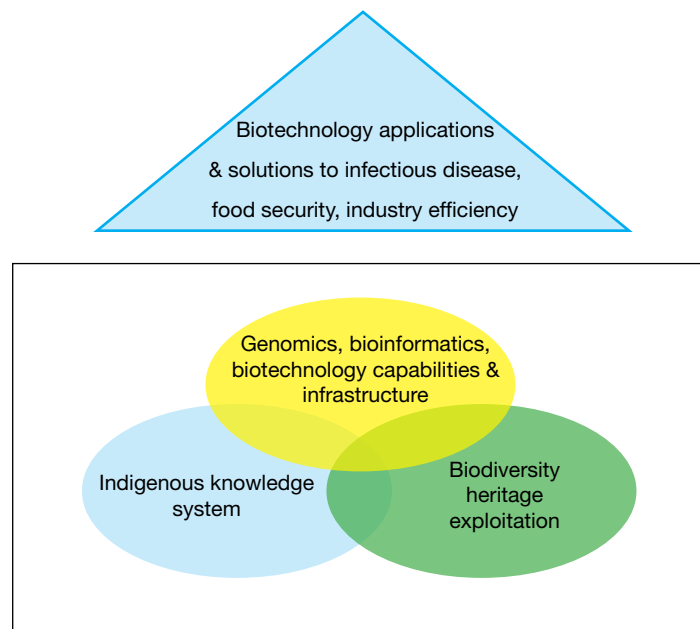


Figure 4: Interface between biodiversity heritage, IKS and new developments in genomics

The heavy burden of disease in South Africa gives us a special impetus for biotechnology and/or pharmaceutical solutions, particularly to attack the diseases of poverty. The development of research and innovation platforms and programmes will facilitate our ability to provide lasting and sustainable solutions. Innovation in biotechnology will yield creative solutions to these challenges, driven by rapid drug discovery, rational drug design and development, the validation of traditional therapies, and the advances in diagnostics, genomics, proteomics and stem cell technology that enable radical treatment and cure.

Dynamic research platforms have been initiated and the NSI will require more targeted R&D spending and an enabling regulatory environment to achieve success.

Agricultural biotechnology programmes exist to improve crops such as maize, cotton, sorghum, potatoes and sugarcane, but they need further coordination and R&D investment. There must be a focus on genetic modification of plants and animals to facilitate the breeding cycle, improve nutrition and develop greater pest resistance and drought tolerance. This will not only improve food security and boost participation in the agricultural economy – it will also upgrade the efficient production of medically and industrially important compounds.

South Africa's biodiversity should also be used to attract R&D from multinational pharmaceutical companies. The biotechnology strategy will be reviewed during 2007 with the aim of harvesting and directing R&D towards a set of well-defined goals. These goals should address the grand challenge outcomes presented below.

3 The Grand Challenges – *continued*

Grand challenge outcomes	<p>By 2018 South Africa anticipates that it will:</p> <ul style="list-style-type: none">⇒ <i>Be one of the top three emerging economies in the global pharmaceutical industry, based on an expansive innovation system using the nation's indigenous knowledge and rich biodiversity</i>⇒ <i>Have designed and created the appropriate technology platforms, and R&D and innovation infrastructure (including structural biology, functional genomics, etc.) that facilitate diagnostic and medical solutions</i>⇒ <i>Have created and funded five theme-specific consortium-based centres of competence that focus on the five top national health priorities, linked to the growth of the local pharmaceutical industry</i>⇒ <i>Increase foreign investment in South African health-related R&D (excluding clinical trials) through reinvigorated health research, with particular emphasis on pharmaceutical R&D</i>⇒ <i>Have designed and created a platform in 3rd generation biotechnology for application to plant/animal improvement and biofarming</i>⇒ <i>Invest in animal vaccine development and manufacturing facilities to strengthen animal health and production</i>⇒ <i>Have created an active biosafety platform providing regulatory guidance and support for product development in 3rd generation plant and animal biotechnology</i>
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3.2 Expanding the limits of space science and technology

A decade from now South Africa should be an important contributor to global space science and technology. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change confirms that we are now in an era of significant climate change. The social, economic and environmental consequences of these changes underline the need for more systematic monitoring of the earth's systems. To these challenges we can add the consequences of population growth, rapid urbanisation, and increased demand for energy and resources.

Space applications are essential to addressing these challenges in coming decades. With this in mind, the government has proposed a National Space Agency for South Africa to address three strategic objectives:

- Environment and resource management
- Safety and security
- Innovation and economic growth

A core objective in this area is to win a growing slice of the global satellite industry. Annual revenues in this industry have grown from US\$64 billion in 2000 to about US\$90 billion today, with average growth of 6.7 percent in the period 2000-2005. Satellite services now account for about 60 percent of total revenues, with government agencies represented more than half of new satellite business in 2006.

