FORESIGHT SYNTHESIS REPORT: *DAWN OF THE AFRICAN CENTURY*

Foreword by the Minister

In South Africa, the six years since 1994 have been characterized by the need to understand and shape the future of this country and my Ministry has initiated a range of initiatives aimed at meeting this objective. In the science and technology field these initiatives include the White Paper on Science and Technology, the National Research and Technology Audit, the Review of Science and Technology Institutions and the National Research and Technology Foresight (NRTF).

The Science and Technology White Paper, published in 1996, was based on the twin concepts of innovation and a national system of innovation (NSI). The NRTF report is an important milestone that allows us to put real content into the NSI and thereby develop a framework of goals within which our technology programmes can be shaped. NRTF findings indicate a decline in the resource-based economic activities such as mining, primary agriculture and traditional manufacturing. In contrast, new developments in biotechnology, information and communications technologies and new materials signal the future ascendancy of a knowledge-based economy. The wealth of biological diversity in South Africa and our immense tourism potential have, as in other studies, been identified as focal points for growth.

There are a number of challenges that need to be overcome though. The human resources skills base and the ability to commercialise the new emerging technologies remain major obstacles. These challenges remain the priorities of this Ministry. However, the involvement of approximately 5 000 South African stakeholders in the NRTF offers hope in that we have created cohesive networks of our best minds as by-products of the process. These networks, now accustomed to thinking analytically about the future, will be invaluable in tackling the challenges ahead.

I would like to thank all those who have helped make the NRTF possible. The thousands who formed part of the sector working groups or contributed to the Delphi studies formed the core of the process. We also received much useful advice and material assistance from sister Ministries in countries that have traveled the foresight road. In particular, I would like to thank the Government of the United Kingdom and Minister Lord Sainsbury for unstinting support. Since we began our own study we have also been granted observer status at the OECD Science and Technology Policy Committee. My participation in the June 1999 Ministerial meeting made it clear to me that Foresight will become a classic planning tool for governments. Our NRTF has

given us insight into the possible futures that face South Africa as a country and it now up to us to shape that future.

Dr. Ben Ngubane
Minister of Arts, Culture, Science and Technology

Foreword by the Deputy Minister

The completion of the National Research and Technology Foresight (NRTF) is a major milestone in that it demonstrated that South Africans could work together for a common cause. The Foresight project brought together individuals from a number of sectors and required cooperation among several government departments and stakeholders in the academia, science councils, the private sector and civil society.

As part of the effort towards understanding the National System of Innovation, network analysis was conducted to identify experts that were nominated to be in the Foresight process. The networks identified appear to be mainly in Gauteng (52%), the Western Cape (23%) and the Eastern Cape (8%). The experts in South Africa are predominantly men (86%) and are mainly over 40 years of age. There are, however, differences across sectors. One third (33%) of the experts in 'Financial Services' are women, while sectors such as 'Mining and Metallurgy' and 'Manufacturing and Materials' remain strongholds of male dominance.

These results don't come to us as a complete surprise. In fact, they confirm long-held views of the gender bias within the South African science and technology community. The findings lay squarely at our door the challenge of bringing in more women and blacks into the mainstream of science.

The outputs of Foresight highlight areas such as Bio-informatics and Biotechnology and digital technologies, etc. as the growth areas of the future. The current situation in South Africa, where most women are working in the biological sciences, provides us with a unique opportunity to leapfrog the contribution of women to the cutting edge of science. This does not, however, afford us the luxury of not having to address the issue of gender equality. The mainstreaming of the contribution of women in science will remain the major challenge facing this department.

I wish to thank all those who participated in this important study, which allows us to shape the future and improve the quality of life of all South Africans in the years to come.

Mrs Bridgette Mabandla
Deputy Minister of Arts, Culture, Science and Technology

A View of the Future

"We shall not cease from exploration and the end of all exploring will be to arrive where we started and know the place for the first time." – TS Eliot

The hardest part of the Foresight was simply imagining the future. This may not seem surprising, given the fact that almost always even the past is disputed and most of us only dimly see the span of the wavefront we ride which constitutes the present. Nevertheless, going into the new millennium, we South Africans are a people almost abnormally focused on the here and now, no matter how tenuous our understanding of it may be. At this point in our history we care about practical things, such as bringing infrastructure to poor people and reducing the budget deficit. This mindset influences our picture of the future very strongly: we strive towards a rosier version of the present. This was not always so. There was a time ten years ago when we strode towards a mountain pass, beyond which lay another country. We are in a different phase now, one of consolidation and of finding ourselves. This phase, although infinitely preferable to the previous one, holds its own perils, not least of which is an unwillingness to think profoundly about the future.

It is in this context, one of consolidating the present, that the Research and Technology Foresight took place. In the initial workshops which were held across the country to decide on the sectors which would form the basis of the study, key stakeholders were asked to imagine the challenges facing South Africa twenty years in the future. There was a very strong tendency for these highly intelligent people to simply list the accepted challenges of the present. In a sense, they were constrained by their commitment towards making a success of the country we had struggled for so long to bring into existence. Even some of the events occurring today which affect our country, such as those in the Great Lakes region, were unthinkable in South Africa three years ago.

The key to liberating participants in the Foresight from the concerns of the present was the scenario approach. Thinking about the future within a set of clear frameworks made the tough questions easier to ask. It placed the "blame" of exploring sometimes very unattractive options on those who had devised the game, rather than on those playing it. What we have done in the Foresight is to induct key South Africans in a highly structured type of exercise which is gaining currency throughout the world. We hope we can build on this and that we have initiated a culture in our country of thinking profoundly about the future.

After these remarks about how we South Africans see the future, is it actually possible to say what the main technological drivers of the 21st Century will be? I would venture that the basis for these drivers has already been laid in the 20th Century.

Quantum Mechanics, the precursor of almost all profound innovations of the 20th Century, will continue to be critical. The applications, however, will be in areas such as the fine control of macromolecules and in quantum computing. Information Technology will surge ahead and arise in ever more surprising areas. Biotechnology will move even more rapidly, challenging us to the very roots of how we imagine ourselves as human beings. In particular, the most startling innovations will occur at the confluences of these three profound scientific currents. If we want to be a competitive country, and indeed a competitive continent, we need to ride them and to know as best we can where they are taking us.

Dr Rob Adam

Foresight Board Chair and Director-General of Arts, Culture, Science and Technology

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Abbreviations and Acronyms

DACST..... Department of Arts, Culture, Science and Technology
GERD..... Gross Expenditure on R&D
GIS ..... Geographic Information Systems
HR..... Human Resources
ICT..... Information and Communication Technology
IPR ..... Intellectual Property Rights
MCST ..... Ministerial Committee on Science and Technology
NGO..... Non Governmental Organisation
NIC..... Newly-industrialised countries
NRTF ..... National Research and Technology Foresight
NRTA ..... National Research and Technology Audit
NSI ..... National System of Innovation
OECD ..... Organisation for Economic Co-operation and Development
R&D ..... Research and Development
R&T..... Research and Technology
S&T ..... Science and Technology
SET..... Science, Engineering and Technology
STEEP ..... Social, Technological, Environmental, Economic and Political
STN ..... Strategic Technology Node
SWOT ..... Strengths, Weaknesses, Opportunities and Threats
SMME ..... Small, Medium and Micro Enterprises

Executive Summary

This Synthesis Report condenses the work of the foresight project team; twelve sector working groups and three cross-cutter working groups into a document of some eighty pages. Their work has spanned a period of some two years and involved more than three hundred and fifty working group members and hundreds of other role players drawn from across the broader community. Scientists, engineers and technologists, social scientists, policy analysts, government officials, health practitioners, trade unionists, NGO staff and community activists have participated in this, the first South African National Research and Technology Foresight (NRTF) study.

The NRTF project has been a significant learning experience for the participants. The various parties – benefited from exposure to new processes and ideas, not to mention the valuable networking that the foresight catalysed. It is intended this foresight will be not be a one-off event, but the beginning of a continuing process that informs the functioning of the country's national system of innovation.

The first stage of the work involved setting the parameters and scope of the study. An immediate decision had to be that of selecting for consideration the sectors deemed to be of most relevance to South Africa. These are:

- Agriculture and Agroprocessing
- Biodiversity
- Crime Prevention, Criminal Justice and Defence
- Energy
- Environment
- Financial Services
- Health
- Information and Communication Technologies
- Manufacturing and Materials
- Mining and Metallurgy
- Tourism
- Youth

In actually performing the foresight use was made of a number of methodologies that have gained wide support in similar studies carried out elsewhere, especially Delphi surveys and scenario analysis. These tools were adapted to the local context and used to identify technologies and research areas that would both promote an improved quality of life and lead to wealth creation.

This Report also provides a brief sketch of the country's research and technology base. This is followed by a summary of the work of each sector. These summaries offer thumbnail sketches of the sector characteristics and the key recommendations made

by the sector working groups. The summaries also include reference to particular problems that arose in the work, such as sector definition, access to information or divergent viewpoints. Care was taken to ensure that the key recommendations tabulated in this Report follow those in the original reports as closely as possible. The intention is that these provide an accurate picture of the sector recommendations. The interested reader will find the detailed reasoning behind the sector recommendations in the separately published reports.

The synthesis itself is found as Chapter 5 where the generic recommendations and key research and technology areas have been extracted and gathered together. These were obtained by sifting across the sectors and to scan across the sectors for common technology thrusts. Some special features of the NRTF are noted, contradictions are addressed and explanations for these are proposed.

As an organisational schema for the generic recommendations (see pp. 56) it appeared natural to use the three strata of a national system of innovation.

The generic recommendations are thus organised into three sections:

- Infrastructure
- Institutions
- Superstructure.

The key technologies (see pp.58) are collected into nine thrusts having a 'hard' technology focus, with a tenth category set aside for technologies having strong societal impact or economic relevance. These are:

1. Health
2. Clean renewable energy
3. Advanced information systems
4. Sustainable natural resources
5. Genetic manipulation
6. New materials
7. Bio-informatics
8. Processes and control
9. Flexible production
10. Social and economic

Social concerns emerge as a very strong current in the recommendations, with the problems of HIV/AIDS, human resource development, underdevelopment and environmental sustainability looming large. Regarding technologies, the imperatives of playing an active role in the knowledge society of the new century are recognised, with strong attention being given to bio-informatics and its implications in agriculture, health and the development of new materials. The issue of sustainability was identified as a key driver for new processes in mining, manufacturing and energy management.

In general the picture that emerges is of a national system of innovation that is currently performing at a level somewhere between the developing countries and industrialised countries. Given the country's capacities in health, engineering, mining, construction, information technology, and previous expertise indefence and aerospace, it is argued that a combination of in-house development, joint ventures and outright technology importation should be followed.

There is unanimity that the information and communication technologies will play a key role in the economies and societies of the next century and that these have a special role to play in the management of people, the environment and manipulation of materials and matter.

The Report concludes with some suggestions regarding the next steps to be taken in beginning the process of implementing foresight. This depends as much upon private sector investment as on government commitment. South African industry is frequently labelled as suffering from shortsightedness and of being cut off from academic research (and vice versa). The foresight by contrast tries to push out the planner's horizon to around twenty years.

A mixture of medium and long-term technological opportunities has been identified across the sectors. These opportunities represent a balance between supply, demand and end use. But the potential benefits of technology development or adoption cannot be evaluated in isolation of policy. In particular, development and applications are closely linked; as is evidenced in the strategies summarised in this Report. Whilst the Foresight exercise has been a useful initiative, real added value will only be realised in the future.

The National Research and Technology Foresight is a tool that is to shape future technology deployment. Hence the choice of title for this Report: Bokamoso. This is a Setswana word that translates as 'all the tomorrows'. We feel it is an apt slogan for the research and technology foresight.

Chapter 1:
Why a Research and Technology Foresight?

As the dispossessed take possession of their lives, their future, and begin to define who they are, where they are going and the milestones along the way, thus we must set ourselves tasks that will make the next century an African century, for in doing so, we shape the road ahead and become the authors of the narrative as it unfolds before our very eyes and in our lives.
President Thabo Mbeki: The Millennium Debate, 19 November 1999

1.1 Foresight

The telegraph was the communications medium of the steam age. From the invention through to the wide deployment of the telex machine took a century of continuous development. By contrast, from the first experiments at the transfer of information across a network of computers (ARPANET) to the browser-enabled Internet required less than 25 years. The telex was never a home-based device; the Internet is. The personal computer, mobile telephony and the Internet have already changed the way professionals and the middle classes work and play. Further changes are unpredictable, extremely rapid and likely to be profound. The 'Internet year' is reckoned at three months, such is the pace of innovation.

The Internet, e-commerce, and edutainment form the basis of the 'wired' society. New software demand drives the need for faster and larger memory devices; faster and larger memory devices create new software possibilities. While Moore's Law has provided a good indication of the rate of increase in memory densityover a 30-year period, it cannot indicate the evolution of the associated technologies. It takes a particular insight to see the latent possibilities in technologies, especially those that may arise by combining them. Jules Verne[1], writing in 1863 'foresaw' the facsimile machine as a home device a century before its realisation. He could envisage photography and telegraphy as a single medium. Ernest Rutherford, the great physicist could not conceive of viable nuclear energy. We see the future through a glass darkly. To cite an example of failure, the attainment of safe and economical nuclear fusion as a source of power has been promised since the 1950s. We are still waiting.

Over the last few decades a desire has emerged among the leading economies of the world to find ways and means of predicting where technology is heading and what its impacts upon society might be. From the early years of technology forecasting, with

its promise of accurate prediction of the future path of technologies, realism has since emerged that the quest for zero error in forecasting is futile.

The last decade has been a period of intense change, political, economic and technological. The cold war has ended, and regional ethnic conflicts have multiplied. New trading blocs have emerged, and new ways of doing business are arising as industries merge or disappear entirely. To this must be added the products of biotechnology - especially genetically modified organisms, mobile communications, and new methods of manufacture offering exceptional quality and custom batches. These are all ingredients of the knowledge society.

The former emphasis on precise forecasting has instead shifted toward a softer process known as technology foresight. Given the current rapid developments around Internet technology, such a more modest approach becomes even more sensible. To paraphrase Bill Gates, we tend to underestimateinformation technology development on a five-year horizon and overestimate what the ten-year future will be. The software giant among giants, Microsoft, did not grasp the significance of the World Wide Web until Netscape had shown the size of the potential market.

'Technology foresight' is a family of processes intended to capture the dynamics of change by placing today's reality within the context of tomorrow's possibilities. It acknowledges the likelihood of a range of potential futures and seeks to add new dimensions to our present thinking.

A useful working definition[1] is that technology foresight is a systematic attempt to look into the longer-term future of science, economy and society with a view to identifying emerging generic technologies likely to yield the greatest economic and/or social benefits.

All such foresight activities involve systematic processes geared toward anticipating the longer-term future on a ten -to thirty -year horizon. The value of foresight is both through the prompt identification of emerging generic technologies, -and the synergies that the process creates among those who participate in the foresight activities. Conceptualising foresight in this way offers a very broad framework for operation. Hence the naming of South Africa's process as the National Research and Technology Foresight (NRTF).

This is an era where many governments have recognised the value of investment in research and development. Technology foresight is being seen as a valuable tool for balancing socio-economic demands with science and technology 'push'. By this means the hard choices of allocating public funds to research may be better informed: which technologies, still at the pre-competitive stage, should the State support? And where will 'value for money be found'? Finally, in seeking to shape and plan our future,

foresight allows, indeed, almost requires, careful consideration of the environmental impacts of technology choice.

Technological foresight is inherently proactive and reflects the belief that today's decisions and actions influence the future. By building pictures of alternative futures we are able better to assess how well current and proposed research and technology systems might serve our children and us.

Although foresight[2] may use several forecasting techniques (e.g. Delphi analysis, trend analysis, scanning, and relevance trees), the outputs of the two techniques differ significantly. The emphasis in foresight is not prediction but the realisation that addressing the future necessitates the management of uncertainty. A richer and well-informed context for current decisions is developed via a dialogue involving all relevant stakeholders that emphasises the human abilities of forethought, creativity, systems thinking, analysis and judgement. The wider the range of perspectives that are explored, the more broadly the benefits may be felt. Transparency is essential for foresight processes. The underlying assumptions, analytical framework and information inputs must be accessible for universal review. Such openness also provides space for engagement between nonconformist and conventional views.

