FORESIGHT MINING AND METALLURGY REPORT

Foreword

As chairperson of the Mining and Metallurgy Sector of the Foresight project, it is rewarding to see, contained in this report, the outcome of this important process. The Department of Arts, Culture, Science and Technology (DACST) is to be congratulated on its initiative in getting this far-reaching activity off the ground. Ours is one of twelve sectors that most significantly impact on our county's future development. However, the direct and indirect contribution that our industry makes to the country's prosperity is often not as well recognised as it should be.

South Africa's future growth and prosperity have been and will continue to be closely linked to the mining and metallurgical industry. Almost fifty per cent of our income from foreign exchange arises from this industry and there is scope to more than double the revenue in the next 20 years. If we are to continue to benefit and develop further from the treasure chest of minerals South Africa has been blessed with, we must ensure that we continue to improve our global competitiveness.

Research and Technology play a very important part in this industry. However, we have limited financial resources to invest in Research and Technology and it is essential that we identify and prioritise those areas in which we can most benefit from research. The foresight survey carried out in this sector resulted in a response that emphasised both wealth creation and quality of life for all our people as the major issues. Quality of life has a special significance in the South African mining sector and is directly related to both health and safety, but it is also very much influenced by wealth and job creation.

This foresight exercise is an ongoing process and the outcome of this report should be seen as a first important step in the process. Government, industry and research institutions are encouraged to continue with and to refine this process. However, there is much that can already be done to implement the findings based on this first report. I would like to thank DACST for initiating this project, and in particular Phil Mjwara for his advice as well as the members of our Sector Working Group for their dedication, expertise and invaluable support.

I would like to acknowledge the late John Stanko for his contribution to the early stages of the Foresight project and especially Brian Protheroe on whose shoulders the considerable responsibility as Sector Coordinator rested. This report is largely a testament to his tireless efforts. Time will tell how well we managed to capture the essence and the spirit of Foresight in this report. However, the commitment to implement the findings will be the ultimate recognition of its value.

Dr N A Barcza
Chairperson: Mining and Metallurgy Sector Working Group

Contents

List of Acronyms and Abbreviations

DACST .... Department of Arts, Culture, Science and Technology
DC .... Direct Current
DME .... Department of Minerals and Energy
DTI .... Department of Trade and Industry
GDP .... Gross Domestic Product
HSRC .... Human Sciences Research Council
IDRC .... International Development Research Centre (Canada)
IDZs .... Industrial Development Zones
IT .... Information Technology
NGOs .... Non-governmental Organisations
NRF .... National Research Foundation
NRTF .... National Research and Technology Foresight
NSCNational Steering Committee (of Service Providers to the Small-scale Mining Sector
R&D .... Research and Development
S&T .... Science and Technology
SADC .... Southern African Development Community
SAIMM .... South African Institute of Mining and Metallurgy
SIMRAC .... Safety in Mines Research Advisory Committee
SMMEs .... Small, Medium and Micro-enterprises
SWG .... Sector Working Group
THRIP Technology and Human Resources for Industry Programme

Executive Summary

The National Research and Technology Foresight (NRTF) Project is one of a number of initiatives launched by the Department of Arts, Culture, Science and Technology (DACST) as part of its mandate to review and reform the science and technology system in South Africa. The NRTF Project looks at various sectors of the South African economy, and mining and metallurgy was one of the 12 sectors chosen.

The Mining and Metallurgy Sector Working Group, the operational arm of the project, was made up of about 30 knowledgeable people from government, the mining industry, labour, science councils, and tertiary education institutions. The aim of the Working Group was to identify research and technology topics and strategies for the mining and metallurgy sector in South Africa that could realise substantial economic and social benefits for the country over the next 10 to 20 years. DACST committed itself to using the results of the Foresight exercise as an important input into its investment in research and development.

The work of the Sector was carried out by way of a number of workshops in which the Sector Working Group members participated. The structure of the workshops was such that the members were taken through a process, which led to the development of outputs in fulfilment of the terms of reference of the Sector Working Group. The process began with the preparation of two reports for the Working Group. They were the International Scan prepared by consultants, and a Local Study prepared, in part, by the Sector Coordinator. Using this information as a starting point, together with the concept of macroscenario thinking, the Sector Working Group developed an analysis of the sector from both a current and future perspective.