To date, South Africa has been primarily a consumer of space technologies. There is a need to develop systems and sub-systems to support our requirements and to grow the local industry. Six thematic programmes are targeted and defined below:

Space sciences

Space sciences, in this context, are concerned with the study or use of everything above the surface of the earth, from the atmosphere to astronomy, space physics, geodesy and so on. South Africa has already taken notable steps forward in this area, including building the Southern African Large Telescope. The country is also bidding to host a large radio telescope, the Square Kilometre Array. The DST has developed the Astronomy Geographical Advantage Programme, which aims to use the excellent viewing conditions on the subcontinent, and the depth of engineering and scientific talent available locally, to attract international astronomy projects. Southern Africa is investing to become a premier astronomy hub.

The development of a space technology programme provides an opportunity to use satellites to conduct astronomy observations from space. Telescope-loaded satellites will be geared to complement terrestrial research in global partnership programmes. Tracking stations able to download data from satellites will position South Africa as a competitive location attracting international investment.

Earth observation

Earth observation involves all activities connected with the collection of information on the earth's surface or atmosphere. Such information underpins virtually all public policy decisions, from public health to water resource management, to protection of the ecosystem. This programme will focus on two key missions: understanding the planet, and providing data for decision-making in support of the social benefits indicated in the accompanying box.

Communication

This competency area will focus on the development of technologies and applications in collaboration with the end users – mainly the Department of Communications. Potential applications include providing communications in emergency or disaster situations when terrestrial networks are down. There are also promising applications in telemedicine, distance learning, and e-commerce.

Societal benefits of earth observation

- Disasters - Reducing loss of life and property from natural and human-induced disasters
- Health - Understanding environmental factors affecting human health
- Energy - Managing energy resources
- Climate variability and change - Adapting to climate variability and change
- Water - Improving resource management
- Weather - Improving forecasting and warning
- Protection of ecosystems - Improved management of terrestrial, coastal, and marine resources
- Agriculture - Supporting sustainable agriculture and combating desertification
- Conserving biodiversity - Understanding, monitoring, and conserving biodiversity

3 The Grand Challenges – *continued*

Navigation

Originally developed for military use, space-based positioning and navigation services have found a growing range of civil applications in recent years. These include assistance to the movement of people and goods by road, rail, air or sea; civil protection; management of natural resources (e.g. fisheries); development of land infrastructure (e.g. energy networks); urban planning; and keeping track of moving objects. Promising applications for positioning and navigation in the coming decades include fleet and traffic management, location-based services, and search and rescue. This competency area will focus on developing applications and services in navigation, timing and positioning.

Engineering services

This field includes providing launch services, and maintaining ground segment, testing and integration infrastructure. South Africa has a range of facilities¹¹, and there is a strong argument to incorporate these into a single entity to support the space programme.

Expertise development

For a successful space science and technology programme, South Africa must develop critical mass in specific areas of expertise, from radio-frequency engineering to system engineering, and from software development to propulsion systems.

Grand challenge outcomes	<p>By 2018 South Africa anticipates that it will have:</p> <ul style="list-style-type: none">⇒ <i>Independent earth observation high-resolution satellite data available for all of Africa from a constellation of satellites designed and manufactured in Africa</i>⇒ <i>Undertaken at least one launch from South African territory in partnership with another space nation, and have in place a 20-year launch capability plan</i>⇒ <i>Specified and co-built a domestic/regional communications satellite and secured a launch date and ITU slot for its operations</i>⇒ <i>Become the preferred destination for major astronomy projects and associated international investment in construction and operations</i>⇒ <i>Will have constructed a powerful radio-astronomy telescope and used it for world-class projects</i>
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3.3 In search of energy security

The three principal global energy challenges are:

- The need for energy security as supply and security concerns converge
- Protecting the environment, particularly given high levels of fossil-fuel emissions
- Access by the developing world to affordable, safe, clean and reliable energy

¹¹ These include the Satellite Applications Centre within the CSIR; the Overberg Toetsbaan, a division of Denel; and the Houwteq Test and Integration Facility

3 The Grand Challenges – *continued*

Energy and the economy

South Africa is experiencing the longest period of sustained economic growth in its history, and through ASGISA, the government aims to raise the growth rate to at least 6 percent by 2014. Even at present levels of economic activity, however, energy supply is found wanting. To ensure accelerated and sustainable growth, energy supply infrastructure must be increased.

While short- to medium-term measures are implemented to resolve existing tight supply, long-term energy supply infrastructure planning must be prioritised, including a more structured planning relationship between government and the private sector. The government has already signalled its intention to place greater reliance on nuclear power, natural gas and various renewable forms of energy.

The projected capacity to meet peak national demand (2003 to 2022) based on modest economic growth of between 1 to 2 percent was about 55 000MW for 2020. Given the upswing in economic growth over the last few years, a simple calculation assuming average economic growth of 5 percent over the next 10 years produces an electricity demand projection of about 60 000MW by 2018 and 90 000MW by 2022.

The following matrix presents a possible electricity generation profile in 10 years, given the above policy drivers and projections.