1.2 The Role of the Department of Arts, Culture, Science and Technology

The National Research and Technology Foresight (NRTF) Project is one of the major policy-informing initiatives launched by the Department of Arts, Culture, Science and Technology (DACST) as part of its general mandate to review, reform and re-direct the S&T system in South Africa. Another such initiative was the National Research and Technology Audit[3] (NRTA), which reported in late 1998. In addition a comprehensive set of reviews was conducted on ten of the major science, engineering and technology institutions, namely the eight Science Councils, Weather Bureau and the Atomic Energy Corporation. These reviews focused on the competencies of these organizations and in some cases led to significant restructuring.

Local interest in foresight was catalysed in 1993 when the International Development Research Centre of Canada, at the request of the Mass Democratic Movement, conducted a mission[4] to assist in developing S&T policy that might be relevant to the future democratic South Africa. The mission report assessed the status of the system and outlined the steps that needed to be taken into account when transforming S&T practice and structures. The report suggested the conduct of a research foresight since it was felt that such an exercise "to identify priorities for strategic research could be a powerful tool in forging a democratic South Africa".

Shortly after the establishment of the Ministry of Arts, Culture, Science and Technology in 1994, the Minister announced the intention to carry out a Foresight exercise. In the White Paper on Science and Technology, Preparing for the 21st Century, Government made a commitment to using the results of the foresight exercise as an important input into its decision-making on investment in research and development.

The Foresight results would also inform the allocations made by the Innovation Fund, research capacity-building programmes in the higher education sector, and other government and private sector structures.

The White Paper on Science and Technology envisages three goals in respect of innovation[4]:

- The establishment of an inclusive system of technological and social innovation;
- The development of a culture that values the advancement of knowledge as an important component of national development;
- Improved support for all kinds of innovation that is fundamental to sustainable economic growth, employment creation, and equity through redress and social development.

As a model for analysis of its S&T system, and in support of these goals, the White Paper suggested the adoption of the conceptual framework of a national system of innovation (NSI). This approach has been used internationally since the late 60s and assists in giving order to what might otherwise seem to be a completely disordered system. A national system of innovation comprises the network of organisations and firms and the interactions among them, formal and informal, as they operate to produce science and technology in the national context of law, regulation and policy. If it is to qualify for the title, a national system of innovation should constantly generate new research, processes and products. A necessarily includes infrastructure, both physical and social. Other elements to be considered in the working of the NSI include national and international law, culture, intellectual property rights, trade policy, standards, secrecy laws, industry-academic relations, intellectual capital and access to financial capital.

Systems of innovation may be thought of as having a national character, but in some cases a set of regional systems of innovation may be a better unit for analysis. In South Africa for example there are regional concentrations centred on the Johannesburg-Pretoria conurbation, around Greater Cape Town and on the Durban-Pietermaritzburg corridor. It is likely that these three regional systems of innovations will exhibit some characteristics that distinguish one from another.

The linkages in an NSI are important in defining the flows of information and finance among institutions. The latter is easier to quantify[1] than the former. More important than the linkages is the capacity for institutional learning since without this facet it will be impossible to keep up, let alone catch up.

In embarking upon the NRTF, the Department took the view that the Foresight process and its outputs would help the role players of the NSI in their decision making and give stronger coherence to the activities of its various component institutions. Not only would the foresight identify areas for immediate action, it would provide stronger direction for investment. Planning of the NRTF began in late 1995 and it was formally inaugurated in July 1996.

The objectives of the NRTF are displayed below.

Process objectives

- Identify those technologies and latent market opportunities most likely to generate benefits for South Africa
- Develop consensus on future priorities amongst the different stakeholders in selected sectors
- Co-ordinate the research effort between different players within selected sectors
- Reach agreement on those actions that are needed in different sectors to take advantage of existing and future technologies

Output and implementation objectives

- Contribute to broad policy guidelines in S&T consistent with the National Strategic Vision
- Identify possible funding priorities for publicly funded research
- Build capacity in foresight methodologies
- Gather intelligence, particularly for industry, on future opportunities
- Encourage greater R&D investment from industry
- Improve communication between the public and private sectors in S&T
- Advise on the implications of the findings for skills development
- Focus capacity development in the tertiary sector

1.3 Present Tense

Our democracy is but five years old. In these, its formative years, considerable work has been done in developing policies and structures that promote democracy and lay the basis for an improved and sustainable quality of life. Particular emphasis has been given to the role of women, the underdevelopment of rural communities, and the need to reduce marginalisation of the disabled.

During this period we have had to engage with our past, its failures and successes. We are now part of the community of nations, interacting through more open protocols, hosting our own multi-national corporations, dealing more intensely with those of other countries, and experiencing the consequences of eased mechanisms for foreign investment. Globalisation is a dominant force in world economies.

This new and rapidly changing environment marks the transition from industrial society to the knowledge society. Technological development has accounted for the emergence and growth of industries and processes throughout the life span of the industrial society, with energy, chemicals, manufacturing and communications being among the main drivers. In the knowledge society the technologies are softer, with information and communication technology (ICT) achieving a prominent global role. ICT has shown such power to shape corporations and economic activity that there are fears that the gap between North and South will widen yet further, with the world dividing into the 'wired' and 'non-wired'. Worse still, one might see theemergence of large pockets[2] of marginalised peoples overlaid with a stratum of highly mobile knowledge workers who share a global work ethic and maybe even 'global' values.

Other perspectives are less gloomy. Technology does not stand still and many developing countries may be spared the need to invest vast sums in fixed line communication systems. As the World Bank[3] notes: "Countries which are able to seize the opportunities these technologies present will be able to leapfrog into the future, even though they lack a developed communications infrastructure today. In fact, countries with little existing infrastructure … can proceed directly to the use of wireless technologies and fibre."

At home we face the challenge of transforming a society with huge disparities, a rent social fabric, and seriously threatened environment, into a nation at peace with itself and able to compete in the global market place.

South Africa is a powerhouse on the African continent. It accounts for some 40% of Africa's GDP, with 40% of that GDP originating in Gauteng Province. Over the last two decades the South African economy has shifted further along the path to becoming a service economy. The share of GDP due to agriculture has fallen, as has extractive mining, while the importance of the financial service sector has continued to grow. Manufacturing remains the largest contributor to GDP. However, the extractive industries still dominate the foreign trade statistics. These trends and factors are shown in Table 1.

The country has pockets of world class technology development, witness the oil-from-coal industry, offshore oil-from-gas, health care, deep mining, information systems, armaments, information technology, forestry products and food processing industries. But the country is a net importer oftechnology, although it is generally

successful as a technology adopter and extender. The strength and expertise of its corporate sector is evidenced by the considerable offshore trading that South African multinationals now engage in with significant international presence in banking, mining, construction, brewing and information technology. These are present areas of competence: the NRTF is intended to assist in identifying areas where new competencies will need to be developed or enhanced.

But in the words of President Mbeki, South Africa is a society of two nations: one rich, and one poor, one white, one black. In an economy plagued by severe disparities, on a continent still struggling to emerge from the consequences of colonialism and mismanagement, these very strengths can exacerbate and further create weaknesses. The Foresight study was conducted in this context.

Table 1: Factors in GDP, 1976-1996 (R bn.)

	1976	%	1996	%	Change
Agriculture	2.1	7.5	22.6	4.7	-37.4
Mining	3.3	11.5	39.1	8.1	-29.7
Manufacturing	6.8	24.1	114.9	23.8	-1.2
Utilities	0.8	2.8	19.0	3.9	42.4
Construction	1.4	4.9	14.3	3.0	-39.7
Trade	3.9	13.9	77.8	16.1	16.2
Transport	2.7	9.5	37.2	7.7	-19.4
Financial Service	3.2	11.1	65.4	13.5	21.6
Communications	0.5	1.6	9.4	2.0	20.2
Government	2.9	10.2	73.5	15.2	48.9
Other	0.8	2.9	10.0	2.1	-28.9
Total	28.3		483.0		

As is the case in South Africa's relations with the international community, the country has until recently been excluded from initiatives in both Africa and the Southern African region. In the past few years however, South Africa has joined the Organisation of African Unity to become an active and often leading participant of the African group in various S&T -related international agreements. South Africa has also participated in the environmental activities of theUnited Nations Economic Commission for Africa, and in meetings relating to environmental management and biodiversity of the African Ministerial Conference on the Environment. It plays an active role in the World Commission on Large Dams, has an increasing role in international mediation, and has participated in peacekeeping and de-mining operations. As with the global community, it is likely that South Africa's relations with Africa will become more influential, although its relatively high levels of development compared to other African states could present areas of tension over certain issues.

1.4 This Report

The Synthesis Report provides an overview of the Foresight process and the main findings. Its major function is to unify the diverse strands into a coherent whole, to

collate the common and highlight the divergences. The report provides description and analysis. It is necessarily a selection from the sector reports, to which the interested reader should refer for detail.

The synthesis is not an evaluation as such. A summative evaluation of the Foresight process itself will be commissioned in the near future. The impact evaluation of the foresight must wait far longer.

The way that the Foresight was conducted is presented in chapter 2. Of course this brief description cannot adequately present the reader with a sense of the intellectual ferment that went into conducting the Foresight. That is an experience that the sector working groups can best relate.

In Chapter 3 the research and technology base is described so that readers may share a common picture of the platform upon which future research is conducted and technology is to be managed.

Chapter 4 provides sketches of each sector working group and their recommendations for action. Each sketch is a condensation of a full text report that in many cases ran to nearly a hundred pages. To produce the sketch required fine sifting, the combination of findings, and isolation of technologies. Care has been taken to sift but not adulterate.

The synthesis itself is to be found in Chapter 5. In effecting synthesis a framework was necessary, and the most obvious choice was to do this from the perspective of the national system of innovation.

The synthesis ends with a concluding analysis and notes on the next steps: the wider promotion of the foresight recommendations.

Chapter 2:
How the Foresight Study was Conducted

"I never think of the future, it comes soon enough". Albert Einstein, 1930.

2.1 Learning From Others

Technology forecasting had its origins in the late 50s and early 60s within the defence-related sectors of the United States where the Delphi technique and scenario analysis were developed and refined. But it was really the Japanese experience that persuaded many countries of the necessity to carry out systematic investigation of technological possibilities. The Science and Technology Agency (STA) of Japan conducted its first Delphi survey in 1970 with a thirty-year horizon in mind. This survey has since been repeated at five - yearly intervals with an ever-increasing sense of its value. Given Japan's lead in the approach, its experience has been used as one of the justifications for foresight exercises. The evidence is that twenty years down the line the first STA study did impact positively on decision-making regarding technology choice and investment. This finding generates confidence that foresight is justifiable since no country can afford to do everything.

From the Japanese lead a number of other countries, mainly, but not exclusively from the OECD, have conducted technology foresight. The list is constantly growing and includes the United States, Canada, Netherlands, France, Germany, United Kingdom, Sweden, Norway, Hungary, Thailand, Nigeria, New Zealand, Australia, and South Korea. The approaches to foresight have been equally diverse, including Delphi surveys, brainstorming, relevance tree construction, scenario analysis, and technology scanning, and canvassing of expert opinion.

The outputs of foresight include the identification of critical technologies, recommendations for investment, the establishment of new structures, and the creation in both the public and private sectors of an awareness of the value of foresight activities. Creating such awareness is complex, and requires an appropriate balance between two of the intrinsic tensions in foresight: technology-push versus market-pull, and top-down versus bottom-up.

Lastly, foresight may help in the shaping of a national vision, provide anticipatory intelligence, and support advocacy, education and communication.

Experience suggests that successful foresight requires the involvement of a wide variety of stakeholders who follow a process ultimately characterised by what Irvine and Martin[1] term the five 'Cs':

- Commu nication among the stakeholders;
- Concentration on the longer term;
- Consensus attainment on directions and priorities;
- Co-ordination of future R&D activities;
- Commitment of decision-makers to acting on the results.

It is now a given that the research and technology foresight process is as important as the product. Since science and technology cut across many sectors including industry, non-profit sectors and society at large, it is important to involve all the significant stakeholders. For a foresight product to be acceptable it is imperative to maintain continuous interaction with research users and the scientific community during the process.

Industry involvement and commitment are key to the success of the Foresight exercise. The role that industry plays in economic development puts more emphasis on its involvement, especially with regardto successful take-up of the Foresight outputs. Government's principal role is to create an environment within which industry can compete successfully in the global arena. Technological progress and human resource development lay a base for continued economic growth and job creation, areas in which industry should play a crucial role.

2.2 Sectors and Sector Working Groups

As noted above, foresight exercises have been conducted in various countries. However, no two foresight studies are identical at process or output level. While outputs may be broadly similar there are significant disagreements regarding the time horizons for attainment of new technologies let alone one's own capacity to play a decisive role in this.

The foresight exercise in South Africa, though informed to some extent by those of other countries, had to adopt its own approach to fit the local context. Some of the unique features of the South African Foresight are addressed below.

Consultation

Perhaps the feature that most distinguishes the NRTF from other foresight studies is the extent of involvement of organised labour and NGOs in the process. In other countries foresight has often been conducted by experts alone, or has had an overt bias toward industry views or the market. The South African NRTF was specifically designed to involve stakeholders such as industry, government, organised labour and

civil society through a process of consultation. This inclusive approach was an attempt to give ownership of the process to all sectors of our population.

Broad approach

The methodological approach adopted in the foresight employs a combination of techniques effected by a number of sector working groups (SWGs) that operated under an overall Advisory Board.

The Advisory Board. adopted the following as the mission for the NRTF:

To promote technological innovation and deployment by identifying opportunities for economic and social development through a national research and technology foresight project.

The various techniques used by the SWGs include SWOT (strengths, weaknesses, opportunities and threats) analysis, scenario analysis and Delphi surveys of opinions on research and technology trends. The methodology further differs from that of other countries in that, to contextualise sector work, macro-scenarios for S&T in South Africa were developed to provide a uniform frame of reference for all sectors. Scenario analysis has enjoyed considerable popularity in South Africa in the last decade, especially in shaping decisions in the political and economic domains. The Foresight scenarios build on and extend this capacity.

Choice of sectors

The process followed to select the foresight sectors is also a special feature of the NRTF. A series of countrywide workshops in which participants were asked to identify future priorities for the country were conducted. The sectors that were finally selected therefore have drivers that include social development, technological development and wealth creation. In contrast to the sectors chosen by some other countries, our sectors are not in one-to-one correspondence with the decomposition of GDP or stock exchange sectors. The decision to include 'Youth' as a sector focus was made after widespread discussion. It reflects the fact that youth make up 60 percent of the population and in many cases bear the brunt of the social deprivation and violence. The twelve sectors are:

- Agriculture and Agroprocessing
- Biodiversity
- Crime Prevention, Criminal Justice and Defence
- Energy
- Environment
- Financial Services
- Health
- Information and Communication Technologies
- Manufacturing and Materials

- Mining and Metallurgy
- Tourism
- Youth

In addition three cross-cutting themes were studied:

- Education/human resource development/skills development
- Beneficiation
- Business development.

Of course it is possible to debate endlessly the combinations or exclusions that constitute the above choice. We point out that the silence regarding transport was deliberate since the Department of Transport was already busy with its own forward look entitled 'Moving 2020'. Not surprisingly transport issues arise in the NRTF especially in the energy, environment, tourism and mining sectors.

Sector working groups

The sector working groups were the operational arms of the study. Each sector working group was tasked to perform analyses of the sector and to identify issues, as well as suggest research and technology solutions to sector challenges.

Different countries have applied various methods in selecting panel or sector working group members. In the United Kingdom a method known as co-nomination was used, while in France the exercise was primarily carried out by appointed expert panels. Co-nomination5 is a survey-based technique that allows the major stakeholders and the broad community to participate fully in an open exercise of identifying those individuals who are to participate in SWGs. For the NRTF project, DACST suggested that a combination of methods be used. These were:

- Co-nomination
- Direct appointment by DACST in consultation with the Advisory Board and project management team.

The co-nomination objectives were to:

- identify key individuals who would serve as members of the SWGs in the Foresight project;
- build a database of experts who might be consulted by SWGs at later stages of the project.

A separate report presents detailed findings of the co-nomination study, conducted during 1997-98. The major findings of the report, based on statistical and relational analysis of 1131 questionnaire responses across twelve socio-economic sectors, are summarised below:

- Experts in South Africa are predominantly men (86%) and most are over 40 years old (70%).

- Experts are 'compartmentalised', with 43% being experts in only one of the socio-economic sectors, 28% having expertise in two sectors, and 12% spanning three sectors.
- Expertise is highly concentrated in certain regions of the country, with 75% of all respondents working in two of the nine provinces, i.e. Gauteng (52%), and the Western Cape (23%).
- The expert community is eager to communicate with the world, with 67% of all respondents nominating one or two overseas experts, mainly from the USA, UK, Australia and Germany.