Part of the Foresight process involved testing the outputs by means of a survey questionnaire distributed to the wider audience in the mining and metallurgy sector in South Africa. The Foresight survey carried out on this sector resulted in a statistically significant response that emphasised both wealth creation and quality of life as the major issues for all our people. Quality of life has a special significance in the mining sector and is directly related to both health and safety. The serious impact of HIV/AIDS over the next 10 to 20 years on our human resources, productivity and the economy, was noted as the priority issue by the respondents to the survey.

Wealth creation and additional topics related to quality of life that were also highly rated covered the development and implementation of technologies to improve the cost-effectiveness, safety of mining, and competitiveness of metallurgical operations. Ten technology themes were used to group the most highly rated issues. The most feasible and attractive themes are considered to be implementable in the short to medium terms. Mineral processing, health and safety, information technology and transportation fell into the former category while automation and robotics and downstream added value fell into the latter category.

It was felt that in most cases the above technologies could be achieved within six to 15 years, and there was a preference for the technology to be developed in South Africa or to promote joint ventures if international input was required. Also, this view was common to all the technologies under consideration. Similarly, there was an overall view that financial, technological and infrastructural factors represented the major constraints on the implementation of the projects.

The other technologies are only implementable in the longer term.

The sector study also emphasised the opportunities arising from the underpinning strengths in the mining and metallurgy industry, in particular, the development of downstream products, processes, and new business that impact on job and wealth creation. Much of this provided input into the work of the Beneficiation Cross-cutting Working Group and their report.

In the White Paper on Science and Technology, DACST committed itself to using the results of the Foresight exercise as an important input into its investments in research and development within the science budget, particularly with regard to the Innovation Fund. To date, the Innovation Fund has directed support in four focal areas, namely crime prevention, the information society, biotechnology and value addition, none of which has provided an effective "window of opportunity" for mining-related projects. Therefore, such a "window" needs to be created if the outputs of the Foresight study are to be implemented.

Chapter 1: Introduction and Process

1.1 Introduction to the Foresight Process

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 a range of potential futures and seeks to add new dimensions to our thinking by providing:

- a way of thinking about the longer term future and how it could differ from the present;
- a means of testing our current views and policies; and
- a way of overcoming the difficulties of static or retrogressive analyses.

Foresight provides a valuable mechanism for serious consideration of significant technical trends and their relationship to socio-economic needs. Foresight is inherently proactive and reflects the belief that the future is influenced by today's decisions and actions. By building complex pictures of alternative futures we are better able to assess how well current research and technology systems might address our future needs.

Although foresight may use several forecasting techniques (e.g. Delphi analyses, trend analyses, scanning and scoping), the outputs 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 dialogue, involving all relevant stakeholders, which 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 will be felt.

Transparency is essential for foresight processes. In several countries, the establishment in both the public and private sectors of a foresight culture has been a precondition for the comprehensive long-term visions of future possibilities and needs that are so important in providing appropriate contexts for the effective integration of foresight with decision-making. Creating such a culture is complex, and requires an appropriate balance between two of the intrinsic tensions in foresight: science-push versus demand-pull, and top-down versus bottom-up. The following four common errors must be avoided for this culture to flourish:

- No prior consensus on the need for foresight.

- Initial suspicion/cynicism of researchers, professionals and other stakeholders not adequately addressed.
- Bias towards established disciplines of panels dominated by elite specialists and scientists.
- No institutional machinery in place to translate foresight findings into specific policy initiatives and resourced action, preferably involving both the public and private sectors.

Consultation process: Since Science and Technology (S&T) cuts across many sectors including industry, non-profit sectors and society at large, it is very important to involve all the possible participants. The research and technology foresight process is as important as the product. For a foresight product to be acceptable it is imperative to maintain continuous interaction with research users and the scientific community during the process. This type of consultation increases the level of 'buy-in' and commitment from all involved.

Industry involvement: International experience shows that industry involvement and commitment are essential to the success of the foresight exercise. The role that industry plays in economic development puts more emphasis on its involvement, especially with regard to successful implementation of the foresight outputs. It is also important to note that although the aim of the project is to facilitate the country's global competitiveness, it is companies that compete, not government. Government's role is to create an environment that will help industry to compete successfully in the global arena. Technological progress and human resource development lay a base for continued economic growth and job creation (Taeyoung Shin, Ministry of Science and Technology, Korea 1997 APEC Symposium on Technology Foresight, Thailand), areas in which industry should play a crucial role.