Coal & gas including large hydro (50 000MW)	Nuclear equivalent to > 4 x Koeberg capacity (8 000MW)	Renewable energy sources (2 000MW)	Energy generation sources
Clean coal technologies Carbon capture and sequestration	3rd generation nuclear reactors Pebble bed modular reactors	Solar, hydro, wind, ocean/wave, biomass and waste	Technologies for cultivating energy sources
Eskom, Sasol, PetroSA, CEF/SANERI and Universities	Eskom, Necsa, PBMR, IST Nuclear and Universities	Eskom, CEF, Sasol, independent producers, SANERI and Universities	Research organs in the NSI
Electricity Liquid fuels Cooking & heating	Electricity Process heat Hydrogen	Electricity Biofuels Hydrogen	End uses

Figure 5: A possible South African energy matrix, 2018

Major R&D thrusts

Clean coal technologies

Coal is South Africa's primary energy source. It provides 88 percent of commercial energy needs and plays a vital role in meeting liquid-fuel requirements. Although government's policy is to diversify the energy portfolio, coal is certainly abundant enough to ensure security of supply for years to come. With newer technologies such as integrated gasification combined cycle, energy from coal can be an environmentally friendlier process. Progress along these lines includes Eskom's first pilot underground coal gasification project at Majuba. Adoption of clean-coal technologies could bring a new environmentally benign dimension to the use of coal-to-liquids (CTL) Fischer-Tropsch technology to produce transportation fuels.

From an R&D perspective, it makes sense to position SANERI, Eskom, Sasol and various CEF subsidiaries to work together to advance clean coal technologies. South Africa's competitive edge in cheap electricity and CTL technology is dependent on reducing the environmental footprint of processing coal.

Nuclear energy revisited

The recent flare-up of oil prices is a sobering reminder of the volatility in the energy market, the limits of fossil fuels and the need for stable, reliable, non-polluting sources of electrical power that are indispensable to a modern industrial economy.

The South African government is in the process of finalising a Nuclear Energy Policy and Strategy. The goal is to have between 20 and 25 percent of electricity generated by nuclear power, compared to about 6 percent today. Most of the envisioned nuclear power facilities will use Generation III pressure water reactors (PWR). The Pebble Bed Modular Reactor (PBMR) may only contribute after 2015.

In contrast to current reactor designs, many new-generation nuclear plants incorporate passive or inherent safety features that require no active controls or operational intervention to avoid accidents in the event of malfunction. These are collectively termed Generation IV reactors. South Africa's PBMR programme is seen as the most advanced in the development of Generation IV reactors.

For the long term, South Africa needs to strengthen the innovation chain in nuclear energy science. R&D to support conventional reactors in materials, safety, waste, reactor physics and so on must be planned and coordinated. Agreements with international companies bidding to build conventional reactors for South Africa should include knowledge-transfer systems, enabling the development of local expertise to meet the industrialisation agenda.

Embracing renewable energy technologies

Internationally, investment in renewable energy projects has been growing despite a significant slump in overall global investment trends. Yet less than 1 percent of the 40 000 MW of electricity generated in South Africa originates from renewable energy sources. Our energy policy environment is in line with international trends and is conducive to the development of the industry. However, the creation of the appropriate knowledge base to support the nascent industry was largely ignored until the establishment of the National Energy Research Institute in 2006. South Africa possesses known technologies, but the challenge lies in commercialisation and coherent policy interventions for easy adoption.

The promise of hydrogen

Hydrogen and fuel cell technologies are widely seen as possible energy solution for the 21st century, yet it is far from clear how we will achieve what has been called the “hydrogen economy”, in which energy is stored and transported as hydrogen.

At the core of fuel cell innovations is the platinum catalyst. The emerging fuel cell market is expected to grow to a multi-billion dollar international industry. This places South Africa, which holds 87 percent of known platinum reserves, in a highly advantageous position.

3 The Grand Challenges – *continued*

The DST is working to establish a specific policy framework to realise opportunities in these areas, along with a science and knowledge base that will ensure that South Africa benefits optimally from the nascent hydrogen economy.

Grand challenge outcomes	<p>By 2018 South Africa anticipates that it will have:</p> <ul style="list-style-type: none">⇒ <i>Expanded the energy supply infrastructure, with more than 50 percent of new capacity coming from clean coal technologies and nuclear plants</i>⇒ <i>5 percent of energy used coming from renewable sources, 20 percent from nuclear and 75 percent from coal (of which 30 percent would be based on clean coal technologies)</i>⇒ <i>Expanded the knowledge base for building nuclear reactors and coal plants parts; source more than 50 percent of all new capacity locally</i>⇒ <i>Successfully integrated uranium enrichment into the fuel cycle and feeding into the commercial reactors</i>⇒ <i>A well-articulated energy efficiency programme and per capita energy demand reduced by 30 percent</i>⇒ <i>A 25 percent share of the global hydrogen infrastructure and fuel cell market with novel PGM catalysts</i>⇒ <i>Have demonstrated, at pilot-scale, the production of hydrogen by water splitting, using either nuclear or solar power as the primary heat source</i>
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3.4 Science and technology in response to global change

Important changes are taking place in the global climate, but there is still great uncertainty about how earth systems operate. South Africa is positioned to serve as a unique laboratory given its proximity to the Antarctic, the Southern Ocean, and the Agulhas and Benguela currents – and to make a major contribution to understanding climate change. This is, above all, a strategic consideration. Our ocean resources are critically dependent on the cold Benguela current and its high biomass. Drought and flood patterns can have a massive impact on food security and agricultural production. Our unique biodiversity could be destroyed by average temperature changes and invasive species that find the new conditions favour their rapid propagation.