Those familiar with the history of South Africa will know that white people are disproportionately represented in comparison with their black compatriots in the S&T professions by a ratio as high as 50:1. This imbalance is a fact of history, and is slowly changing. It naturally presented a problem to the execution of the Foresight: how to ensure that the working groups were duly representative by race and gender? In the event, of 354 SWG members, 276 were males and 78 females; whites totalled 221 and blacks 133. Thesedistributions are not representative of the population distribution, but are significantly better than the imbalances in the S&T sector.

The second challenge was to ensure that the various stakeholder groups were sensibly and adequately represented so that the Foresight would have intellectual and political credibility.

The stakeholder distribution is shown in figure 1, which indicates some dominance by industry.

In addition to SWG members, there were other important participants in the Foresight project. These include a pool of experts generated through the co-nomination process that participated in the Delphi survey. The stakeholders are organisations and institutions identified during the general foresight and sector-specific consultations who served as a reference group to the SWG. The involvement and participation of these role-players was important to the project in providing feedback, peer review and additional expertise.

2.3 The Methodology

Broadly speaking the SWGs followed a common methodology to arrive at a set of verifiable conclusions regarding the research and technology priorities for their sectors.

The first step entailed development of a mission for the sector, followed by the commissioning and analysis of two environmental scans.

International scans:

These were studies examining current technological, market, policy and strategic trends of the sector internationally. In most cases the study was effected by an independent agency.

Local scans:

These were reviews of the current status of the sector in South Africa with a focus on research and technology. In most cases the review was effected by the SWG co-ordinator.

Identify SWOT and STEEP factors:

On the basis of the above information a SWOT analysis was performed. In addition, major social, technological, economic, ecological and political (STEEP) factors were identified for the sector. These three processes provide a picture of the current sector situation.

Logic Chain Methodology:

Some SWGs followed the 'Logic Chain Methodology'. This methodology was used to analyse information generated from the SWOT and STEEP processes and was adapted from that used in the United Kingdom's Foresight Programme. 'Logic Chain Methodology' is a framework for considering the implications, constraints, synergies and knock-on effects of technologies at all stages of development.

Sector-specific scenario:

As the benefits from the outputs of the NRTF project will only be realised in the long term (10-20 years), a set of macro scenarios were constructed (see below). Based upon the macro-scenarios, sector-specific scenarios were developed and analysed. These scenarios were intended to promote a more open-ended view as to where the technologies and society might be heading and how the two influence one another.

Delphi Survey:

The above five processes laid the basis for the development of questions to be used in a Delphi survey. The respective SWGs developed the questions in workshop sessions. In all close to 10,000 questionnaires were sent out, with a return rate in the order of 15%. This satisfies the requirement of test reliability.

Strategic analysis and choices:

Based on an analysis of the Delphi Survey, future research and technology challenges and market opportunities over the next 10-20 years were identified and

recommendations developed around them. Plotting the technologies against attractiveness and feasibility criteria facilitated this selection.

2.4 The Macro-scenarios

Long-term strategic planning and sound decision-making are based on the realisation that in times of changes, the future is highly unpredictable. A systematic and imaginative way of thinking is crucial to prepare for the future. One of the powerful tools for thinking ahead in an organised manner is scenario analysis, which also prepares the mind to recognise the signals of change before they fully unfold. Scenarios rely on historical data such as long-term demographic forces, while anticipating the surprising turns of a very complex world such as changes in political order and markets. These scenarios help the human eye to at least recognise the possibilities of change in the socio-economic environment of the country. Besides helping nations or communities to see the future with different eyes, scenario thinking has been used to position leading corporations of the world in uncertain times.

In South Africa the mining houses and financial services companies have considerable in-house expertise in scenario planning methods. In the public domain the best-known scenario exercise is that known as the Mont Fleur Scenarios, which were developed in 1992 and used to illuminate the options facing a new democratic government. It is in this light that the NRTF found it useful to incorporate scenario planning into the NRTF as a useful means of re-positioning South Africa's research and technology strategy.

Two workshops, with diverse participants from various backgrounds, were conducted to take the scenario work forward. In the first set of workshops a thorough examination of the driving forces or key uncertainties in the strategic agenda was undertaken. This led to brainstorming of alternatives to 'official' futures, keeping in mind the driving forces. This method of scenario construction is known as the 'Inductive Method'. After the first set of workshops, necessary research was done to consolidate and align the strategic concerns and those that came out of the workshop.

The second workshop followed up on the initial brainstorming. At this time, alternative scenarios were developed. From this myriad of scenarios, the four most useful ones were chosen according to a particular set of criteria. Scenarios had to be:

- Relevant, i.e.: illuminate current circumstances and concerns, and link into current mental models;
- Emergent, i.e.: make the invisible visible, and challenge current thinking;
- Plausible, i.e.: fact-based and logical, and improve systematic understanding;
- Clear, i.e.: distinct alternative hypotheses/models, and accessible and memorable.

Each of the scenarios depicts a different route to 2020, within which the role of S&T is teased out. The scenarios are based on four possible outcomes of an interaction of various key drivers of the socio-political, economic and technological environment.

These four stories about the future were used in the NRTF project to develop sector-specific scenarios that enabled the working groups to generate and test ideas for their sectors. The macro-scenarios necessarily show some overlap with each other, yet are sufficiently distinct to provide credible alternative futures.

2.5 Delphi Surveys

One of the process objectives of the foresight exercise was to assess latent market opportunities and technological trends and inform decisions on the balance and direction of publicly funded science and technology for the next twenty years. From the outset it was recognised that it was not possible to have all the necessary expertise on a panel of manageable size, especially considering the broadness of the sectors. To gain the necessary commitment and consensus needed to make decisions and implement the foresight product, it was crucial to effect consultation with a cross-section of stakeholders concerned with each sector. A substantial amount of consultation was done through the working group members, associated individuals and the reference groups. However, a much more structured dialogue with stakeholders was required to test preliminary strategies suggested by the working group. This intensive and continuous consultation gives the Foresight a unique characteristic compared to other similar processes. This becomes even more pertinent to South Africa, whose science and technology system has been characterised by relatively little communication between academia and industry.

The method chosen to achieve this objective was the questionnaire-based Delphi Survey. The Delphi approach ,which originated in the US Rand Corporation involves the scoring of a questionnaire by informed experts. The results of the scoring are then fed back to participants who are given an opportunity to score their responses again. This process may be repeated a number of times until 'consensus' is reached. In practice two rounds are sufficient to reach consensus on most items. Proceeding beyond two rounds is generally regarded as a waste of time and money.

The main objectives of the Delphi Survey were to:

- access the views of business, civil society, and science and technology communities on future developments in markets and technologies;
- help to gain a commitment to results and consensus developments; and
- inform stakeholders at large about major issues being addressed by the foresight.

The Delphi survey was conducted by means of a questionnaire compiled from the discussions and opinions of the working group, which was sent by post and hosted on a web page. The Internet option, although clearly less popular than conventional mail, was another first for South Africa in terms of conducting a Delphi survey.

Delphi items must be concise statement of events, achievements or other phenomena upon which views are sought, an unambiguous expression of what, in the questioner's, view, had to be achieved. They must incorporate any key conditions but exclude separate issues that warrant additional topics. To help the working group in communicating which state of development they had in mind, the guiding notes to the questionnaire defined four items to be used:

- Elucidation: scientifically and theoretically to identify principles of phenomena;
- Development: to reach a specific technological goal for completion of a prototype;
- Practical use: the first practical use of an innovative product or service; and
- Widespread use: significant use, i.e. significant market penetration to a level where a product or service is in common use.

Underlying the questionnaire, and common to all twelve of the Foresight sectors, was a framework comprising six major variables. This was to provide a common basis for the comparison of information between sectors. Five of these parameters guided the input of information with regard to-

- the importance of the statement to South Africa in terms of wealth creation and quality of life;
- South Africa's standing with regard to this activity relative to southern Africa and the rest of the world;
- the likely time-frame for realization of the statement;
- how South Africa might acquire the necessary technology or capacity; and
- key constraints to realising the statement.

The sixth class of information requested for each statement was the level of confidence that the respondent had regarding the information that he or she was supplying - low, medium or high, depending on whether they were unfamiliar with, knowledgeable or expert in the field outlined in the statement. The survey results are analysed according to the confidence levels of the respondents e.g. High, Medium or Low, and/or combinations. Owing to the fact that the survey method tends to average out any really innovative applications, working groups brainstormed additional wild card technologies for inclusion in the final prioritisation process. In this way it was possible to include both pragmatic short to medium term opportunities and long - term, high risk, high return opportunities.

Chapter 3:
The Research and Technology Base

Chance only favours the mind prepared for it.
Louis Pasteur.

3.1 The SET Institutions

The research and technology capacity of the country is well described in the National Research and Technology Audit and no attempt will be made to duplicate the findings of that study here. One of its findings was that despite serious shortcomings, there is "... a solid foundation from which a national economic and social renaissance can occur". The country boasts twenty one universities and another fifteen technikons (polytechnic institutions), nine parastatal Science Research Councils that share a parliamentary vote of R1,5 billion., and many other government science, engineering and technology organisations in the environmental, medical, veterinary and security domains.

In 1997 Government commissioned a series of evaluations of certain of the state-funded science, engineering and technology institutions (SETIs). An overall analysis[1] concluded that the "system of Public Sector SETIs have developed over many years into a sophisticated and comprehensive system that, in some but by no means all fields, has a fairly-good track record in producing internationally-competitive technological innovations. As such it has potential to contribute to the sustainable development of the South African economy and society". But the same review noted that the system was characterised by poor interactions and networking especially between the SETIs and the Higher Education Sector.

It is recognised that there is extreme demographic imbalance in the numbers of school leavers who embark on higher education studies in SET. This is a structural problem requiring government intervention, which will only yield positive results in the medium term. In the private sector, expenditure on R&D as a portion of sales turnover is, by international standards, on the low side. Publicly funded research tends to be concentrated on agriculture, mining and manufacturing, while health, community services, energy and housing have received less attention. But there has been a recent shift in funding toward health research.

3.2 Research and Development Trends

In general, South Africa is not a world leader in research and development. Research and development (R&D) expenditure in South Africa was 0,7% of the GDP in 1997. When compared to developed countries, this is not substantial. South Africa's share of innovations and high technology activities is also relatively low[2]. For example, in 1996 the U.S. Patent and Trademark Office registered some 250 patents that originated in South Africa. This compares with 600 from Israel, 1800 from Australia and, in the USA, a total of more than 110,000.

South Africa's research output is also relatively low, but in line with the investment in R&D (ibid.). Roughly 0,5% of research papers listed between 1990 and 1996 in the Science Citation Index originated in South Africa. In 1995 clinical medicine made up 27% of these, while 11% were in the fields of plant and animal science, 10% in physics, 7% in chemistry, 5% in geoscience. Biology and biochemistry yielded 5%, ecology/environment 3%, and molecular microbiology 2%. There were particular strengths in niche areas of ornithology, anthropology and archeology.

The ratio of gross expenditure on R&D (GERD) to national GDP may be used to benchmark against other countries. Comparison figures are shown in table 2 below.

Table 2: GERD by country

Country	Year	% of GDP total
Hong Kong	1995	0,1
Singapore	1992	1,0
Korea	1993	2,3
Taiwan	1993	1,7
Indonesia	1993	0,2
Malaysia	1992	0,4
Thailand	1991	0,2
China	1992	0,5
India	1992	1,0
South Africa	1997	0,9
Japan	1992	3,0
France	1991	2,4
Germany	1989	2,8
UK	1991	2,1
USA	1988	2,9

South Africa's GERD/GDP ratio is similar to that of Hungary, Spain, Portugal, Chile and Brazil, but remains well below the 2% average for the industrialised countries and leading nations such asJapan and the USA. An additional fact to take into account when doing such benchmarking, is the high disparity of research spend within sub-sectors of the manufacturing sector.[3] Table 3 shows that the R&D spend is particularly strong in the aerospace, professional goods and communications sub-sectors.

However, it is possible to spend a great deal on R&D without producing successful high technology products; it is also possible to produce high technology products without a local R&D base.

South Africa's potential for international cooperation was examined in a study[4] commissioned to investigate the scope for targeted cooperation of its R&D organs with institutions in the European Union, i.e. South-North. That study sought to identify world-class institutions and researchers in South Africa who could engage in collaboration with European Union peers with the aim of achieving added value outcomes and industrial spin-offs. The major findings of that study were that such potential existed though the main concern of those surveyed was 'lack of funding and high costs of research'. External contacts among thelocal researchers were found to be quite strong: of publications surveyed 19% had foreign co-authors. Most existing European Union cooperation was with Germany, the United Kingdom and France. Internationally the major collaborating nation is the United States with Switzerland the third most important.

Sector	Gross output (R millions)	R&D expenditure	R&D Expenditure per Gross output (%)
Food beverage and tobacco	43 053	80,29	0,19
Textiles	16 006	9,96	0,06
Wood products and furniture	6 486	7,04	0,01
Paper, paper products and printing	16 626	7,87	0,05
Chemicals ex drugs	7 840	178,88	2,28
Drugs	3 680	27,38	0,74
Petroleum refineries	14 028	27,34	0,19
Rubber and plastics	8 237	27,99	0,34
Non-metallic mineral products	7 215	19,86	0,28
Iron and steel	14 343	28,55	0,2
Non-ferrous metals	4 358	40,51	0,93
Metal products	15 408	19,45	0,13
Non-electrical machinery	12 552	246,85	1,97
Electrical machinery	6 147	85,63	1,38
Radio, TV and communications	2 710	139,1	5,13
Motor vehicles	19 275	79,79	0,41
Aerospace	600	74,33	12,39
Other transport equipment	466	2,49	0,53
Professional goods	847	55,52	6,55

Four areas of common interest between South Africa and the then Framework Programme IV where collaboration already existed and might be further extended were found to be in:

- Biotechnology
- Agriculture and fisheries
- Biomedicine and health
- Sustainable management of renewable natural resources.

But it is worrying that the local R&D spend is concentrated in relatively few sub sectors, and that sectors which have been losing market share since the reduction of

trade barriers do not appear to be investing in R&D to catch up with their international competitors. More worrying is that this spend has decreased substantially since 1993. An additional concern is that South Africa has failed to harness R&D and innovation development within the small-business sector, which internationally is the most robust source of R&D and innovation.

Moving to Africa, South Africa is credited with some 17000 scientists and engineers active in R&D. Over the period 1992 - 1996 SA was ranked 27th in the world by frequency of citations of papers produced,[1] being slightly behind Argentina and ahead of Hong Kong, Mexico and Brazil. According to FRD statistics[2], South Africa, within Africa as a whole contributes 37% of the output, ahead of Egypt and Nigeria.

Chapter 4:
The Sectors

4.1 Agriculture and Agroprocessing

Introduction

South Africa contains elements of the developed world, both in technology and infrastructure. Yet these elements co-exist with a considerable lack of development, particularly in rural areas. This is also reflected in the country's expenditure on agricultural research which is average compared to that of other developing countries, but less than that of developed countries. By contrast, the relatively small contribution of agriculture to GDP and that of manufacturing (which is higher) classify the country as relatively developed.

Sector Characteristics

- Contribution to GDP: 4% to 5%
- Foreign exchange earnings (1994) R7, 24 billion.
- Agroprocessing comprises 25% of manufacturing industry contribution to GDP
- Direct employment: 10,5% of work force with spin out of another 16% in other sectors.
- Forestry industries turnover of R12 billion. Net surplus export of R2 billion.
- Fisheries wholesale value of R1, 2 billion.
- High potential arable land is 3% of the total country
- Total factor productivity has risen 50% over the last five decades
- Research spending is around 1,04% of agricultural GDP

Within the more highly developed agricultural sector of South Africa, awareness and use of high levels of technology are advanced. However, most of thetechnologies have been found to be product and process technologies, with few support and information technologies. Approximately 30% of technologies are imported, primarily from the more developed countries. The sector therefore tends to be an adapter and user of technologies developed elsewhere, with a somewhat limited innovation base. However, the adaptation of the imported technologies has allowed South Africa to process, transport and market products to discerning markets within the country as well as to the most developed world economies.

The skills base in agriculture does not compare well with that of developed nations. There appears to be an insufficient number of people with high skill levels. The more developed the sector becomes, the more critical this component will be when competitiveness, particularly in the area of high technology value addition, is considered.

The country has considerable biodiversity, and while there has been some utilisation of this resource, there are a number of examples of other countries developing products based on the local gene pool. There appears therefore to have been a reticence to develop local products, and in this regard, the country must fall behind many other countries, both developed and developing.