Implementation: Depending on the goals of the exercise, some countries have formal implementation programmes for foresight outputs while others do not. The Japanese foresight, for example, has no formal implementation phase, but provides background information for decisions taken by others on their priorities. The government research and development prioritisation process is informed by many other sources, including foresight outputs. The UK foresight outputs were intended to inform the priorities of publicly funded institutions. A foresight fund from which identified projects were supported, was established. The private sector was also encouraged to take up foresight outputs.

1.2 South Africa's Foresight Process

The National Research and Technology Foresight (NRTF) Project is one of a number of initiatives launched by the Department of Arts, Culture, Science and Technology (DACST) as part of its mandate to review and reform the S&T system in South Africa.

Interest in foresighting started in 1993 when the International Development Research Centre (IDRC) of Canada, at the request of the Mass Democratic Movement, conducted a Mission on S&T Policy for a Democratic South Africa. The mission report outlined the steps that needed to be taken into account when transforming S&T, and also assessed the status of the system. The report emphasised that a foresight exercise should be conducted.

Shortly after the establishment of the Department of Arts, Culture, Science and Technology in 1994, the then Minister announced the Department's intention to carry out a foresight exercise. The project was formally inaugurated in July 1996. **In the White Paper on Science and Technology, DACST committed itself to using the results of the foresight exercise as an important input into its investments in research and development within the science budget.** The Foresight results would also inform the management of the proposed **Innovation Fund** and research capacity-building programmes in the higher education sector.

1.3 South Africa's approach to foresighting

Although foresight exercises have been conducted in various countries, the objectives, the foci and the approaches tend to vary according to circumstances. A case in point is the nature and extent of participation in the foresight process by the broader community. In Japan, for example, such processes tend to involve only science, technology and industry experts, while in countries like the Netherlands, the broader community is usually involved. Methodological approaches tend to differ as well. The Japanese usually focus only on conducting Delphi surveys of future technological trends, whereas the UK foresight employed various methodologies including Delphi surveys and scenario analysis. The United States concentrates instead on drafting lists of critical technologies.

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

- **Consultation**: Perhaps one of the distinguishing features of South Africa's Foresight is the extent of wider community involvement in the process. The foresight programme has been deliberately designed to involve stakeholders such as industry, government, labour and civil society. This inclusive participatory approach is an attempt to give ownership of the process to all sectors of our population.

- **Methodology**: The methodological approach adopted in our Foresight employs a combination of techniques. These include strengths, weaknesses, opportunities and threats (SWOT) analysis, scenario analysis and surveys of opinions on research and technology trends. Our methodology also differs from that of other countries in that, to contextualise sector work, macroscenarios for S&T in South Africa have been developed to provide a uniform frame of reference for all sectors. The section on methodology addresses all of the techniques to be used in the South African Foresight exercise in more detail.

Foresight sectors: The process followed to select the Foresight sectors is also one of the special features of our process. 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 reflect the goals of the exercise and have drivers, which include social development, technological development and wealth creation.

The National Research and Technology Foresight (NRTF) Project aims to systematically identify research and technology areas, and market opportunities, that are likely to generate socio-economic benefits for South Africa in the longer term (10-20 years). In particular it seeks to —

- identify those technologies and latent market opportunities that are mostly likely to generate benefits for South Africa;
- develop consensus on future priorities amongst different stakeholders in the selected sectors;
- coordinate the research efforts between different players within the selected sectors; and
- reach agreement on these actions that are needed in different sectors to take full advantage of existing and future technologies.

The project has been divided into three phases:

1. **The pre-Foresight stage**: This is a pre-Working Group phase, which was aimed mainly at refining the design of the project, consultation with various stakeholders, and selection of the Foresight sectors.

2. **The main Foresight stage**: This is the phase during which a group of about twenty-five individuals (the Sector Working Group) will analyse a given sector and decide on future priorities. The group will reach agreement on those actions that are needed in different sectors to take full advantage of existing and future technologies.

3. **The post-Foresight stage**: This is the phase that will see the implementation of the Foresight outputs.

1.4 Foresight Sector Selection

One of the crucial activities of the pre-Foresight Phase was the sector selection. The sector is the core operational component of the entire Foresight process. It was therefore decided that sector selection would be conducted in an inclusive and transparent manner, with a strong focus on participation and empowerment.