Worldwide, “greenhouse” gases and other emissions are believed to be responsible for altering the earth’s climate. Even though few countries produce a large proportion of these gases, the effect is global. The projected effects of climate change in Africa include increased incidence of malaria, schistosomiasis and other vector-borne diseases. Urgent responses are required, including research on prevention and early warning systems, field detection and treatment, public health infrastructure requirements and treatment regimes.

South Africa is well positioned to lead research on the continent in terms of understanding and projecting changes to the physical system; the impact of these changes; and mitigation to limit their long-term effects. Mitigating climate change also provides an economic opportunity for South Africa; therefore, the country needs to develop a strategy to take advantage of the so-called “Green Economy”.

Grand challenge outcomes	<p>By 2018 South Africa anticipates that it will have:</p> <ul style="list-style-type: none">⇒ <i>An internationally recognised science centre of excellence with climate change research and modelling capability, benefiting the entire continent</i>⇒ <i>Robust regional scenarios for the rate and impact of climate change and extreme weather conditions for South Africa and the continent</i>⇒ <i>Initiated climate change adaptation and mitigation actions</i>⇒ <i>An internationally recognised centre of excellence focused on the Southern Ocean and its contribution to global change processes</i>⇒ <i>Strengthened research and global monitoring capabilities on Marion Island, Antarctica and the Southern Ocean in partnership with other nations</i>
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3.5 Human and social dynamics

Human and social dynamics are at the core of nearly every major challenge facing South Africa – from climate change to creating a competitive and innovative workforce. The fifth grand challenge is to increase our ability to anticipate the complex consequences of change; to better understand the dynamics of human and social behaviour at all levels; to better understand the cognitive and social structures that create and define change; and to help people and organisations better manage profound or rapid change.

In keeping with these goals, the DST will develop a long-term programme to increase basic understanding of human behaviour. In today's world, behaviour, science and technology are deeply intertwined, and advancing one without considering the other's, yields limited results.

The socioeconomic problems that we face require focused work by teams of cross-disciplinary experts. And while the grand challenges presented in this plan stress technological innovation, the DST recognises that technologies cannot be developed without giving thought to how they will affect and be received by human beings.

The Ten-Year Innovation Plan advocates research in areas such as paleoanthropology, archaeology and evolution genetics. This research will provide evidence-based support for interventions in learning processes and education, indigenous knowledge systems and heritage literacy.

Computer modelling will be applied increasingly to cognitive, socio-cultural, developmental, and neurobiological studies to understand how people learn. In the area of decision-making and risk, the study of individuals' responses to risk, their judgment in selecting options among the choices available, the perception of uncertainties facing us in today's world, and the treatment of risk in collective and private decisions are all highly dependent on the work of cognitive, behavioural, and social psychologists.

3 The Grand Challenges – *continued*

As South Africa strives to become an innovative society, it is essential to support the public understanding of and engagement with science. Government's starting point is that the members of public are not merely passive recipients of science and technology, but are important players in processes that shape the focus and patterns of science, technology and development.

Persistent and chronic poverty

The latest socioeconomic indicators¹² show that between 2000 and 2005 there was a decline in poverty as measured in several categories. The data also shows, however, that poverty remains at an unacceptably high level and despite sustained economic growth and job creation, many South Africans remain unemployed.

There are myriad reasons for the persistence of chronic poverty – and not only in South Africa. This underlines the need for improved, science-based information to direct development-oriented decision-making. Over the past decade a global consensus has emerged that science and technology can play a growing role in addressing socioeconomic problems. This recognises the bottom-line pressure for delivery of affordable services in energy and health, and access to clean and safe drinking water and sanitation.

Government also recognises the scope for ICT platforms to improve health care and its delivery, to enhance access to information on government services and to strengthen education. The DST is working on developing instruments to harvest technology from publicly funded research activity and put it to use on a not-for-profit basis to improve the lives of the poor.

Grand challenge outcomes	By 2018 South Africa anticipates that it will have: ⇒ <i>Applied science and technology activities to achieve the Millenium Development Goals on livelihoods and affordable access to services</i> ⇒ <i>Recognition as a "knowledge hub" on social sciences research in Africa</i> ⇒ <i>Socio-culturally based models that accurately reflected the learning behaviour of the South African national system of innovation</i>
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The grand challenges imply the development of an environment that encourages innovation. Creating and nurturing such an environment is the topic of Section 4.

¹² Development Indicators, Mid-term Review. The Presidency, South Africa (2007)

4 Innovation as a National Competence

As suggested by the title of this report, scientific and technological innovation are crucial to developing a more competitive foothold in the global economy, and to addressing pressing developmental needs. However, South Africa has yet to effectively mobilise innovation in support of economic growth. This “innovation chasm” is a major weakness in our economy.

This problem was first identified in the National Research and Development Strategy, and flowed from the realisation that the domestic market for medium-high technology products and services on the one hand, and local research on the other, had nothing in common. Inevitably, this led to extensive importation of technology and intellectual property, resulting in an unfavourable technology balance of payments.