Direct government expenditure on extension and advisory services is high by most countries' standards. It is roughly equivalent to 2,4% of the agricultural GDP and compares with 1,04% for the average African country, 1,2% for Latin America, and less than 0,5% for Europe and North America. Advisory services are also provided for commercial farmers by the private sector, including cooperatives, input suppliers, commodity organisations and farmer unions. These services are estimated to be at least as large as those provided by the public sector.

While there are examples of the successful transfer of technology to small farmers, linkages between research and extension (and training) have generally been weak. A far more pronounced approach to farming systems research and extension (FSR-E) is being considered. This will enable researchers to involve farmers in the adaptation of technologies under field conditions so as to maximise benefits to farmers.

Internationally, biotechnology has been an important contributor to economic growth. South Africa, whilst ahead of some developing countries in this area, lags behind the North and there is a lack of visibility pertaining to the efforts and products of biotechnology. International trends in the preservation of agro-biodiversity and genetic resources have been slow. South Africa, with its rich base in biodiversity currently lacks suitable technologies to exploit these in a sustainable manner.

Key Recommendations

Value addition should become a focal area for investment and research. Technology development will therefore have to focus on downstream consumer requirements, both locally and internationally.

Nine strategic technological nodes underpin the required development and competitiveness of the sector during the next twenty years. Investment is required in the following areas:

- Agroproduction systems including breeding technologies, focused and intensive production systems and extended, on-farm production life cycles.

- Biotechnology for a more rapid and efficient means to diversify and improve the food and other industrial product base. Biotechnology may be applied in combination with traditional breeding techniques for the elucidation of novel genes, for ease of processing, for improvements of crops and animals, and for legal use.

- Natural resource management and utilisation to support sustainable utilisation of natural resources (soil, water, air and genetic resources) in agriculture and agroprocessing activities. These include water-saving technologies, bio-solutions and monitoring technologies.

- Technology transfer is important for South Africa because of an identified weakness in its technology transfer system, particularly within the less developed agricultural sectors. This field includes training and extension, education, international technology transfer mechanisms and Intellectual Property Rights (IPR).

- Processing technologies to increase competitiveness within the global environment and to enhance wealth generation for all stakeholders, will require improved technological capacity within the fields of product preservation, handling and packaging technologies.

- An enabling environment focused on appropriate socio-economic research to optimise efficiency and benefits, strategic mechanisms to formulate and adjust policy for R&D, access and availability to updated information in all sub-sectors and related activities and adequate asset development.

- Market development and maintenance to provide market information, consumer education, and continuous development of markets, all of which impact on technology development. A specific sector that needs this is SME producers and processors.

- Systems modelling technologies give insight into the probability of events, which creates a capacity for risk management and planning. Modelling can therefore make it possible to understand most of the previously mentioned strategic nodes.

4.2 Biodiversity

Introduction

Biodiversity is the number and variety of living organisms on earth, the millions of plants, animals, and microorganisms, the genes they contain, the evolutionary history and potential they encompass, and the ecosystems, ecological processes and landscapes of which they are integral parts.

Much local knowledge has been generated in the field of biodiversity. It is embodied in trained people, in scientific publications, databases, and herbaria and museum collections, as well as in the traditional knowledge retained in the oral histories of rural communities.

Sector Characteristics

- Natural product-derived pharmaceuticals contribute an estimated US$120 billion to global pharmaceutical sales in 1997, approximating 40% of total sales.
- World trade in raw botanical materials was estimated at US$8 billion in 1997.
- South Africa is the 3rd most biologically diverse site in the world, with 13 000 unique plant species.
- There are opportunities in sustainable hunting, fishing and community based natural resource management. Hunting alone generates over R400 million per year.
- Indigenous knowledge of medicinal plants is fairly well documented.

Increasingly, losses to biodiversity are being recognised as 'opportunity costs'. This, together with technological advances such as molecular tools for screening chemicals, and an ever-growing market for natural products, is resulting in an unprecedented surge of commercial interest in wild species. New types of foods, medicines, agricultural inputs, ornamentalplants, and other products form the economic base for large corporations and industries that have established themselves as 'life science giants', some having annual turnovers of up to $30 billion.

South Africa is uniquely placed within this context because of the country's rich biodiversity, well-developed infrastructure, scientific and technical capacity, and comprehensive knowledge of the fauna and flora. However, the country has largely failed to benefit from its genetic resources, and little interest has been shown in the domestic development of indigenous species.

In Australia biodiversity was adopted as a topic by the parastatal research institute CSIRO during their three year strategic planning exercise. In the UK's Foresight Project, reference to biodiversity issues was made in the panel on Agriculture, Natural Resources and Environment, but the German Delphi study made only one reference to the topic in the context of bio-indicator development. Thailand listed extraction and use of medicinal plants and development of biosensors as key foresight areas.

If harnessed in a strategic but sustainable manner, biological resources have the potential to reap significant economic benefits.

Key Recommendations

- Capacity development for managing biodiversity.
- Develop strategies for conservation and sustainable resource use.
- Develop and maintain a basic inventory of biodiversity resources.
- Identify and conserve biodiversity in a system of protected areas.
- Monitor global change and its impacts.
- Develop nature-based tourism, especially new package tours under community control. ICT developments such as personal digital assistants (PDAs) will become increasingly important.
- Research is required on the valuation of biodiversity and value addition of products and processes dependent upon biodiversity.
- Improved access to biodiversity information through application of ICTs is a prerequisite for developing equity and access to biodiversity resources and improving protection, co-management and shared benefit bio-prospecting.
- Reduction of the impacts of development on biodiversity through alternative bio-resource use and assessment of the effects of improved living standards on biodiversity.
- Integration of indigenous knowledge systems including validation of and standards for indigenous products, services, knowledge and technologies.
- Development of biotechnology products.

4.3 Crime Prevention, Criminal Justice and Defence

Introduction

For the purposes of the NRTF, it was recognised that there are two parts to this sector, namely the safety and security of society as a whole and the safety and security of individual citizens. Safety and security of society was regarded as security against threats from outside the borders of the country, or threats from within against the very fabric of society, while safety and security of citizens was regarded as internal security of the individual and property.

During discussions on the focus of the sector, the SWG decided that the name of the sector was inappropriate. The main reasons were as follows:

1. The original name was too close to that of the cognate Government Ministry, while the intention was to cover a much broader focus.
2. It was strongly felt that safety and security of society covered macro-areas such as poverty, unemployment, and the economy rather than the issues of crime and defence.

As a result the SWG agreed to change the name of the sector to Crime Prevention, Criminal Justice and Defence.

Sector Characteristics

- International trends show an increase in violent crime, crime syndicates, drug trafficking, corruption and fraud.
- The cost of crime is estimated at an annual R43 bn.
- Major external military threat is not viewed as highly probable in the near future. Defence readiness is thus oriented toward secondary roles.
- Internationally the main trend is an increase in internal conflicts, with most of the new events being in Africa.
- Local adaptation of relevant technology occurs mostly within the private security industry.
- Defence R&D is about 15% of the defence acquisition budget. Local defence contractors have the capacity to effect rapid and cost-competitive development.
- The United Nations and, regional and sub-regional organisations are becoming involved in conflict prevention, management and resolution, first through diplomatic means and then through peace missions.

- Some countries do not comply with international agreements on nuclear, biological and chemical weapons. Development is still taking place in detection, protection, decontamination, and simulation.

Research is relevant in all areas of the sector as so little is known about the realities of crime and the social aspects of it. On the other hand, most research for technological development is in the defence-related section, with some in the private security industry.

The process used to determine the key technologies for this sector was problematic since the purpose of research and technology in this sector is not directly for wealth creation or improved quality of life. These are important, but as an indirect consequence of achieving a better safety and security situation. The technologies that promote safety and security are not necessarily the ones that have the greatest effect on wealth creation or quality of life. Nonetheless for reasons of cross-sector consistency the prioritisation of items was based on a ranking by the stakeholders of 'importance to South Africa' in relation to wealth creation and improvement to quality of life.

There was also discussion on the relevance of this ranking for the defence sector. Again the prime objective of the defence-related industries is notwealth creation or even quality of life directly, but rather the safety and security of the citizens of the country. The wealth creation in this sector comes from the export of goods or services, while quality of life arises from a feeling of security from attack by external forces.

Not all the respondents were from the defence 'family' covering the Department of Defence, SANDF, Armscor or defence-related industry. Non 'family' respondents constituted about 22% of the profile. Comparisons between the two groups showed that while the non-defence respondents were less confident in their responses, there was a large degree of congruency in the ten most important statements, and therefore the results obtained from all the respondents were used.

The most important statements were mainly those that concern export of defence technology or have a high humanitarian element, such as de-mining technologies. This despite lack of clarity how this technology would directly improve the quality of life of South Africans.

Key Recommendations

Unfortunately the results of the Delphi survey had to be divided because of the possible exposure of sensitive defence information. Thus the crime section and the defence section of the survey were analysed separately.

Crime prevention and criminal justice

- Research is essential in the fields of information processing and information storage, especially dynamic real-time data processing as it relates to detection, identification and analysis of people (organisms), locations and objects.

- Development of a system of integrity analysis for the identification of corruption.

- Research specific to the particular problems of our society such as surveillance of crime hot spots, curbing vehicle theft, movement of arms, drug trafficking, safe movement of cash, stock shrinkage, and rapid and reliable identification of persons is required.

- Development of a system of integrity analysis for the identification of corruption.

Defence

The analysis showed that the defence sector requires virtually the same information handling capabilities as that of crime prevention and criminal justice. Accordingly the first key recommendation reads as:

- Research is essential in the fields of information processing and information storage, especially dynamic real-time data processing as it relates to detection, identification and analysis of people (organisms), locations and objects, with an emphasis on portability and robustness of equipment.

The Delphi statement that was thought to be the most important for the defence sector gives rise to the following recommendation:

- Maintain and extend capacity that allows for widespread use of sensing technology for humanitarian and military de-mining and mine clearance.

In addition,

- Affordability, dual-use technology, accelerated transition and development of a strong technology base should be the generic considerations for the defence-related industries.

- Where conversion to civilian use is attempted, this should be directed at specific markets, and utilise existing core competencies.

- Capabilities in military vehicle technology and driving simulators must be maintained and extended.

- Expertise in field artillery should be capitalised on to expand exports.

- The applications of telemedicine to the military terrain requires development through joint ventures.

4.4 Energy

Introduction

The enhanced greenhouse effect, tropical deforestation, acid rain, the problems associated with nuclear waste management, the destruction of habitats by hydroelectric dams, air quality in cities and other environmental fears have led societies to question the sustainability of a way of life based on high levels of energy use.

In common with most countries in the world, energy sector activities cause significant positive and negative environmental and resource impacts. These generate a number of environmental challenges, some of which result from the lack of infrastructure investment in poor residential areas, while others result from the methods adopted to exploit the country's natural resource endowments. These environmental impacts vary in scale and severity, ranging from the local level where peoples' health is affected on a daily basis, to regional and global impacts where the effects are more difficult to identify and control. On the other hand, lack of access to energy sources, through affordability or other factors, could also have a negative effect upon the rate of development, which itself is needed to raise income levels.

Sector Characteristics

Some important sector characteristics are:

- Energy constitutes 15% of GDP. Industry, mining and commerce consume 60% of energy; transport 24%; agriculture 3%.
- Households consume 24% of the country's energy. Of these 60% had access to electricity. Nonetheless 65% of household energy was obtained from wood.
- There are abundant coal and uranium reserves, some offshore gas, but no crude oil.
- South Africa produced 179 450 GWh of electrical energy in 1997. Eskom generated 96% of this. This is the cheapest coal-sourced electricity in the world.
- Nuclear energy contributes about 3% of the national primary energy supply.
- Clear tropical skies provide among the highest levels of solar radiation in the world.
- Renewable energy yields 10% of primary energy
- About one-third of fuel demand is met by the synthetic fuels industry.
- The country has a high energy intensity due to its (deep) mining and metals industries. It produces 1,4% of global carbon dioxide emission but only 0,4% of world GDP.

Integrated energy planning (IEP) is a process involving various technical functions to supply and use the information, which is required to inform policy development in the

South African energy sector. Such capacity does not currently exist within Government but is available in the private sector.

In a report commenting on South African energy policies released in May 1996, the Organisation for Economic Co-operation and Development's International Energy Agency stated that 'the lack of good data is a major weakness in the energy policy making process in South Africa. It also hinders transparency in the energy sector'.

The Department of Minerals and Energy manages a limited non-nuclear research programme, of R20 million per year. The Atomic Energy Corporation (AEC) spends approximately R30 million p.a. on energy-related research. Research spending by Eskom currently amounts to R123 million p.a. and is increasing. Government spending on energy research has decreased steadily since 1990, particularly on nuclear energy.

Internationally R&D is providing incremental technological improvements to wind power, photovoltaic conversion, solar thermal plants, biomass conversion, geothermal extraction and wave energy sources.

Internationally the main R&D emphasis is toward improved efficiencies in electric power production and transmission. There are large research programmes in the road transport sector on vehicle and power unit design, alternative power sources, and energy storage technology. High-speed trains would not necessarily achieve greater fuel efficiency than conventional trains, but could encourage a modal shift from road and air traffic.

A number of nuclear reactor design concepts have been advocated for the longer term (year 2030), the aim of which is to take the evolutionary path a stage further, with greater use of inherent and passive safety features. The designs are aimed at addressing the problem of public acceptability of nuclear power. If they are successful, these concepts could open up new markets for nuclear technologies. The Pebble Bed Reactor is one such development.

Key Recommendations

- Stimulate the development of Centres of Excellence in areas such as Coal Discard Utilisation, Clean Coal Technology, Photovoltaic Energy, Gas-Based Energy, and Industrial Competitiveness.

- Conduct a techno-economic study of low cost solar water heating and electric hybrid systems to develop strategies for implementation.

- Within the framework of environmental policy, remove disincentives and introduce appropriate incentives that promote energy efficiency across the industry,

construction and transport sectors, with immediate emphasis on low-cost solutions and use of recycled materials. Develop concise standards for energy efficiency as this relates to climatic region.

- Promote deployment of solar photovoltaic systems by development of institutional and financial mechanisms to improve access. A combination of basic R&D, technology purchase, and establishment of joint ventures to develop local applications should be followed.

- Institute mechanisms for regional co-operation, particularly with the SADC States, for development and deployment of low-cost and innovative energy applications e.g. gas-based systems.

- Promote measures to attain economies of scale for the manufacture of low cost paraffin appliances that comply with safety and performance standards.

- Support joint venture activity between utilities and manufacturers for electricity distribution and reticulation. This will serve to retain world status in metering technologies.

- Small-scale energy storage for stand-alone applications should be supported through joint venture activity with Centre(s) of Excellence in other countries.

- A demonstration project on the viability of bulk solar thermal power generation should be established with international technical and financial partners to form the basis for strategic planning on large-scale commercial energy production.

- A medium-scale demonstration project on high efficiency power generation from coal should be launched.

- Low cost energy supply and alternative delivery for rural SMMEs should be supported through pilot projects of a number of different applications, including the exploration of the social acceptance of the technology. These would involve rural development agencies and include developmental, information, and training and support functions.

- In the area of high efficiency electricity transmission, superconductivity and high voltage direct current systems, the relevant technologies should be imported and implemented as joint ventures, possibly on a regional basis.

- Development of a knowledge-based energy information system, and energy simulation and modelling skills is recommended.

4.5 Environment

Introduction

The scope of the sector was defined as the interaction of human endeavour with the biophysical environment. The sector working group identified six focus areas: air, land/soil, water, the coastal zone, waste and integrated/cross-cutting issues.

The environment sector has areas of considerable overlap with other sectors, notably in respect of biodiversity, agriculture, manufacturing and energy. The concept of sustainable development is central to biodiversity conservation and management. It is given impetus through the Constitution, which supports the concept of "ecologically sustainable development and use of natural resources while promoting justifiable economic and social development". Accordingly, human and technological resources and investments must be realigned to ensure that the future development path is environmentally and socially sustainable.

Sector Characteristics

- In most OECD countries employment in environment-related fields is about 1% of the total employment
- South Africa is a semi-arid country, receiving only approximately half the world average rainfall, which is spread disproportionately across the country from east to west.
- Most of the land area (86%) is used for crop cultivation or livestock production, with less than 10% conserved.
- Some species are under threat from desertification, and over-collection for medicinal, ornamental and horticultural purposes. Invading alien organisms present another threat since they replace indigenous animals and plants.
- South Africa has a coastline stretching for some 3000 km from Namibia in the west to Mozambique in the east. The country controls the exploitation of natural resources within the 200 nautical miles of the South African Exclusive Economic Zone.