A strong driver behind this approach was the recognition that an important determinant of the success of the Foresight initiative is the level of 'buy-in' and ownership of the process by the various stakeholders. Another driver was the possibility of using the sector selection as an opportunity to set up a database of expertise to draw on for the running of the project.

In order to fulfil these objectives, the method decided upon for Foresight sector selection was a series of countrywide workshops for organisations and institutions that have a stake in research and technology. Care was taken to ensure that the participation in each workshop was as diverse as possible, with the workshop delegates drawn from a wide range of stakeholders. Eight such workshops were conducted; three workshops were held in Gauteng and one each in KwaZulu-Natal, the Western Cape, the Eastern Cape, the North-West and the Northern Province.

In total, delegates from 21 academic and research institutions, 34 businesses or industries (including business and trade associations), 10 national government departments or policy NGOs, as well as many provincial government departments, and all eight major science councils, have participated in this workshop process. In addition meetings with a sector selection focus have been held with representatives from an umbrella civic organisation, a provincial trade union confederation and a youth organisation.

The diversity of the sectors was evaluated taking into account the overall national situation derived from available data. This included current and projected employment figures, GDP contributions, export and other significant statistics. In addition, some local and international trends in each sector were traced and current policy initiatives noted. Finally some key drivers and constraints for sectoral development were identified. These analyses were presented to the Foresight Advisory Board and DACST, who together with the Foresight Management Team, have decided on the 12 final sectors to be run in this Foresight Project.

The twelve Foresight sectors chosen are the following:

- 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

Three cross-cutters were also identified, but they were to be run as additional sectors. They are the following:

- Education/human resource development (HRD)/skills development
- Beneficiation (value addition)
- Business development.

1.5 Foresight Methodology

The process followed was developed in order to achieve the following:

- **Vision**: The White Paper on Science and Technology envisages a future where all South Africans will —
  - enjoy an improved and sustainable quality of life;
  - participate in a competitive economy by means of satisfying employment; and
  - share in a democratic culture.

In order to attain this vision, three goals will have to be reached:

a) The establishment of a system of technological and social innovation;
b) the development of a culture which values the advancement of knowledge as an important component of national development; and
c) improved support for innovation, which is fundamental to sustainable economic growth, employment creation, equity through redress and social development.

- **Foresight mission**: To promote technological innovation and deployment by identifying opportunities for economic and social development through a National Research and Technology Foresight (NRTF) project.

In order to implement the above process it was necessary for the Department of Arts Culture, Science and Technology (DACST) to appoint a Coordinator for each of the twelve sectors, as well as select the Sector Working Group.

1.5.1 Sector Working Group

The Sector Working Group (SWG) is the operational arm of the project. The group is tasked to undertake an analysis of the sector and identify issues as well as research and technology solutions to sector challenges. Identification of expertise for participating in the Foresight Working Group was undertaken through a co-nomination process.

Different countries that have embarked on similar exercises have applied different methods. 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-nomination is a survey-based technique that allows the major stakeholders and the broader 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, adapted to our situation to identify members of the SWGs.
- 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; and
- build a database of experts who would be consulted by SWGs at later stages of the project.

Four iterations of co-nomination have so far been carried out. The response rate was above 30 % and 2 573 names have been generated so far. Most of the respondents were from higher education institutions (35,3 %) and 88,2 % were males. There were very few individuals from previously disadvantaged backgrounds and from labour organisations identified via co-nomination. To make sure that the make-up of Working Groups was representative, other individuals were appointed directly into these groups.

The SWG for the Mining and Metallurgy Sector was selected from people who were either nominated through the co-nomination process or were appointed by a relevant department of government or organisation. Details of the co-nomination process, including the names that came out in the Mining and Metallurgy Sector's co-nomination process, are available in a separate report. About 30 nominees indicated their willingness to serve on the Mining and Metallurgy Sector Working Group (see Table 1).

The terms of reference of the SWG included investigating the future socio-economic challenges facing the sector and identifying the impact these would have on the sector.

Through a series of workshops the sector was analysed within the South African context while recognising its contribution to the global and regional economy. The SWG then identified market opportunities and research and technology requirements that would help the sector to enhance its performance and also address social issues.