Some progress has been made in this area – notably through targeted public investment in advanced manufacturing, ICT, biotechnology and resource-based technologies. The system continues to evolve, but it is universally agreed that the current pace of progress is inadequate for South Africa’s needs.

Innovation plan of action toward 2018

In 2006 the DST began developing an innovation plan of action informed by other national policies, reports and statistics.

The national R&D survey published by the Human Science Research Council (HSRC) showed that in 2005 business enterprises accounted for 58.3% of the total R&D performance in South Africa compared to 40.1% by the public sector. The total investment in R&D in 2005 amounted to 0.92% of GDP, demonstrating that South Africa has a realistic chance of achieving the 1% target of GDP set for 2008. It is vital that national public policies and the existing innovation instruments are redesigned to create a strong incentive for innovation. This includes improving access to finance, an innovation-friendly regulatory environment and strengthening the NSI. These challenges are discussed below.

From innovation to commercialisation

The major obstacle to commercialisation of technological innovations is financing, due to the high risk and complexity of R&D investments. New creative funding mechanisms that could help address this problem are emerging in some public-private partnerships. Such partnerships have potential to help close the financing gap and to become effective financing vehicles for medium-high tech and high-tech innovations.

To address the fragmentation of funding instruments, this Ten-Year Innovation Plan introduces the establishment of a Technology Innovation Agency (TIA). This agency will incorporate, among others, the Innovation Fund and the Biotechnology Regional Innovation Centres. The TIA will help to establish of a network of competence centres focused on market opportunities in partnership with industry and public research institutions.

4 Innovation as a National Competence

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The TIA's broad objectives are to:

- Act as a technological agency that will provide funding and complementary services to bridge the gap between the formal knowledge base and the real economy
- Stimulate development of technology-based services and products
- Support development of technology-based enterprises – both public and private
- Provide an intellectual property support platform
- Stimulate investment (venture capital, foreign direct investment, etc.) Facilitate the development of human capital for innovation

This plan also stresses the need to establish an Intellectual Property Management Office to enhance protection of intellectual property rights and ensure synergy with other policies. It will also develop national capacity to manage technology licensing and commercialisation.

Optimising R&D value from state-owned enterprises

South Africa's existing institutional arrangements are not up to the task of migrating the economy from a resource to a knowledge base. This goal requires a new learning curve and a more rapid transfer of technology and learning to local institutions. In this regard the state-owned enterprises, many of which serve strategic economic functions, will play a key role. While development of such new approaches is at a very early stage, an example of the method that may be required is presented below, using Eskom's projections for the development of enhanced nuclear energy capability.

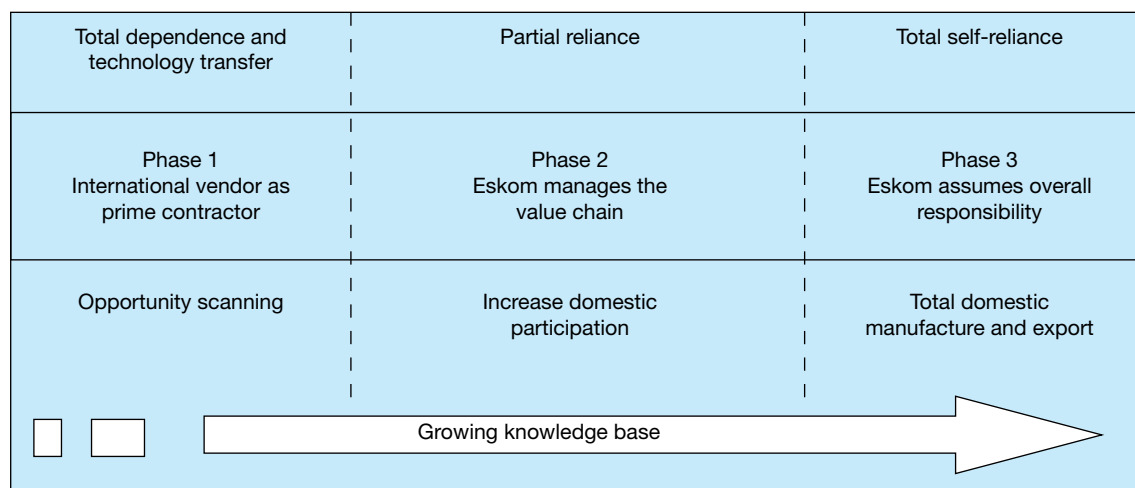


Figure 6: Learning from technology transfer opportunities

4 Innovation as a National Competence – *continued*

The figure above is a schematic outline of the process of indigenising nuclear energy technology. It depicts South Africa's projected transition from a nuclear energy industry importer (Phase 1) to an innovator and exporter (Phase 3). Throughout, the process entails interaction of local players with international technology vendors.

This process requires a common agenda and collaborative work all along the nuclear innovation value chain – including at procurement phase and by stipulation of technology transfer programmes. This will require clustering of industries along the value chain in the form of well-designed technology parks.

Similar approaches may help other state-owned enterprises develop new methods to optimise R&D value.