South Africa shares with other countries the environmental challenges posed by an increasing population, urbanisation and the attendant problems of pollution, resource depletion and habitat degradation. These are complicated by the local combination of environmental concerns associated with developed economies and those more typical of developing countries.

The new participation in global political forums has coincided with a trend away from reliance solely on regulation as a tool for environmental improvement, towards a

multifaceted approach, including greater use of economic instruments and increasing attention to the total process.

The current international research position and likely future trends are as follows:

- Budgetary appropriations for environmental R&D have increased, with typically 2 % - 4% of GERD spending in many OECD countries (USA < 1%).
- Air pollution reduction will rely on the continued development of emissions reduction technologies particularly in the energy sector.
- Research on waste management considers the economics of incineration, the development of waste-as-fuel technology, and improved reclamation and recycling.
- Legislation and the scarcity of water drive research into water treatment. Membrane technology, bio-remediation and improved modelling techniques will become important.
- Industrial energy conservation and the use of cleaner, less energy-consuming process technologies will continue to attract government and industrial support.
- Increased demand for environmental services is to be expected.
- Coastal zone management is a key research area.

Key Recommendations

- Develop technologies that make optimum use of limited water resources.

- South Africa should take a leadership role in developing and applying regionally appropriate technologies and systems for optimising resource use and re-use and minimising waste in all sectors.

- A national initiative should be undertaken to arrest the degradation of soil on agricultural land and help farmers to practice sustainable land use.

- Develop a range of decision support tools designed to assist planners at all levels to make more sustainable choices.

- Develop national capacity to assess and implement critical technologies that support sustainable development.

- Ensure that secondary education students have a good understanding of the basis for, and importance of, environmental sustainability. At the tertiary level a teachable discipline of environmental assessment and management is required.

- Create a national training and accreditation scheme to ensure that those with responsibility for resource management and environmental decision-making are adequately skilled.

- Systematically reduce of our dependence on the use of fossil fuels while at the same time making a substantial investment in research into renewable energies, such as solar and wind energy.

- Undertake a substantial strategic initiative to provide communities with the information and technological access necessary to be able to understand and manage their environment.

- Put significant research effort into identifying potential sustainable uses for South Africa's plant resources and developing appropriate commercial pathways to market them.

- Develop environmental entrepreneurship training and support programmes.

- Develop the capacity both at the community and the professional scientific levels to monitor key aspects of the health of the environment.

- Develop and commercially apply innovative, environmentally friendly materials such as bio-degradable plastics.

- Launch various research projects needed to deal with pollution remediation.

- Develop sustainable local capacity for the commercial use of inshore marine resources, including sea weeds and shellfish.

- Significantly improve capacity to model atmospheric circulation at a variety of levels, from local to regional, and to accurately predict droughts and extreme weather conditions.

4.6 Financial Services

Introduction

The Financial Services Sector started out as the Business and Financial Services Sector. However it was felt that this scope too wide and that 'Financial Services' would provide a more focused approach. The sector includes banks, insurance services and the financial markets. Potential points of focus could also include a look at capital flow mechanisms and venture capital availability.

The financial services sector is world class and has long been regarded as an innovator. The sector is an avid user of information technology and is constantly testing the financial regulations, seeking space for new financial products. But there is no discernible strategic plan for the sector as companies tend to work in isolation and secrecy.

The collapse of NIC banking sectors in 1998 had a negative impact on South Africa, but not nearly as severe as that in the East. Still, the lesson is that the economy is vulnerable to the new mobility of speculative capital that de-regulation has created.

Sector Characteristics

- Within Africa, South Africa comprises 5% of its population, but accounts for 40% of all industrial output, 25% of GDP, over 50% of electricity and 45% of mineral production.
- Financial services contribute (1997) 18% of GDP.
- The financial service sector is rated 11th of 53 countries included in the World Competitiveness Report (1997).
- Cross border transactions in bonds and equities in the major advanced economies increased from 5 % of GDP in 1975 to between 1 and 7 times GDP in 1997.
- Internationally, telephone transactions represent the fastest growing retail bank channel.

A major force at work is the convergence of information and communication technologies and the way that this is redefining the role players of the sector. The global nature of communications platforms today, in particular, the Internet is promoting further integration of the world economy. At the same time, the low cost of establishing a presence on the World Wide Web is making it possible for businesses of all sizes to develop a regional and global reach, and for consumers to benefit from the wider choice of goods and services on offer. Key issues will be different payment media, database management and the provision and maintenance of secure operations.

Globalisation will be a key theme in future developments. This will entail:

- An increase in the technical capabilities for engaging in precision finance, that is, for unbundling, repackaging, pricing, and redistributing financial risks;
- The integration of national financial markets, investor bases, and borrowers into a global financial market place;
- The blurring of distinctions between financial institutions and the activities and markets they engage in; and
- The emergence of the global bank and the international financial conglomerate, each providing a mix of financial products and services in a broad range of markets and countries.

Key Recommendations

- Re-oriented education and training are needed to take cognizance of global and technological trends in financial services. This implies the following:
  a. The national education system takes and actively initiates a major shift in the content and method of relevant education at all levels, including school level.
  b. Financial service education and training should be included in programmes for trainers and teachers.
  c. A standards generating body should be set up for the financial services sector.
  d. All relevant training institutions should encourage the wider use of electronic business simulation techniques.

- Appropriate, competitive institutional frameworks and innovative tax incentives will help to promote SMME development.

- A small business development framework should be established to stimulate and broaden the activities of development agencies.
  a. New processes and resource acquisition capabilities are researched and developed for provision at the customer's locality.
  b. An existing financial services sector organisation should be appointed to develop and manage a risk database for use by risk capital providers.

- Measures are required for the provision and extension of financial services to rural and informal communities and un-banked people. This represents the greatest untapped market in the short-term. A review of institutional mandates (e.g. PostBank), financial de-regulation and introduction of incentives to the industry may promote this. Smart card technology may play an important role in this development.

- The banks, in conjunction with other traditionally non-financial service players, actively promote the widespread use of electronic cash in the form of smart cards

and electronic credits largely to replace the use of physical cash as a means of paying for day-to-day consumer transactions. This process will need to be driven and co-ordinated by an appropriate impartial body to secure the high degree of co-operation required. All electronicdelivery systems must ensure secure transactions through certification, encryption, authorisation and verification.

- Government, in collaboration with private sector institutions should
  a. promote the SA financial services industry locally, in the rest of Africa and abroad.
  b. further develop and create an enabling environment for small financial institutions
  c. facilitate international links for local players through developments in information and communications technologies
  d. establish an appropriate and representative working group to review applicable legislation, including but not limited to financial service legislation.

4.7 Health

Introduction

South Africa has embraced a strong human rights culture codified into the Bill of Rights and Constitution. The foresight team on Health took particular care to incorporate these values into its approach, especially in respect of equity, access, the free flow of information, and personal empowerment of individuals' health.

Since Hippocrates, the Nuremberg Code and the Declaration of Helsinki, there have been professional codes of conduct, common oaths and bonds and intrinsic trust that have guided the practice of medicine and medical research. Recent technological advances have substantially changed clinical and research practice, and now present considerable ethical challenges. In the context of increasing health care costs, the allocation of national resources for health should be based on the best available scientific and economic evidence. The extension, interpretation and protection of ethics in health care and research, as an intrinsic value system, should guide all health professionals.

Sector Characteristics

The following is a brief summary of the demographic and health profile of the country:

- The population comprises 50.5% women and 49.5% men distributed as 76% African, 13% White, 8.5% Coloured, and 2.5% Asian.
- 45% of the population is younger than twenty; this proportion varies across groups.
- Fertility levels have been declining; the total fertility rate is now around 4.
- There is a relatively high incidence of high-risk fertility in South Africa. In 1993, 15% and 16% of the births respectively were to teenagers and women over 35 years of age.
- The population aged 60 years and over was 6.1% in 1995 and will reach 9.2% by 2020.
- Until recently mortality rates have been decreasing, but are being reversed by the impact of HIV/ AIDS. At the end of 1996, an estimated 2.4 million adults were HIV+. Antenatal surveillance has revealed an increased prevalence from 10.4% in 1995 to 16.1% in 1998. HIV/AIDS is now the most significant disease influencing the health of the nation.
- It has been estimated that there were 160 000 TB cases in 1996, of which 42 000 cases could be attributed to HIV.
- The major cause of death amongst 1-4 year old African children is through infectious diseases.

- Adult mortality among African males is as high as that in Sub-Saharan Africa.
- The country is classified as a middle-income country by the World Bank, with 8,5% of GDP spent on health care. 60% of this is spent in the private sector.
- The entire southern African region has experienced one of the most severe malaria epidemics recorded in recent times. Bilharzia remains a neglected public health problem.
- South Africa is a key player in the pharmaceutical industry in Africa.

The overall pattern of deaths reflects the triple burden experienced in South Africa - the combination of poverty related diseases, chronic diseases and a high toll due to intentional and unintentional injuries. It is against this background that the policy of Essential National Health Research (ENHR) was adopted in order to facilitate advancement toward attaining the goal of equity in health research, and to operationalise the concepts of equity and social justice. The task of ENHR is to manage health research on a national basis and to use that research to promote health rationally andequitably. In order to achieve these goals knowledge is drawn from a wide variety of disciplines including social, natural and medical sciences.

The development of a national policy for health information systems started in April 1995, with the aim of providing the various types and formats of information needed for management, statistical, and epidemiological purposes in health care delivery.

The challenges for medical/health research and development are:

- The 'unfinished agenda' of childhood infectious diseases and poor maternal and peri-natal health
- Re-emerging infectious diseases as a threat to human health
- Inefficiencies in health service delivery.

Broader Picture

World-wide improvements in health care and health status have led to a number of demographic changes, an 'aging North', able to afford expensive drug and treatment regimes, and a 'young South' poorly equip-ped to meet the increasing demands for food, clean water, education and other basic necessities. More than half a billion people are still chronically malnourished, more than 1,2 billion people lack access to safe water, and about 800 million lack access to health services.

Environmental trends with a health implication include a growing number of people living in water-scarce countries, water degradation, the depletion of fish resources, deforestation; biodiversity loss, global warming and ozone layer depletion.

A growing trend is that governments are defining themselves no longer as sole providers of essential services and social development, but rather as facilitators and regulators.

Globalisation is exerting more pressure on resources for health care.

International health foresight studies indicate that patients will become more pro-active regarding their own health care, and that their health care will be more customised. The medical paradigm will broaden from an almost exclusively bio-medical approach to a bio-psycho-socio-economic approach.

Key Recommendations

- Funding for the new research agenda must be sufficient to recruit the best scientists from both local and overseas institutions. The ensuing research must actively include capacity building, skill transfer and on-site training.

- For research and development to have an impact on the quality of life of the country's people and its competitiveness, the research portfolio should focus on local issues including niche areas, that may or may not form part of the global agenda.

- A modular and flexible national health information system that has the ability to be integrated into a national information system has to be developed and implemented.

- Enhancement of health service delivery through optimisation of management, extended use of telemedicine, and novel ways of developing public-private partnerships must be explored.

- Personal health care technologies underpinned by self-empowerment and personal responsibility should be introduced. These must be cost-effective, easy-to-use, robust and supported by the health system.

- Cost-effective prevention and treatment technologies are the most important area for the medical science research base in South Africa. Research must follow a dual strategy involving modern biological sciences and indigenous knowledge systems.

- The above priorities should be accompanied by two ongoing campaigns namely:
  a. National health, violence and safety promotion and prevention
  b. Focus on health promotion among youth.

- Establish a Disease Control Institute.

4.8 Information and Communication Technologies

Introduction

The accelerating rate of technological development and the social, economic and cultural changes that follow in its wake have stretched even the strongest existing institutions and organisations and the fabric of even the most advanced societies to their limits. Many argue that technological innovations, particularly in the Information and Communications Technology (ICT) sector, are the main drivers of these changes. Others speak of an emerging 'knowledge society' as the fundamental cause. The working definition of information and communications technology covers digital technologies facilitating the acquisition, processing, presentation, management and communication of information. These technologies include, for instance, the micro-electronics, photonics, computer and telecommunications industries.

The Information and Communications Technology (ICT) sector is unique because it represents a scientific discipline and industry in its own right, as well as cutting across all other sectors. Even a cursory glance at the other sectors reveals the all-pervasive role of ICT at the close of the 20th century. The ICT sector is also unique in its pace of change and the rapid convergence of 'traditionally' distinct areas of human endeavour - broadcasting, print media and telecommunications. Indeed, it is almost impossible to construct a definition of ICT that will last longer than about six months. The boundaries shift continually. While vehicle manufacturers and energy suppliers are presently the largest global corporate players, new ICT conglomerates are challenging this position.

Sector Characteristics

Trade in ICT products and services was worth over a trillion dollars in 1995. On the one hand the ICT sector is dominated by the G7 countries and a few large, international corporations, while on the other, small entrepreneurs with the right niche products are able to enjoy rapid growth with reasonably modest start-up costs. Over half of the growing world- wide information processing market is related to software production. Growth areas include software packages and systems integration services.

Some features of the sector are:

- South Africa is the 20th largest country market for ICT products and services, accounting for 0,6% of worldwide revenues. 60% of PCs are connected to networks, which compares favourably with OECD norms.

- In Financial Services there are 74 PCs/100 employees; with around 24 in Wholesale and Retail; 17 in Manufacturing and 7 in Government.
- Over 95% of hardware revenues by distributors are from imported products and components.
- South Africa contains a third of all main lines and 85% of all cellular subscribers in Africa.
- Telkom (70% state-owned) is the 28th largest telecommunications operator in the world.
- Telkom's expansion is being financed on the international bond markets with the intention of reaching under-subscribed peri-urban and rural areas and becoming the primary international African hub for telecommunications, computing media and international services.
- The country is the largest Global System for Mobile Communications (GSM) market outside of Europe, and the fourth fastest growing GSM market in the world. By 1997 20% of the country's telephone volume were mobile units.
- In 1993/4 the telecommunications industry was estimated to have a turnover of roughly R3 billion, employing some 7 200 people.
- ICT professional services had a turnover of R2, 3billion. in 1995, but little of this was spent on cutting edge R&D.

The Industrial Revolution produced a social compact among governments, workers and employers which, while exploiting the ordinary worker, sustained growth in capitalist economies for over a century and spawned competing ideologies to the right and left. That balance is now being challenged by a shift to new ICT-mediated modes of producing goods and services. The new paradigm is enabled by ICTs while simultaneously driving the development of new ICTs.

- Distance and time are no longer limiting factors in production.
- Companies locate operations based on local labour skills and costs, taxation and incentive arrangements.
- Concentration on 'core business' provokes outsourcing and creation of 'virtual business entities'.
- ICT deployment challenges the bureaucratic/industrial organisational model.
- '7 x 24 working' is replacing the working week with part-time, more flexible hours and shifts to short-term flexible contracts.
- In OECD countries the service sector is now becoming dominant.
- Telework presents the opportunity to work from geographically isolated communities, but may bring with it problems of isolation and exploitation by absentee managers.
- Labour market flexibility may reinforce insecurity and isolation in the industrialised world and lead to less tolerance of different conditions and value systems.

Key Recommendations

As might be expected, ICT features to a greater or lesser extent in all the sectors of the NRTF. Indeed, in some sectors, like Crime, Youth, and Financial Services, many of the most important possibilities for the future have a strong ICT component. Because of this cross-cutting role, another level of analysis was applied to the ICT sector using the concept of strategic technology maps. This method assists in clustering technologies and their association with one or more of ten Strategic Technology Nodes (STNs).

The ten strategic technology nodes are platforms representing major opportunities that merit further investigation, even though several were not prominent in the combined survey results of the other eleven foresight sectors. STNs can, and often do, depend on each other to varying degrees. In this way four 'super clusters' of STNs emerged.

1. The 'Future Web', already termed Internet II. This is the successor technology to the current World Wide Web and Internet. .
2. Research and Technology in the 'Intelligent Solutions' super cluster, that deals with ICT solutions that replace people, enhance people, or enhance their environments.
3. Knowledge and Learning-intensive Solutions.
4. A well-functioning ('healthy') ICT industry

Examining the layers of the technology map below the STNs leads to ten additional recommendations.

- Establishment of capability and capacity in photonic, bio- and molecular micro-circuitry.
- Development of capability and capacity in one or more of radio, low-cost satellite and stratospheric platforms.
- Establishment of world-class expertise in database and server technologies.
- A national strategy should be developed to enhance research and technology in distributed, cooperative application platforms.
- Develop new local expertise in content digitisation technologies.
- Existing capabilities and expertise in CAD/CAM techniques, intelligent manufacturing processors, robotics, intelligent transponders, and embedded systems should be extended.
- Existing pockets of excellence in spatial numeric environments ('Future GIS', virtual reality, including distributed environments) should be further extended.
- High priority should be given to collaboration between the Safety and Security and ICT sectors in respect of crime-related matters.
- Assess the longer-term attractiveness of the Bio-ICT and/or the Smart Environments STNs.
- High priority should be given to a significant level of research and technology investment in Human Language Technologies.