1.5.2 Sector Coordinator

In addition to assisting in the compilation of the local study, sector coordinators provide research and analytical support for the SWG members and coordinate all the sector activities. This is achieved by performing the following tasks and responsibilities, inter alia:

Research and resourcing: Sector coordinators are responsible for looking for additional or missing information during the working phase of the project. In cases where the SWG requests that a particular study be commissioned (if important information is not available), the sector coordinator bears responsibility for coordinating that task.

Coordination: Together with the chairperson, the sector coordinator is responsible for coordinating inputs from SWG members. Apart from coordinating the general sector activities, sector coordinators draft any interim reports required, and compile the final sector-specific project report.

Table 1: Mining and Metallurgy Sector Working Group Members

Sector Coordinator: Brian Protheroe		
Title	**Name**	**Organisation**
Mr	D I Baker	Department of Minerals & Energy
Mr	E Baloyi	Department of Trade and Industry
Dr	A Banyini	Medical Bureau for Occupational Diseases
Dr	N A Barcza	Mintek
Mr	R D Beck	Anglo American Corp.
Mr	S Bosman	AST Consulting Group
Sir	R Bromley	ASPASA
Dr	M Moll	Iscor: Mining
Mr	B Dennis	Hulett Aluminium Ltd Consultant
Mr	D H Diering	Anglo American Corporation of SA Ltd
Mr	JR Dixon	Avgold
Prof	R M S Falcon	Falcon Research (Pty) Ltd
Prof	G A Fourie	Mining Engineering Department
Dr	C Frick	Council for Geoscience
Dr	R G Gürtunca	CSIR Miningtek

Facilitation: In addition to his/her coordinating activities, each sector coordinator also assists the chairperson by facilitating some sessions.

1.5.3 Stakeholder Group

A stakeholder group has been established which includes not only the people nominated in the co-nomination process but also representatives of all the other important participants in this sector. This is the group that participated in the survey. The stakeholders are from those organisations and institutions identified during the general Foresight and sector-specific consultations, which serve as a reference group to the SWG. The involvement and participation of these role-players is important to the project in that they —

- are a reference group to give feedback
- participate in the Delphi survey
- become a source of expertise for specific issues
- form part of the peer review process and thus participate in the evaluation of the project.

The list of stakeholders who participated in the survey is available separately on request.

1.5.4 Foresight Process

The key components of the Foresight Process are shown schematically in Figure 1 and are explained below.

The above process consists of the following underpinning activities:

- **Boundary conditions**
  The boundary conditions define the sector foci, which were formulated on the basis of inputs from other sector stakeholders. The SWG finalised these foci.

- **Sector foci**
  Each sector developed its own focus areas within the broader science and technology environment. The purpose of the foci is to ensure unanimity of purpose of the SWG and to ensure integration and linkages with other sectors.

- **International study**
  A team of consultants carried out a study examining international market trends, policies and strategic plans, social and political trends, and research and technology trends that may impact on the Mining and Metallurgy Sector.

- **Local study**
  A review was made of the current status of the sector in South Africa with the focus on research and technology.

- **Situation analysis**
  On the basis of the above information, a situation analysis consisting of an external environment analysis and an internal profile of the sector was done. The sector strengths, weaknesses, opportunities and threats (SWOT) were identified. In addition, major social, technological, economical, ecological and political (STEEP) drivers and constraints for the sector were developed. This information provides a picture of the current sector situation.

- **Scenario building**
  The scenario-building activity consists of macroscenarios and sector-specific scenarios. Macroscenarios are coherent, consistent and logical views of the future in the 20-year time frame of science and technology in South Africa. These macroscenarios were completed by the Foresight Management Team, using inputs from various stakeholders through a process of 'scenario development'. Sector-specific scenarios, based on the macroscenarios, are developed for each sector and capture the sector-specific futures related to science and technology for that sector.

- **Survey**

Opinions of people in the sector who are knowledgeable on various issues were sought by way of a questionnaire-based survey that focused on perceptions of South Africa's status (current and future), as well as appropriate strategies that may improve our competitiveness.

- **Strategic analysis and choices**

The sector identified future research and technology challenges and market opportunities over the next 10-20 years and then developed strategies around them.