To achieve sustainable progress in all these areas, South Africa must radically strengthen its human capital development and knowledge generation. This is the subject of Section 5.

5 Human Capital Development and Knowledge Generation

Human capital development and knowledge generation are core elements of the knowledge-based economy.

Current human capital situation in South Africa

Figure 7 compares PhD production rates in a number of developed and developing countries. While a comparison with the developed countries is informative, it is the comparison with the developing countries such as Taiwan, Brazil and India that is relevant to South Africa. To build a knowledge-based economy positioned between developed and developing countries, South Africa will need to increase its PhD production rate by a factor of about five over the next 10-20 years.

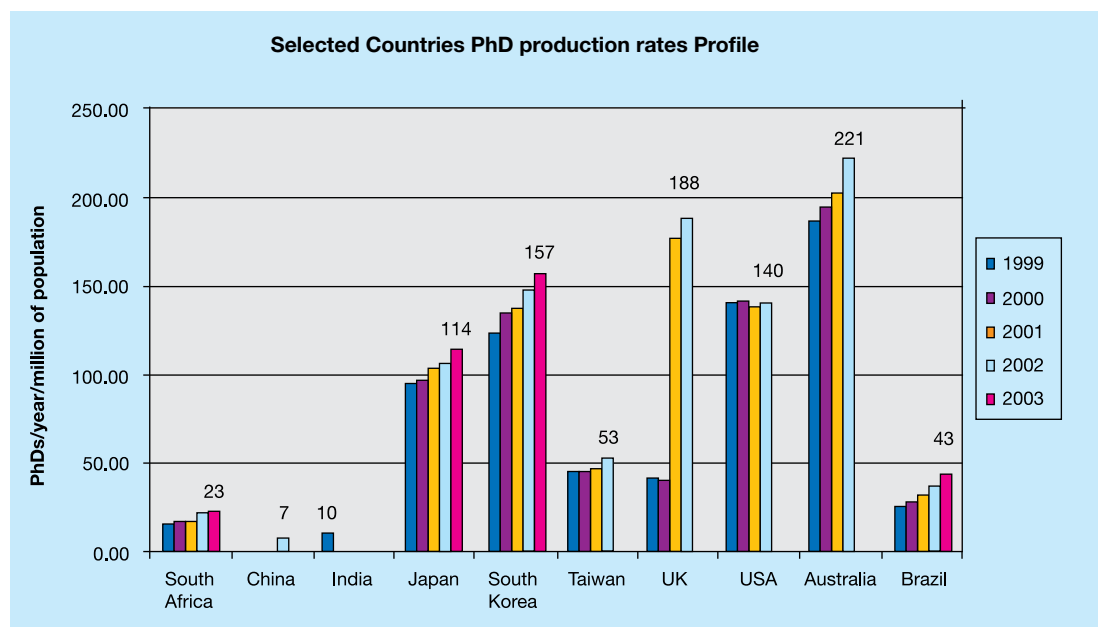


Figure 7: International comparison of PhD production rates

The challenges of human capital in the NSI are both qualitative (rates of knowledge production) and quantitative (number of PhDs produced). As Figure 8 shows, in the age group 25-34 in the year 2000, South Africa produced 0.05 PhDs per 1 000, a figure far below that of leading knowledge economies.

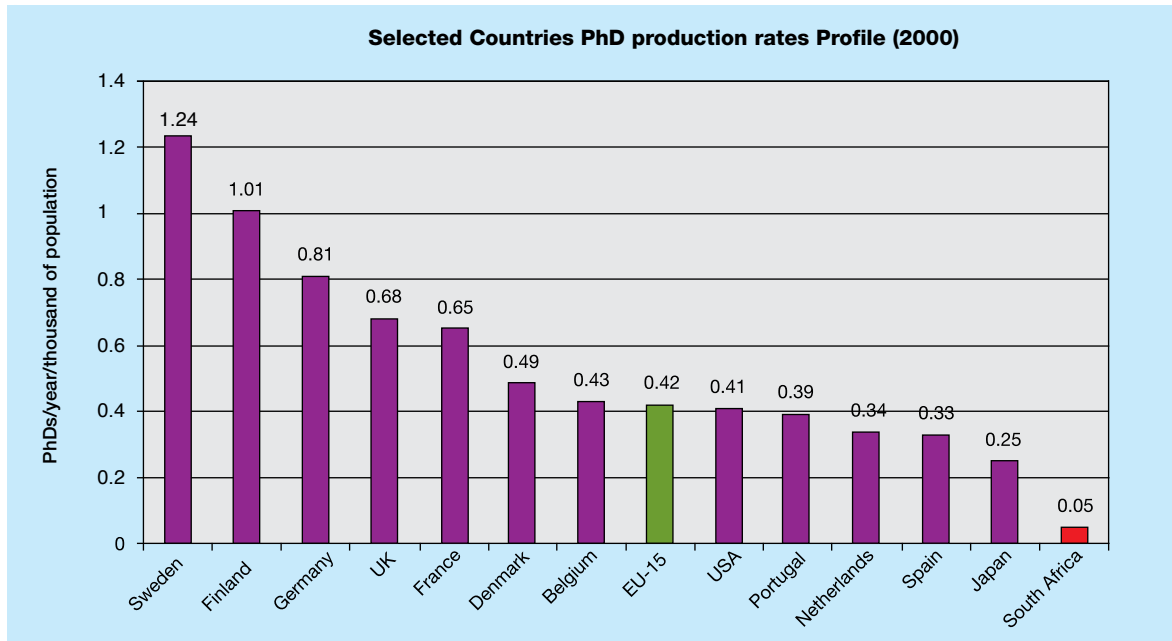


Figure 8: Number of SET PhDs per 1 000 of the population in age group 25-34 years