4.9 Manufacturing and Materials

Introduction

In the new millennium manufacturing will be a global activity. This transformation results from three key factors:

- Trade liberalisation;
- Technological developments that reduce transport and communications costs while simultaneously increasing efficiency and effectiveness
- Reductions in the costs of transactions between countries and the development of cost-reducing institutions, and a move towards more compatible commercial laws and standards.

At a macro-economic level this new global environment has resulted in over-capacity, a consistent and continued fall in real prices for manufactured products, and the rapid transfer of technology and production to low-cost countries. Production and investment decisions are now based on whether a host country offers internationally competitive production costs, what the size and access of the host country market is, and the strength of the research and development and engineering skills base in a country.

Manufacturing is moving into an era of tri-polar global competition, with the broad trading blocs of Asia, Europe and North America, defining the playing field for all other manufacturing competitors.

Consumers of manufactured goods now demand product reliability, conformance quality, product customisation, volume flexibility, design flexibility, low price, new product speed and exemplary after-sales service

These deliverables have required successful manufacturers to adopt a process of continuous improvement and massive investment in newmanufacturing technologies and innovations and information systems. Manufacturers are now also required to embrace a broader, more complex paradigm involving themselves, their suppliers, and their customers as partners in a 'value net'.

Sector Characteristics

- Developing countries' share of world manufacturing exports increased from less than 10% in 1970 to 35% in 1996; their share of manufacturing value addition has increased steadily to 17,4% of world MVA.
- Developed countries' MVA continues to decline as they continue to outsource their manufacturing base while developing their local service and financial sectors.

- The manufacturing sector contributes 24% (1998) to GDP and provides 19% of workforce. But GDFI has fallen from 27% in the 1970s to 17% in the 1990s. Within the increased market share of developing countries, South Africa's earnings decreased from 12% in 1975 to 1,5% in 1993.
- 3rd lowest level of specialisation in the world.
- Comparatively high unit labour costs, high overhead and marketing costs, poor labour skills, low productivity, adversarial employment relations, poor work ethics and practices, and poor diversity management.
- High reliance on imports of capital equipment and machinery.
- Inherent advantages in raw materials negated by dual pricing and import parity pricing policies.
- The domestic market is small and export remains focused on primary goods.
- Insufficient expenditure on R&D within the materials and manufacturing sectors.

Five major trends were identified as possible factors that will shape future work patterns as well as lifestyle patterns.

1. Service industries and service within product industries will become increasingly important.
2. Knowledge capacity will become the discerning factor in future growth and development. This moves away from traditional thinking, which gauges a nation's capacity to grow on the basis of the volume of land, labour and capital it has at its disposal.
3. The industrial age is coming to a close and the future lies in the age of information.
4. It is accepted that individual worker contributions to organisations will become increasingly important, implying that the perception held by the 'worker' will need to evolve, as will the importance of stakeholder activity and decision making.
5. Highly diversified organisations may wane and the dynamism of small business will figure prominently in the new Information Age.

Three overarching trends were viewed as being particularly pertinent to the materials and manufacturing sector in the next 20 years. First, there will be increased migration to and adoption of new product-development tools such as CAD, CAM, rapid retooling methods and virtual prototyping. Secondly, flexibility will become increasingly important in all spheres. Thirdly, the recycling of limited natural resources and life cycle analysis will become increasingly prominent issues in both product and process development and implementation.

Key Recommendations

Frequent comments arose relating to human resource issues, with the impact of crime on the skills base and productivity and profitability being raised several times. A second theme related to changing mindsets regarding work, work practices, ethics, philosophies and relations and technology. A third theme was that certain Delphi

survey statements were 'not relevant to South Africa'. This comment appeared so frequently that one concludes there was no strongly shared vision among the respondents as to the present or future positioning of the sector.

In developing a methodological approach by which to capture the complex and varied nature of the sector, an interpretive structural model called 'the enabling model' was developed. This model is based on the identification of interdependent nodes of influence, and highlights the necessity of a holistic approach to supporting the growth of the sector. Recommendations are made for each of these nodes.

- Apply resources to making the environment for product and process innovation more nurturing and supportive. This requires among other initiatives, pre-competitive R&D support, expertise in technologies that reduce time-to market, expansion of local venture-capital, and an incubator system that applies international standards to the stimulation and support of start-up companies.

- Over the next 10 years market focus must be achieved by supporting specific industrial clusters that will result in an ability to innovate and compete in world markets. This includes cross linkage between 'materials oriented' value chains and 'system industries' (e.g. automotive engineering).

- To achieve market alignment, resources and support should be concentrated on 'winning sectors'. This support includes industry-specific support centres, R&D to increase downstream manufacturing, decrease time-to-market in the key beneficiation and materials chains, quality control and environmental standards.

- Steps should be taken to transfer and diffuse best practice methods. This requires policy on quality-control mechanisms that are internationally accepted and adoption of industry sector norms and standards as a best-practice benchmark. These include development of environmental technologies to ensure product/process compatibility with markets and foreign government regulations.

- Promote the shift to a more competitive manufacturing culture by establishing industry-specific 'golden triangles' of industry, universities and government. Information acquisition and dissemination will be an essential component of this co-operation.

- An urgent increase in human-resource competency at all levels of the labour force is needed.
  a. Develop more strongly industry-focused, 'tertiary education institutions' with integrated curricula. Increased supply of engineers, scientists and technologists especially in ICT and design is needed.
  b. The strategy on skill provision must include a review of immigration policy.

c. Improved quality of management.
d. Develop technologies that will allow continuing education at all levels in the work environment

- Information management competency and support infrastructure are needed to participate in e-commerce, knowledge management and automated production.

- The legislative and regulatory framework must be re-designed to decrease the costs of R&D and innovation in the manufacturing and materials sector. This necessitates review of policy on tax rebates, expanded assistance to venture capital, incubators, R&D and R&D institutions, and restructuring of the IPR system.

- Selective innovation, continuous improvement aand value addition must be supported and grown to increase competitive capabilities.

- Effort should be focused on appropriate product and process design to leverage the benefits of cheap energy and abundant raw materials. Such efforts must be balanced by effective waste management and recycling.

Capacity to anticipate 'next generation' developments is essential for informed decision-making.
- Strenuous effort is needed to develop niche information-age products that build from local strengths.

- Specific encouragement should be given to the linkage of natural science research to the field of 'smart' and new materials.

4.10 Mining and Metallurgy

Introduction

The mining industry laid the basis for the industrialisation of South Africa. The organisation of mining labour contributed to the emergence of specific forms of labour legislation later codified into the apartheid system. First diamonds, then gold drew foreign miners to these shores. Colossal fortunes were made. Many workers were crippled or killed through industrial accidents. With further exploration the country became a major supplier of a wide range of minerals including platinum, vanadium, nickel, cobalt, manganese, chromium, iron, titanium, copper, asbestos and coal. Today the South African mining industry, though a declining factor in GDP, is still the largest earner of foreign exchange.

In addition to the threat to mining viability posed by historically low commodity prices and loss of capacity in higher education institutions for mining education, is the serious impact that HIV/AIDS is having on the work force.

Of major foresight studies carried out in the OECD countries and Korea, none identified mining and metallurgy as a sector. This is in keeping with the fact that strategic thinking on mining and metallurgy research has recently undergone a period of significant change. There has been, in the last decade, an almost total demise of centralized research institutions in the major industrialised mining countries. By contrast South Africa maintains centralized mining and metallurgy expertise through two statutory Science Councils, Mintek and CSIR. As a major world minerals player, and for the above reason, a mining and metallurgy foresight sector was created.

Sector Characteristics

- Mining and minerals beneficiation were responsible for 11% of GDP and over 50% of foreign exchange earnings in 1995.
- Global standards, international trade agreements, global regulations, including social and environmental may dictate investments in future.
- Industrialised countries are transferring primary metal and mineral processing capability to mineral supplying countries provided the investment risks are acceptable.
- Mining is increasingly dominated by a few large multinationals
- Coal will continue to be a major energy source and clean burning uses will be actively sought.
- African minerals suppliers will seek ways to achieve beneficiation of primary products.
- Gold is likely to diminish still further in importance as a 'store of national wealth'.

- Environmental concerns will continue to force substitution of metals with recyclable alternatives.

Key Recommendations

A set of key technologies were identified. These underpin ten major themes for development of the sector. The themes themselves are clustered according to feasibility, cost and priority.

High feasibility: cost not a major constraint; R&D knowledge exists; technology base exists

- Significantly improve both the underground mining transportation systems and the national surface transportation network to maximise the cost-effectiveness of the production and export of mineral and metallurgical products.

- Establish the necessary on-line information technology database, comprising exploration data on mineral resources, mining and mineral processing technologies and the production of added value products. Develop information systems, to enable the more effective exploitation of mineral resources and added value products, and for the simulation and control of mining operations, both underground and on the surface. Deploy practical and more widespread application of IT in education and training.

- Improve mineral processing technologies to enable the more cost-effective and wider exploitation of mineral resources taking environmental requirements into account. Non-toxic solubilization, bio-leaching, and other smelting and leaching technologies should be explored.

- There is a need to address the HIV/AIDS issue vigorously as it is impacting negatively on the health and safety of the workforce and on the competitiveness of the mining industry. Evaluate the impact of HIV/AIDS on occupational health diseases and safety issues of the underground workforce.

- Develop technologies to allow for the improved interactive training of mine workers that influence occupational health and safety issues on mines.

Moderate feasibility: Higher cost; more new knowledge required

- Only through the mechanization of underground mining operations will the medium to long term competitiveness of the industry be maintained, with a significant improvement in the health and safety of the workforce. Ensure that automation, robotics and control as well as information technology integrate closely with the

programme of work. Impacts on employment should be managed through policy that operates across sectors.

- There is a need to find longer term internationally acceptably solutions to the surface environment issues that affect the mining and minerals industry; by supporting research into and development of technologies that minimise the impact on both the capital and operating costs and the environment. Work is required on the regulatory framework, especially between government departments, and the development of environmental policies that offer incentives.

- Develop advanced exploration technologies for use underground and in remote areas on the surface, with virtually no drilling. Government in collaboration with industry should jointly support work to evaluate the development of 3D exploration technologies, capable of estimating the economic viability of deposits at depth.

Lower feasibility: Require considerable attention

- There is a need to develop competency in the technologies of automation, robotics and control of plant and equipment, such as mining machines and metallurgical plant, to ensure the long-term competitiveness of the mining and metallurgy sector. Such competency requires investment in these fields at tertiary institutions.

- Develop more cost-effective solutions for the cooling and insulation of deep level mining .

- Support measures that promote added value opportunities to develop competitive advantage by the further processing of local, and in some instances imported, feed materials into intermediate and finished products. Measures include information systems, collaborative programmes of research, and providing the necessary sustainable incentives.

4.11 Toursim

Introduction

Tourism is the world's largest industry, accounting for 11% of the global workforce. It is expected to grow from 672m arrivals in 2000 to 1,046bn arrivals in 2010. Tourism is seen as occupying centre stage in the transition from service economies to 'experience' economies.

In terms of the goals of Agenda 21, tourism is capable of providing a financial incentive for protecting the natural, cultural and social environment.

The sustainable development of the country's unique resource base and cultural heritage is a prerequisite for future tourism development. The transition towards the knowledge economy growing international interdependence calls for sensitive value-added interventions.

Sector Characteristics

- Long haul travel to Africa is expected to grow at 7,5% p.a. in the next two decades.
- Arrivals in Africa will grow from 26m in 2000 to 46m in 2010.
- SADC is expected to capture 45% of inbound African tourism.
- Tourism contributes 8,2% of GDP and directly provides 600 000 jobs. An additional 500 000 jobs are created indirectly.
- Accommodation is highly concentrated with Cape Town, Durban and Gauteng accounting for 40% of room stock.

The 1995 Charter for Sustainable Tourism of the World Tourism Organisation incorporates the following criteria:

- Balancing ecologically sound, economically viable, and socially equitable tourism development.
- Integrating the natural, cultural and human environments in assessing the impacts on cultural heritage and local communities.
- Applying 'ecologically honest' pricing to achieve a more equitable distribution of the benefits of tourism.
- In technical assistance grants targeting priority areas such as environmental and cultural spaces.

Our model for discussing technology in tourism understands that the tourism destination incorporates the mix of attractions and traveller services. This consists of interdependent elements, such as attractions, facilities, infrastructure, transportation and hospitality. In short: attractions draw visitors to an area. Facilities serve the needs

of the visitors while away from home. Infrastructure and transportation provide accessibility to tourist destinations and hospitality is concerned with the way tourist service is delivered. The tourism system is very information sensitive, with marketing a vital element in effectively conveying information to prospective consumers.

After defining the target market, segmentation needs to be addressed. Various communication channels can be used to reach the target market. The Internet is now playing a key role in reaching the market. The application of ICTs across the tourism industry includes the management of the various modes of transportation, travel distribution systems, the hospitality industry, the recreation and entertainment components of tourism. The use of IT in the management of eco-systems, wildlife populations and natural areas, is becoming increasingly important.

Currently the impact of e-commerce in travel is most visible in the growth of Internet reservation systems and automated check-in procedures. Increasingly the look-to-book ratio is crucial for airlines wanting to make the most of e-commerce opportunities by enticing more customers to book via the web. But managing the human service relationships is one of the less obvious challenges facing the airline industry as it seeks to embrace e-commerce technologies such as the Internet, electronic tickets and kiosks. Everything from aircraft maintenance to customer sales and airport operations is facing substantial change as a result of Internet technologies. The Global Network pose both challenges and opportunities in tourism for a variety of services. These include marketing South Africa as a world class tourism destination internationally, direct booking through virtual sites and multifunctional smart cards; e-commerce; airline electronic ticketing; and encryption to make cyber transactions safe.

The SADC region tourism profile is essentially that of developing regions. The countries are well endowed with a range of attractions, primarily based on non-renewable natural and cultural resources and therefore the sustainable management of resources is a key issue. The main origin of tourists is the industrialised countries. Personal safety is a matter that must be carefully managed if tourism disruption is to be minimised. But tourism is a soft target for those prepared to use violence to achieve political objectives. Radical interest groups often choose to damage the tourism industry as a means of gaining publicity.

Good transport infrastructure is critical for the development of tourism in the region. Globally, the airline transport market has continued to expand and this trend is expected to continue. This growth demands improvements in airport and airline capacity as well in the efficiency of the civil aviation industry. A 1997 International Civil Aviation Organisation (ICAO) report on air safety painted a bleak picture of the position in African skies. While South Africa's safety record is good, air traffic control and safety at some regional airports is poor by international standards.

Key Recommendations

High attractiveness and high feasibility, short term

- Investment in multimedia technologies is needed for tourism promotion, management and training.

- To maximise potential targeted investments in tourism infrastructure is needed to leverage private sector investments into less traditional areas that have product strength and can satisfy future market needs. Although the infrastructure base supporting tourism is good, it is highly polarised resulting in limited dispersal of tourists to other areas with potential.

Medium attractiveness with relatively lower feasibility, medium to long term

- The African Renaissance theme incorporating indigenous processes and lifestyle technology opportunities should be pursued as a vehicle for indigenous technology application and community empowerment purposes.

- Local capacity to interact, update and maintain advanced identification and communication systems must be developed and maintained as an expected feature of tourism provision.

- Safety and Security considerations demand that tourism risk management be given top priority.

- Alternative transport systems must be explored. It is recommended that sunken investment in the rail network is capitalised on to explore transport technologies such as fast trains.

4.12 Youth

Introduction

In many countries, educational opportunities still remain elusive to young people. Primary schools are often overcrowded, with overburdened educators and insufficient facilities, and secondary education may be either restrictive or expensive or both.

Industrialised and developing countries have been unable to coordinate youth policy, which usually spans the jurisdiction of a large number of ministries. And where dedicated ministries have been established they often lack the authority and resources to accomplish their objectives.

Youth policy formulation is still a recent phenomenon in the history of most developing countries, and therefore these countries have little experience in implementing their newly formulated policies.

Sector Characteristics

- Young women and men aged between 14 and 35 comprise 39% of the total South African population.
- South Africa has a relatively young and expanding African population, compared with the coloured and Indian population and an aging, shrinking white population.
- Almost half (49%) of African youth live in households that at some point in time are unable to feed their children.
- African youth at 57%, and to a lesser extent coloured youth at 46%, make up the majority of the 52% total of youth unemployment. Asian unemployment stands at 17% and white unemployment at 4%.

Forces, both within and outside their control, affect the health of young people around the world. Accidental death and violence are high among youth. Experimentation with tobacco, alcohol and drugs causes addictions and negative behaviour. Unprotected sexual activity results in unwanted pregnancies and the spread of sexually transmitted diseases especially HIV/AIDS. A lack of information and affordable health care has further adverse repercussions on the health of the youth.

The goals of the National Youth Policy are to -

- Instill in all young women and men an awareness of, respect for and active commitment to the principles and values enshrined in the Constitution and a clear sense of national identity;
- Recognise and promote the participation and contribution of young women and men in the reconstruction and development of South Africa;
- Enable young men and women to initiate actions that promote their own development and that of their communities and the broader society;
- Develop an effective, coordinated and holistic response to the major issues facing young men and women; and
- Develop families and communities that are supportive of young women and men, pressing positive role models while promoting social justice and national pride.

South Africa is not alone in having attempted to apply foresight methodology to the youth sector. For example, the Australian Social Foresight found that the major concerns of young Australians include pollution and environmental destruction, the impact of growing populations, the gap between rich and poor, high unemployment, the effects of automation and immigration, crime and violence, family problems and breakdown, discrimination and prejudice. Young Australians recognise the value of S&T in solving problems that confront society but they do not see this as a universal panacea.

Employment is a major issue of concern to youth and is heading into quite uncharted territory. In this regard international assessment in the field suggests that:

- Technological developments have been neutral in their quantitative effects on employment
- Sectors in which employment has risen with the accelerated introduction of technologies are engineering, office machinery/data processing, data transmission and cellulose and paper manufacturing sectors.

As far as qualitative effects are concerned, the consensus is that low-skilled workers are clearly disadvantaged and that new employment opportunities are increasingly likely in the knowledge-based sector that is made up of a small elite of entrepreneurs, scientists, technicians, computer programmers, professionals, educators and consultants. (The 'layers and pockets scenario again.)

Key Recommendations

In seeking to identify key technologies with which youth will directly interface one must beware of empowering adults at the expense of young persons. One hopes to ensure that youth are placed at the centre of technology discussions in South Africa.

Technology has the potential to be one of the vehicles that young persons could use to attain their aspirations. However, the majority of South African youth have no

access to technology that would meaningfully empower and equip them. The major concerns of young people of this country include employment, good education, skill development, sports and entertainment. Thus, any recommendations on technology must meet this bottom line.

Short-term investment (0-5 years)

- Government should create favourable policies aimed at stimulating the involvement of small business in broadcasting and sourcing local content. Local content should also emphasise youth programming.

- Greater government coordination is needed to ensure that information is presented in such a way that young people can access information on careers and growing economic sectors. Statistics SA should adopt a more effective information dissemination programme, particularly for youth, who need to address their own special issues.

- The human resource base should be developed in schools and colleges of education. This should include the training of teachers on the use of Internet and multimedia technologies. Rural and outlying schools could be linked with tertiary institutions and local municipalities. The goal should be that each school should have at least one computer linked to the Internet.

Medium-term (6-10 years)

- Youth should be given easier access to telemedicine. Government should create the necessary infrastructure in youth centres, schools, and related areas.

- Government policies should support the expansion of mobile facilities, especially in rural areas through various financial incentives. Such expansion should be accompanied by measures to monitor and evaluate the content and quality of mobile facility programmes.

- Government should invest in satellite technologies that will increase the number of radio and TV channels and encourage the development of youth channels. The use of this technology for crime prevention should be encouraged.

- Measures that will promote and systematize early detection and development of sports talent should be put in place. Sports facilities that will advance the participation of women in sport should be developed. Small companies should be more involved in the development of new technologies to improve sports performance.

Long-term (> 10 years) Moderately attractive and feasible.

- Noting that virtual reality has a low feasibility and attractiveness the establishment of a favourable policy framework to encourage the development of virtual-reality technologies is recommended.

Chapter 5: Synthesis

Oft expectation fails, and most oft there
Where most it promises; and oft it hits,
Where hope is coldest, and despair most fits
William Shakespeare: 'All's well that Ends Well

5.1 Foresight and Policy

Through various consultative processes immediately prior to the inception of democracy, and through the normal processes of policy formulation within government, the public has, as never before, been presented with a host of discussion documents, Green Papers, White Papers, Bills and Acts. These have covered all aspects of political, economic and social life. The apex document is the Constitution itself, which lays the basis upon which all else rests. Each of these documents provides a vision of 'a better life for all', which is to be realised through the implementation of the particular policies that are advocated. Some of the policies such as the Growth, Employment and Redistribution strategy are high-level cross-cutting instruments that shape the present and short-term macro-economic environment. Most of the policies indicate how the vision for a particular sector is to be attained. The policies express the intent of government to follow a specific path of action. Budget is then allocated to give effect to that intent.

This intensely rich set of transformational policies has been necessitated by two fundamental agendas, namely the social reconstruction necessary to move toward an open post-apartheid society, and the institutional re-engineering needed to engage with international competition and demands.

The National Research and Technology Foresight differs from the above policy processes and outputs in two fundamental ways. First, it is not a vision assuch, but an informed view of what the future may be. This is no 'master plan', no blueprint. There are many possible roads to the future.

Second, whilst mainly concentrating on technology, the analysis was informed by a strong social and environmental agenda. The NRTF has in effect performed the task of providing a detailed cross-sectoral set of images of the South Africa that might be[1]. In this sense it is 'visionary'. Although the NRTF may differ from customary policy formulation in its approach and scope, it rests and builds upon the various new policies that have been put in place to achieve equity and redress.

5.2 Foresight Outputs

This synthesis report provides a broad overview of what the NRTF has found. The details for each sector are naturally to be found within each specific report. A process evaluation and an impact evaluation will be carried out later. This report, while not constructed as an output evaluation, necessarily includes some comment that is evaluative in nature.

A starting point is to assess the suitability of the sector choices and the effect of this choice upon the NRTF outputs. The twelve sectors that were chosen show various degrees of overlap one with another. In some countries' foresight exercises some of these sectors have been combined; in other cases they have been divided further. So for example, it is not unusual to find agriculture combined with the environment, or to find that microelectronics has been factored out of manufacturing, materials and ICT. Nor do the foresight sectors follow the market segments of the Johannesburg Stock Exchange. So to take three JSE categories, namely transport, retail, and food, none of these are explicit NRTF sectors. However, all threeare dealt with in some measure through the consideration given in agriculture, energy, biodiversity, financial services and ICT.

A test on suitability of choice might thus properly be to determine whether sector selection has led to major omissions from a research and technology viewpoint. But on this issue it is known that comparisons of Delphi surveys across industrialised countries have shown divergence of emphasis at the level of both feasibility and application. Every foresight involves some selection. (For details of the Delphi survey method refer back to page 24).

5.3 Some Strands from the Sectors

A number of overarching concerns emerged across the work of the sectors. These, in no particular order of importance are:

- Internal rich-poor tension and the need for rural development
- External North-South tensions, standards regimes and regulatory barriers
- Opportunities and threats of globalization
- Sustainable development as a fundamental principle
- Raising the base of living standards whilst protecting the environment
- HIV/AIDS and its impact on the social fabric and economy
- Knowledge/information society imperatives
- Human resource development both as constraint and necessity
- Skills loss and reduced capability to absorb new technology
- Public safety and morals and their impact on the social fabric and economy

- South Africa's position in SADC and the African Renaissance
- Lack of investment by multinationals in R&D in South Africa.

In a many cases the survey analysis clearly demonstrates that the dominant concerns relate to the issue of human resources, human resource development and management. Human resource development at all levels and in its broadest interpretation is a major issue raised by Delphi respondents.

A second common issue is the obvious problem of the availability of funding for the various actions that the respondents had in mind coupled with the awareness that in some cases social and cultural constraints would retard and even resist implementation. In part this accounts for the frequent advice that joint ventures are the preferred route to technology development. Is this a case of risk aversion or risk management?

A third is the general perception that local technology development is ahead of most developing countries but behind the industrialised countries.

A fourth matter requires noting, and that is the role of the State. The advice offered by the sectors is strongly coloured by views on whether government should adopt a hands-off or an interventionist stance. No consistent position on this emerged across the sectors, though the balance does lie more toward directed or focused intervention than laissez faire.

Last is the underlying concern that new technologies, especially the ICTs, may widen disparities and lead to further exclusion of the most vulnerable groups in society.

These concerns have shaped decisions regarding what is important in the short-term.

Important sub-themes relate to the specifics of technology development and acquisition, and coalesce around decisions to adopt, manage and adapt technologies and the extent to which one should and can develop, protect and exploit niche technologies.

5.4 Short-term vs. Long-term

The analysis of the Delphi surveys was structured around the concept 'importance to South Africa' that was in turn based upon the two separate categories of 'wealth creation' and 'promotion of quality of life'. Scanning across the twelve sectors one finds, almost without exception, that the five Delphi statements with highest rank relate to short-term implementation of issues that have a low novel technology dimension. The statements generally share attributes that speak to the importance of

access, redress, and sustainability. In some individual sectors this tendency encompasses most of the top twenty statements. One may interpret this as arising from a concern with today's challenges informed by a strong social agenda. This immediately distinguishes the NRTF from other technology foresight studies.

On the other hand, the tertiary education sector was given specific attention by many of the sector working groups who concurred in arguing that measures to increase the production of scientists, engineers and technologists competent in the emergent technologies must be put in place. The message is - we position ourselves with the capacity to engage with the new technologies. Coupled with this is the strong message from the Delphi surveys that we are not internationally competitive. Yet international markets will be crucial in the sector's contribution to wealth creation and quality of life. There is also awareness, both implicit and explicit, that international competitiveness rests on the ability to specialise. And to specialise requires technology management, development and acquisition of leading edge technologies. This set of perspectives speaks to the long haul.

Yet the 'futuristic' technologies are generally relegated to the bottom ten Delphi statements. These refer to the use of biological structures in agriculture and production, genetic engineering, nano-technology, automation, robotics, photonics, cutting edge materials research and so on. These are the emergent or soon to be emergent technologies that will drive production and efficiencies in the next twenty years. Likewise, the power of simulation technologies, which are acknowledged worldwide as a cost-effective component of new product and process development, was given limited prominence in the manufacturing study. The local Delphi indicates this; the international ones do too. These are the technologies likely to drive the NICs and Pacific-Rim economies further.

So there appears to be a fundamental contradiction at work. What must be done now is known? That survival depends upon embracing new technology is known. But the respondents have not declared that engaging with fundamental technology development is the priority. The most significant exception to this position is found in the Defence Sector survey, despite the limitations that secrecy imposed on that survey.

South Africa has a well-developed ability to acquire and adapt technologies, and then to apply these on a large scale through highly effective integration and project management skills. The human resources that underpin this capability are homegrown both by local and expatriate academics, or bought-in from outside as the need arises. Previously the 'total onslaught' mindset drove massive, expensive, polluting but effective projects that yielded nuclear weapons, self sufficiency in materiel, light, medium and heavy weapons, command and control systems, militaryvehicles, missiles, pilotless aircraft, lifetime extension programmes, decision support tools, liquid fuels, and chemical feedstocks.

Under 'total onslaught', shortage of finance was no object. What was needed was bought, overtly or covertly. The technologies were adopted, adapted and extended. What Prof. Linsu Kim[1] of Korea calls 'a constructed crisis' powered local industry to move from duplicative imitation, into creative imitation and then to competitive technology innovation. Witness the ability of the armaments industry to export systems to leading multinational aerospace companies.

A new 'constructed crisis' is now forcing the defence-related industries to focus its world-class technological capability in certain niche areas. This pressure arises from the paring down of the defence-related industries, efforts at possible defence conversion, and the new rigours of parliamentary scrutiny.

Back to the contradiction. More recently local market leaders have been seen becoming global players through the acquisition of foreign companies whose technology they understand and desire. Successful management of the merged companies depends upon technology and project management, and skills in diversity management. South African companies have wide experience of the former and growing experience of the latter. This route to a global footprint does not require the basic R&D needed for high technology innovation. But South Africa clearly possesses the management skills needed to drive these companies and introduce the new services that clients want. Their long-term survival is another question.

Viewing these developments alongside the frequent advice from the sectors that joint ventures are the preferred route to accessing new technologies persuades one that the contradiction is weaker than it appears at first sight. Rather it is more the case of apragmatic assessment. Provided one has the skills to effect the technology transfer it matters less where the technology originated. The science base provides the milieu in which skills are grown, not necessarily where the technological innovations reach marketable form.

Other explanations for the contradiction have been offered in the sector findings:

- While technology is a constraint, the depth and enormity of the human resource constraint are considerable.
- The sample range of respondents who completed the questionnaires may have been skewed towards non-technical respondents, or respondents who had technical knowledge in relation to only one field of technical expertise.
- The technology-related statements were phrased in terms of access and development of technology, but may have failed to take into account the cost of acquiring or applying technology.

It could be argued that the Foresight exercise with its two boundary conditions - promoting quality of life and wealth creation - has served to impose a constructed

crisis on the organisations that have considered the possibilities for future research and technology. A future in which these two conditions are not met would be undesirable. This constructed crisis has more than one facet and is not a simple dichotomy between wealth and clean air, for example. We know that consumption of fossil fuels entails an environmental penalty. Yet open flame heating is the cheapest and easiest energy source for poorer communities to manage. At the same time it is highly polluting and affects the health of the immediate users of the energy, and this cost is shared across society. Does such a situation count as market failure? If so, then there may be a justifiable call on public funds to subsidise more efficient and less polluting energy technologies, ideally based on renewable sources. Theexpectation would be that a rising income floor would enable consumers to move toward yet a higher standard of living that included more efficient and less polluting energy sources.

The strong connection to societal issues that has emerged in the findings may be surprising to some. Then again, it was designed in, and its presence holds hope for attaining the boundary conditions, constructed crisis or not.

5.5 A Framework

As a starting point in lacing together the NRTF outputs, we have identified four drivers that shape the evolution of the individual sectors. The four drivers are basic R&D, technology exploitation, human resources and management, and policy/regulatory/cultural factors. Analysing the dominance of these drivers for a sector allows one to position the sector with respect to the four drivers on a diamond plot[1].asin figure 3. Such modelling should not be taken too literally since it attempts to organise highly complex systems. We further classify the sectors according to their function as predominantly service, extractive or manipulative sectors.

From the foregoing discussions it is clear that ICT is as much a sector as a driver and that it could as well have been placed as an additional vertex. For simplicity it has been placed near the centre of the diagram.

Another problematic sector is the Youth sector. The youth are a presence in almost all sectors or affected by those sectors. While the Youth sector report is strong on ICT development, it is more the case that software development has been spurred by demands of the arcade games market, which is based on youth culture. South Africa finds itself a consumer rather than a shaper of this technology. While human resources issues shape the track of the Youth sector, we feel it has a location nearer to the policy and regulatory vertex.

Tourism on the other hand is a service sector strongly based on management of people and resources that is dependent upon various technologies. We place it midway between these two vertices.

Defence has been separated off from the crime sector as it is so technology intensive. Its survival is highly dependent on technology exploitation and to some extent on basic R&D. The sector has been shedding human resources so we locate it somewhat distant from that vertex.

Environment is highly influenced by policy, whereas the biodiversity sector has a strong element of basic R&D, indeed pure scientific inquiry. Health has a strong research base and therefore lies slightly nearer to that vertex than to technology exploitation.

The extractive group - mining, agriculture and energy is shaped by policy considerations and is equally dependent on basic R&D and technology exploitation.

The foresight study has pegged the size and scope of each sector as it is now, and given a sense of where it might be heading in the short term. Each SWG has tendered a set of high level recommendations for stakeholder action and a list of key technologies that may impact on the sector. The sector reports are heterogeneous one from another, with some quite natural overlap. How does one make sense of the sectors as a totality?

Given the adoption of the conceptual model of the NSI, and the intention that the NRTF should inform the workings of this system, we feel it makes sense to examine the foresight findings in the same terms.

Generically it is convenient to divide the NSI into three main (and interacting) strata:

- Infrastructural: including physical, social, energy and communications, and human resource development
- Institutional: SET institutions, industry, government and civil society and organised labour
- Superstructural: policy, promotional and regulatory structures.

The synthesis will be organised into generic recommendations around these three broad strata. To effect this the key recommendations of the sectors were compared and common strands identified. Particular sector-specific recommendations that carry implications for the broader economy or society as a whole were also identified.