The principal qualitative measure of knowledge production is the output of original articles published in scientific journals. From 1990 to 2004, South Africa's output averaged about 7 000 articles a year, despite indications of increased funding.

South Africa's PhD deficit can be explained, in part, by South Africa's apartheid past; by the limited capacity of the higher education system to enrol and supervise PhDs; and by constraints within individual institutions. Moreover, a great deal is required from a system that has not been very successful in increasing the number of knowledge workers. Any intervention must increase both the numbers of PhDs and the productivity of the system.

Building a human capital pipeline

Interventions to address the South African knowledge worker challenge should be understood in the context of a human capital "pipeline" that starts with postgraduate students at one end, and delivers world-class scientists and researchers at the other.

In 2005 about 1 200 PhDs graduated in South Africa, of whom 561 were in science, engineering and technology (SET). To compete in the global science and technology arena, South Africa's PhD production must grow fivefold, to about

5 Human Capital Development and Knowledge Generation – *continued*

3 000 SET PhDs. This, in turn, means that the average annual human capital pipeline outputs – made up of 26 000 higher grade maths and science matriculants, 15 991 SET undergraduates, 3 200 Honours, 2 900 Masters and 561 SET PhD graduates – will have to be improved qualitatively and quantitatively.

Given the scale discussed above, several points are clear:

- A career path from BSc to researcher level has to be established;
- The Masters and PhD intern programmes have to become significant parts of government-funded research, with graduation targets being a significant part of the monitoring;
- Special interventions to attract potential researchers to senior degrees should be put in place;
- The production line of researchers will have to be monitored for bottlenecks.

In addition to the traditional research-based methods of acquiring PhDs, alternative methods benchmarked against best practice need to be created to cater for practice-based doctorates, professional doctorates and other new routes such as PhD by publication.

Since one of the main objectives of this Ten-Year Innovation Plan is to increase the number of patents and products, it is important that some attention be paid to the number and type of skills in engineering, technology and economic interface, which for purposes of this document we will call innovation skills.

In developed countries such skills are honed at specialist universities, such as MIT in the United States. In our environment, over the short term, there needs to be a focus on integrating innovation studies with academic PhD curricula. This would have to be clearly defined but may include innovation and technology management, product development, technology incubation, project management, and business management.

In the long term, consideration will have to be given to the introduction of this kind of thinking at all levels of tertiary study in science and engineering. This would produce a workforce with the innovation skills that we need and contribute to our competitiveness. Universities and the science councils can play a pivotal role in providing such skills, and they will need to be strengthened.

Knowledge generation and exploitation

This section recognises that whilst knowledge is generated in the context of applications in the grand challenges, it is important to encourage the generation of knowledge in other fields first described in the NR&DS, which include:

- Early-stage research – For example, nanotechnology. This is also known as the “frontiers” R&D area. The focus is on developing technology platforms and a broader base of science and technology competencies.

5 Human Capital Development and Knowledge Generation – *continued*

- Science missions – Astronomy, palaeontology, Antarctic and marine science, biosciences, social sciences, earth systems and environmental sciences. These missions exploit South Africa’s “living laboratories” of local resources and geographic advantage.
- Technology missions – These activities have a natural bias towards applied R&D, with results that can be realised over 3-5 years. These missions include advanced manufacturing technologies, “smart” materials and metals, advanced ICT, 4th generation nuclear reactors manufacturing, and chemicals technology.
- Conventional sectors – Institutional mandates for increased R&D, boosting key national priority sectors (e.g. agriculture, health) and the economy.

The SET institutions mandated to develop these sectors have a tremendous responsibility over the next 10 years to expand research activities, and to train greater numbers of researchers and engineers.

Human capital and knowledge generation

Human capital development actions and outcomes	By 2018 South Africa anticipates that it will have: <ul style="list-style-type: none">⇒ 210 research chairs at universities and research institutions across the country by 2010 and 500 by 2018 (58 were in place in 2006)⇒ About 6 000 PhDs produced per year in all SET disciplines by 2018⇒ About 3 000 SET PhDs/doctorates produced per year by 2018⇒ An optimal ratio of technicians to researchers, commensurate with the country’s requirements⇒ A 1.5 percent global share of research publications (2006: 0.5 percent)⇒ 2 100 Patent Cooperation Treaty international applications originating in South Africa (2004: 418)⇒ About 24 000 patent applications at the South African Patent Office (2002: 4 721)
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All elements of this Ten-Year Innovation Plan require policy leadership throughout government. This is the subject of Section 7.