5.6 Generic Recommendations for Infrastructure

- Further enhancement and deployment of the telecommunications backbone and value-added services.

- Human resource development at all levels and across all sectors using ICT-supported training methods as appropriate. Deployment through multi-purpose community centres is a key pillar of this strategy. Measures to ensure full participation by women and youth are essential.

- The highest priority should be given to school-based health promotion, and awareness programmes geared toward behaviour change in relation to HIV/AIDS, substance abuse, violence, and health and safety. HIV/AIDS is one of the biggest threats to the human resource base.

- New emphases on computer literacy, environment education, and economics education in school, community college and educator curricula. "Each school, a wired school" could become a working slogan. Improved external efficiencies for schooling are essential.

- Realignment of tertiary education to produce more SET graduates, especially in state-of-art systems engineering, intelligent production and process engineering fields. While market forces have already given rise to some such shift, intervention by government is also required.

- High level skills needs should be assured through a mix of incentives: targeted bursaries for study from undergraduate to post doctoral level, provision of resources for R&D, and acquisition of expatriate skills through careful management of immigration policy. Technology transfer occurs through both embodied and disembodied means.

- National capacity in information systems development and management, project management, technology transfer and management, and indeed, innovation management should be further enhanced.

- Accelerated information systems roll out across government to promote management efficiencies and access to information is required.

- Establishment of a network of biological resource centres that collate and store bio-materials.

5.7 Generic Recommendations for the Institutional Stratum

- The African Renaissance theme should be pursued as a vehicle for societal renewal, indigenous technology development and applications, and community empowerment purposes.

- The valuation of and collaboration with indigenous knowledge systems is an essential component of health system delivery, environmental management, and agricultural extension and tourism management.

- Urgent steps toward environmental sustainability with associated pollution remediation measures and intensive R&D toward high efficiency use of low polluting fuels and the exploitation of renewable energy must be promoted. Matters to address include equitable use of resources; careful monitoring of natural cycles; and limiting the concentration of human-derived products in the ecosphere.

- Strategic programmes for the reduction of pollution in power generation, fuel production the mining industry, agriculture and manufacturing need to be developed.

- Effort should be made to establish research triangles involving higher education, industry and government organs in each of the three major regional systems of innovation. Possible focal areas could be intelligent identification systems, biotechnology, low cost and renewable energy, and telemedicine. Once the triangles are established, other industry support such as technology demonstrators and incubators may be provided. Centres of excellence in Flexible Engineering; Renewable Energy; Deep mining could be considered.

- The 'Merrill Land Grant' paradigm of researcher, client, and extension worker to promote technology transfer in agriculture and more generally to SMMEs should be actively adopted.

- Dedicated research funding to promote further development of skills in decision support, command and control, and spatial information systems. Application of modelling, statistical, and monitoring technology to various fields such as environment, crime (detection, prevention, prosecution), to be promoted.

- Support is needed for R&D programmes for intelligent identification and monitoring of locations, organisms and objects, including the identification of information corruption.

- Defence sector capacity to spin out and spin in technologies must be maintained. De-mining technology, military vehicles and other peacekeeping support technologies are growth areas.

- Grasp the opportunities that the Internet presents, and develop the necessary expertise to stay abreast of the evolving and associated technologies. These include telecommunications, database development and management, security, content digitisation, human-computer interfaces, access and displays.

- Develop and extend capacity in the various genetic technologies in the agricultural, energy and medical domains. Bio-production, bio-processing and bio-degradables require particular attention.

- 'Technology for tourism', along with tourism management is a focal area requiring specific institutional capacity, especially information systems.

- The feasibility of introducing affordable, fast and safe mass transit rail systems as an alternative to road transport, and in support of tourism, as well as more efficient transport systems generally should be studied.

- All SETIs should be actively involved in PUSET as a major thrust.

5.8 Generic Recommendations on the Superstructure

- "Create wealth, and manage health" should become a national slogan. 'Health' includes human and environmental well being.

- Provide industry with support to attain world class standards along the value chain through conformance with international quality standards.

- Constant efficiency auditing of measures supporting pre-competitive R&D, provision of venture capital in areas of designated specialisation, and the working of public-private partnerships.

- Removal of impediments to business start-ups, further financial deregulation, promotion of businesses through support centres, and provision of information services.

- Removal of disincentives that promote inefficiencies, such as hidden subsidies leading to sectoral imbalances, or the loss of comparative advantage through incorrect pricing of local raw materials.

- Monitor the impact of new technologies on employment and introduce mitigating solutions as needed.

- Regional co-operation with SADC Member States on cross-border issues (pollution, disease, animal and insect migration) and measures to increase regional markets. A Disease Control Institute should be established as a SADC resource.

5.9 Some Research and Technology Priority Areas

The individual sector reports include the various technologies that were identified as having importance to them over the short, medium and long term. These technologies were found through a lengthy process of analysis involving the international and local scans, Delphi surveys, and feasibility-attractiveness plots. Those technologies identified as most significant were then sifted for commonalty. In this way ten research and technology priority areas emerged.

The time frame within which the individual technologies may be realized (or in the case of adoption of technologies must be addressed) is shown as 🕓 short-term, ⌀ for the medium-term, ⇩ for between ten and twenty years		
Health		
1	Development of vaccines for HIV/AIDS; malaria	⌀
2	Development of prophylactics for TB; hypertension	⌀
3	artificial limbs	⌀
4	Personal diagnosis, management and medication	⌀
5	Microdosing, dosage control	⌀
6	Vaccine cultivation; bio-'pharming'	⌀
7	Telemedicine and micro-imaging	⇩
8	Gene therapy	⇩
Clean Renewable Energy		
9	Methods for reduced energy loss: industry, built environment	🕓
10	Domestic low cost, low polluting fossil fuel and passive solar devices	🕓
11	Use of combustible wastes for clean power e.g. coal discards	🕓
12	Full-scale renewable energies from wind, tidal, geothermal and solar sources	⌀
13	Clean burning internal combustion engines and clean coal technology	⌀
14	Hydrogen fuels	⌀
15	Bio-mass energy sources	⌀
16	Biotechnology energy sources	⌀
17	Alternative nuclear reactor designs	⌀
18	Efficiency gains in power generation and transmission	⇩
Advanced Information Systems		
19	Next generation Internet	🕓
20	Information systems and decision support tools	🕓
21	Security, encryption, compression and storage	🕓
22	Sensing, monitoring, control and simulation	🕓
23	Mobile information and communication systems	🕓
24	'Mass customisation' of applications based on high level languages	🕓
25	Image capture, recognition and enhancement	⌀
26	Virtual reality systems	⌀
27	Identification of locations, organisms and objects (smart cards, bio-metrics)	⌀
28	Artificial intelligence, modelling complexity, neural networks and fuzzy logic	⌀
Sustainable Natural Resources		
29	Bio-mapping	🕓
30	Propagation of organisms	🕓
31	Restoration of environments	🕓
32	Pollution remediation	⌀
33	Waste reduction, removal and stabilisation	⌀
34	Water use efficiency organisms and technologies	⌀
35	Desalination	⌀
36	Artificial photosynthesis to restore air quality	⇩
Genetic Manipulation		
37	Genetic tagging	⌀

The time frame within which the individual technologies may be realized (or in the case of adoption of technologies must be addressed) is shown as ◷ short-term, ⌀ for the medium-term, ⇩ for between ten and twenty years		
New Materials		
40	Polymer development, especially based on coal resources	◷
41	Ceramics	⌀
42	Alloys	⌀
43	Sensors	⌀
44	Prosthetic substances	⌀
45	Bio-degradable packaging	⌀
46	'Smart' and customised materials	⇩
47	Bio-materials especially natural fibres and structural composites	⇩
48	Photonic, biological and molecular switching	⇩
Bio-informatics		
49	DNA analysis and DNA banks	⌀
50	Bio-leaching	⌀
51	Bio-production	⇩
Processes and Control		
52	High efficiency industrial processes, recycling energy	◷
53	Near shape processing	◷
54	Integration and design	◷
55	Automation under remote and extreme conditions	⌀
56	Remote bulk handling	⌀
57	Zero emission extraction, purification and production chains	⌀
58	Miniaturisation and incorporation of 'smartness' into products	⇩
59	Nano-technology	⇩
Flexible Production		
60	Flexible engineering	◷
61	Robotics	◷
62	Human – machine interfaces (bio-metrics, voice recognition and translation)	◷
63	Metallurgy short runs, including Pt group metals	⌀
Social and Economic Issues		
64	Behaviour change: fertility management; sex; substance abuse; violence toward women and the young.	◷
65	The dynamics of the social fabric, including changing patterns of work	◷
66	Ethical dilemmas posed by new technologies	◷
67	Impact of development on biodiversity	⌀
68	Rural development, urbanisation and urban renewal – pushes and pulls	⌀

Chapter 6:
Concluding Remarks

…after climbing a great hill, one only finds that there are many more hills to climb.
Nelson Mandela: Long Walk to Freedom

6.1 What Technology Emphasis?

The above quote reminds us of the S curves so beloved by scholars of technology innovation. Particular industries are depicted as evolving along a path determined by the evolution of the main technology on which the industry depends. This follows an S curve: gentle start, a more rapid mid-life period, followed by a slowing down as the technology matures. New technologies each follow their own S curve.

It is the genius of management to be able to jump from one technology to another in order to stay ahead of the competition, or to perceive where the discontinuities are coming from, especially when these become threatening. This is the significance of the broken arrow.

In like manner economic historians look for a means of characterising longer term epochs. Globally, subsistence farming aside, there is a steady downward trend in the proportion of the labour force involved in agriculture. Over the last two centuries this figure for the United States has dropped from 70% to around 2%; in parallel with this has been the rise and fall of the manufacturing and production sector as the dominant employer. Somewhere in the 1950s employment in the service sector became equal to that in manufacturing and production.

Today knowledge workers are becoming the dominant group in that society. The expectation is that the information society will in turn go through its own life cycle. The industrial society has moved toward the 'information society', and this is steadily eliding into the 'biological society'. No one can predict the length or character of the unfolding life cycles. Equally, while one may describe the various economic phases of the United States, it does not follow that all societies will follow the same sequence over the same time period.

One of the fruits of foresight work has been the realisation that considerable scope for technological innovation resides in the zone where technologies overlap. The most frequently cited example of this is the huge strides made by Japanese industry in the development of mechatronics, where machine tools and microelectronics were united

with such impact. Earlier in this report we noted the predictions of Jules Verne regarding le fax machine. Breakthroughs lurk where seemingly unrelated technologies are brought together.

Accordingly a test that may be applied to our list of key technologies is to ask whether they address the potential in the areas of overlap: matter and information; biology and information; matter and biology. The answer is yes - attention is being given. On the likelihood of major technological innovation occurring locally, the jury is out and will so remain for the next ten to twenty years.

6.2 Back to the Future

It is reasonable to ask whether one or other of the four macro-scenarios (see p.14) has emerged as the dominant shaper of the NRTF outputs. All four macro-scenarios take the forces of globalization and technological change into account, and all four to some extent overlap one with another.

By framing the importance of the technology trajectory in terms of wealth creation and quality of life the opportunity to be outward looking and at the same time concerned with events more locally, is embraced. If wealth creation includes being internationally competitive, then a careful watch on globalization and new technologies becomes important.

Our Way is the Way has a close fit with the circumstances that prevailed during the sanctions era. It also describes an environment where the role of state and capital becomes blurred. This scenario does not emerge in a strong way in the recommendations. Frozen Revolution, where things fall apart, may lurk in the background, but also does not come through in the recommendations. Instead what appears is a cautious mix of advice that assumes a dominance of Global Home, within which the basis for becoming the Innovation Hub is laid.

The macro-scenarios were developed in mid-1997 and are still quite tenable. They continue to provide useful touchstones.

We have been careful to provide synthesis rather than summative evaluation. Nonetheless a verification of whether the broad objectives (see p.6) set for the NRTF were attained must be effected. Herein lies anobvious conundrum. With the benefit of hindsight, it is clear that attainment of some of these objectives lies with the various institutions that comprise the NSI: research co-ordination, intelligence gathering, investment in R&D; research focus. However, the evidence of whether these have been achieved will only become available in the long-term. At that point it may or may not be possible to deduce whether the outcomes arise from the NRTF, some other

definable cause, or 'merely happened'. Assessing the longer-term objectives must necessarily wait.

On the matter of the very immediate objectives the NRTF has met its mandate. Key recommendations have emerged as consensus positions among the stakeholders, and key research and technology areas or processes have been identified. Capacity in foresight methodologies has been built and new networks of R&D practitioners have developed.

The White Paper on Arts, Culture and Heritage[2] advised that "... the failure of many technology transfer initiatives arises precisely because insufficient care has been taken to understand the cultural dimensions of what seemed merely to be technical".

As pointed out in the analysis, the social aspects of technology development and transfer have been given strong emphasis in the sector work. The NRTF has performed well in maintaining a connection with the social and cultural.

It is now over to the organs of State, industry and community to draw out the findings most relevant to their work and use these to shape their own strategies for the future.

Chapter 7:
Next Steps

The National Research and Technology Foresight study set out to capture the imagination of the South African public through an inclusive process designed to scope out possible futures in which research and technology would play a pivotal role. In the same way, the promotion of the foresight findings must be exciting and inclusive.

It is perhaps obvious, but still necessary to state that not only is the NRTF a first; but so is the process of taking it forward. Further, in the same way that international comparability across foresight studies provides guidance but no recipe for the execution of a local foresight, the same is likely to hold insofar as the take-up of foresight findings is concerned. We may learn from one another, but the political, cultural, economic and social contexts are different and decisive. Nonetheless, a study of post-foresight activity in other countries makes it clear that communication, network building and maintenance of enthusiasm are extremely important dimensions of foresight promotion.

A country with very strong state-capital linkage may find it easier to direct considerable public resources to very specific areas of technology; a country with a more laissez faire approach may concentrate more upon the softer issues associated with investment decisions, technology development and take-up. The trend in South Africa is away from state ownership of key industries and a much-reduced involvement in the military-industrial complex.

To some, 'implementation' conjures up the misconception that foresight tabulates a precise set of specific technologies to invest in. Would that it wereso easy. To counter this expectation we instead choose to refer to concepts such as take-up, promotion, and transfer.

The underlying intention in carrying out the Foresight is that some or all of the following will come about:

- Decision-makers in government, industry, science councils and higher education will take up the Foresight outputs.
- Research institutions will adapt their research portfolios toward promising areas of relevant R & D.
- Alignment between government and industry R & D funding strategies will be promoted.
- DACST will use the NRTF as an important touchstone in determining its R & D investments.

- Processes will be put in place to effect knowledge transfer and raise and maintain awareness of technological change and its societal impact.
- Encouragement will be given to institutions and industry sectors to carry out their own foresight exercises.
- The provision of incentives to encourage the use of the Foresight outputs through re-focusing existing funding mechanisms (e.g. Innovation Fund) or the establishment of a dedicated Foresight Fund.

To achieve the above a dedicated organisation will be necessary. This would have the express responsibility of promoting the take-up, promotion, and transfer of the NRTF outputs and managing a second NRTF in the future. Such an organisation would of necessity display high capability for knowledge management.

The immediate tasks of such an organisation would be to effect an action programme that:

- Launches the NRTF outputs and the ongoing programme, at national level and provincial level.
- Promotes the concept of foresight and associated benefits to decision-makers and sector role players.
- Establishes and maintains a foresight web site.
- Promotes and maintains networks and forums to stimulate and develop new and crosscutting technologies, products and markets.
- Continues to upgrade the data available from the Foresight project and prepare for another national Foresight project in the future.

The real benefit of the Foresight will be the extent to which future R&D investment, guided by the Foresight, results in relevant technological achievements enabling an improved economic and quality of life for South Africa and all its people.

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Annexe

Sector working groups terms of Reference

The original terms of reference for each sector working group were:

The sector working groups will investigate future socio-economic challenges facing the sector and identify the impact these will have on the sector. The sector will be analysed within the South African context while recognising its contribution to the global and regional economy. The sector working groups will then be expected to identify market opportunities as well as research and technology requirements that will assist the sector in enhancing its performance and also address social issues. The responsibilities of the sector working groups will be to:

1. Agree on proposed sector foci
2. Analyse the current status of sector
3. Identify research and technology challenges and market opportunities over the next 10-20 years
4. Make recommendations on the identified cross cutting issues/areas
5. Compile a prioritised list of research and technology topics for each sector
6. Make recommendations on implementation strategies
7. Compile the Foresight sector report
8. Help identify research and technology themes towards the designing of appropriate research programmes