6 Science and Technology Across Governments

The knowledge-based economy assumes a greater degree of intergovernmental and interdepartmental cooperation and coordination. In 2004 Cabinet adopted the strategic management model of South Africa's science and technology system. Its core elements were a renewed focus on frontier science and technology programmes; sustainability of the national research base and strong alignment with sector innovation; and science and technology services to enhance service delivery.

The devolution of science and technology budgets allows departments to fund sector-specific programmes that boost research capability. Some national departments have made progress in developing medium-term R&D priority plans, but these are not yet fully funded.

In addition, several other areas require urgent attention over the next decade:

- Interdepartmental science and technology initiatives – In 2007 the DST launched the Science and Technology Managers' Forum to promote greater use of science and technology and strategic coherence between departments. For the forum to be effective, policy administration capacity needs to be further developed.
- Enhanced innovation and growth in priority sectors – Innovation is essential to support government policy – from national industrial strategies, to the sectors targeted for rapid growth within ASGISA, such as chemicals, transport, water infrastructure and ICT infrastructure. National defence R&D is also a priority.
- Public procurement and innovation – The government recognises the potential to make use of procurement to stimulate technological innovation. The challenge is to develop a public procurement regulatory framework that supports local innovations, including SMMEs and technology start-ups.

The Ten-Year Innovation Plan requires policy leadership by DST and strengthened cooperation across government. The DST is responsible for advising Cabinet on the overall health of science and technology in government, and monitoring research expenditure and innovation in industry. To effect this task, DST conducts an annual review, and presents a national expenditure plan to Cabinet.

DST and its partners, the Human Sciences Research Council and Statistics SA, also publish the annual national R&D survey and the biannual innovation surveys. New mechanisms to monitor important indicators such as patents, technology-trade mix, sector performance and technology balance of payments need to be introduced. To encourage innovation, the DST will partner with provincial governments and facilitate the development of regional innovation systems plans.

7 International Relations and Technology Transfer Strategies

To make progress on the grand challenges, South Africa needs to strengthen its international partnerships – to both enhance its knowledge and create a conducive environment for the transfer of technology. Knowledge-based economies are connected through a growing international research and cooperation network.

This is not only a matter of strengthening the science and technology base in South Africa, but of enhancing the role of science and technology throughout Africa.

Over the next ten years South Africa must work to become a preferred destination for science and technology investment. This requires strategic cooperation and collaboration through a range of international and regional forums and established scientific protocols, as well as targeted initiatives with other developing countries.

International cooperation should thus support the Ten-Year Innovation Plan by:

- Providing a base for cooperation in the development of human capital
- Leveraging foreign direct investment through South Africa's extensive bilateral and global research networks and the existing international competencies; and
- Strengthening South Africa's infrastructure development through appropriate international connections

International cooperation outcomes	By 2018 South Africa anticipates that it will have: <ul style="list-style-type: none">⇒ Developed the foreign funding component of South African R&D to 15 percent of the total GERD and maintained this ratio over 10 years⇒ Become a preferred destination for S&T investment, with the location of major international research hubs across the grand challenge domains⇒ Become a leading player in the implementation of the African Research Area under the auspices of the African Ministers Committee on Science and Technology⇒ Stronger relationships with regional entities, including ASEAN, the ACP and Mercosur⇒ Highly functional and productive bilateral relationships with leading science nations on all continents⇒ A functioning strategy to draw South Africans in the diaspora into work on the grand challenges
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8 Conclusion

This Ten-Year Innovation Plan proposes a bold new stance for South Africa to transform towards a knowledge-based economy in support of government's broad developmental agenda. Such an economy can only emerge as a result of long-term policy and resource commitments. The government needs to set the focus, establish the scale, and give appropriate signals to ensure that enabling conditions are in place.

For South Africa, expanding investment in R&D is a particular challenge. The country's small R&D base means that achieving critical mass will require parallel but mutually dependent investments. There is a need to expand R&D activities and to grow research capacity. The goal is an economy in which new knowledge-based industries, and knowledge workers and systems, fuel stronger economic growth.

This plan introduces five "grand challenges" as a way of expanding the research agenda while promoting specific outcomes. The plan also recognises the need to ensure that innovation, by introducing appropriate institutional mechanisms and other instruments strengthens a national competence.

All these goals require a qualitative and quantitative expansion of South Africa's human capital and knowledge base in science and technology. Without these, there can be no fresh winds of innovation.

The projections in the Ten-Year Innovation Plan are based on measurable indicators – in the economy, the workforce, industry, the research base and society. In areas where no such capacity exists, it will be developed.

The implementation of the plan has a number of prerequisites. These include state-of-the-art infrastructure, modern laboratories and research institutions, an NSI that is linked to the rest of the global scientific community and appropriate funding agencies.

Above all, the plan requires political leadership, policy direction and careful attention by the DST and other departments to ensure that South Africa succeeds to implement the grand challenges. In particular, the DST must see to the establishment of effective human capital development and knowledge-generation strategies; the establishment of the Technology Innovation Agency; and ensure effective direction of scientific research programmes in palaeontology, astronomy, marine science and biosciences.