1.6 Scope of the Mining and Metallurgy Sector

During discussions on the focus of the Mining and Metallurgy Sector, the SWG agreed that there would be two distinct parts to the sector, namely Mining, and Metallurgy. It was further agreed that Mining would include exploration, mining operations and equipment, while Metallurgy would include mineral processing and 'added value' primary products. The Working Group noted in the latter instance that close cooperation with the Manufacturing and Materials Sector would be required.

1.7 Mining and Metallurgy Sector Terms of Reference, Mission Statement and Sector Foci

- **Terms of Reference**

The SWG reviewed its terms of reference and decided that no alteration was necessary. They are:

- Agree on proposed sector foci.
- Analyse the current status of the sector.
- Create scenarios for the sector.
- Identify future research and technology challenges and market opportunities over the next 10-20 years.
- Identify issues to be surveyed and develop them into statements.
- Make recommendations on the identified cross-cutting issues or areas.
- Compile a prioritised list of research and technology topics for the sector.
- Help to identify research and technology themes towards the designing of appropriate research programmes.
- Compile the Foresight Sector report.

- **Mission Statement**

In the first of a series of five workshops, the SWG developed the following mission statement for the Mining and Metallurgy Sector:

'To identify strategic research and technology topics and strategies for the Mining and Metallurgy Sector in South Africa that could realise substantial economic and social benefits for the country over the next 10 to 20 years.'

- Sector foci

One of the outputs of the first workshop of the Mining and Metallurgy SWG was a comprehensive list of issues, trends, concerns etc., which were clustered into common issues. In all, eighteen clusters of current and emerging issues were produced.

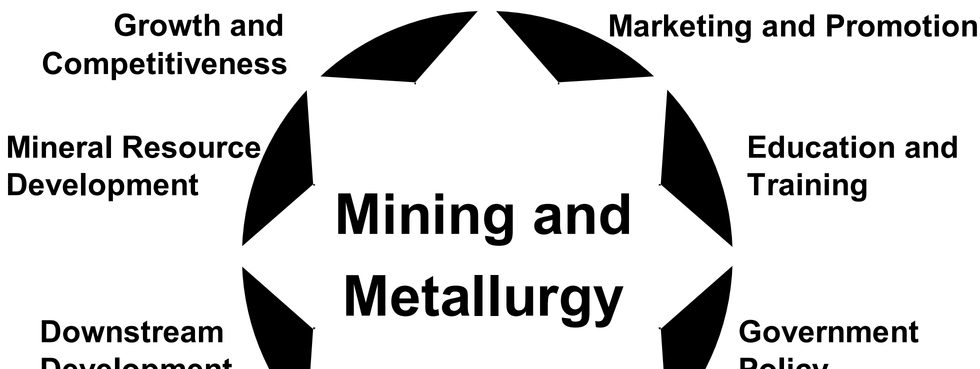
As a result of further interaction with the Working Group, the eighteen clusters were further refined to give eight clusters, which were referred to as the Sector Foci, and which are given below:

1. Marketing and promotion
2. Education and training
3. Government policy
4. Management of research and technology
5. Growth and competitiveness
6. Mineral resource development
7. Downstream development
8. Social responsibilities.

The Working Group agreed that all eight Sector Foci should have both an 'international' and a 'national' perspective. For instance, the Sector Focus 'Government policy' should take cognisance of the impact on the South African Mining and Metallurgy Sector of both domestic policies and the policies being generated in other countries.

The Sector Foci can be regarded as points on the circumference of a circle, while the underpinning issues, concerns, trends etc. that were identified in the first workshop are numerous points within the circle. The circle represents the focus of the SWG and is shown schematically in Figure 2 below.

Figure 2 Schematic representation of the eight foci for the Mining and Metallurgy Sector



1.8 Workshop process

The work of the Sector was carried out by way of a number of workshops in which the SWG members participated. The structure of the workshops was such that the members were taken through a process which led to the development of outputs in fulfilment of the terms of reference of the SWG. The process began with the preparation of two scans for the Working Group. They were the International Scan prepared by consultants and a Local Scan prepared, in part, by the Sector Coordinator. These two scans are covered in summary form in Chapter 2. The full reports are available separately.

The group identified the strengths, weaknesses, opportunities and threats (SWOT) relevant to the sector as defined in the foci. The analysis of the sector SWOT is covered in Chapter 3. Using key uncertainties developed by the Group, and applying them to the macroscenarios, as presented to the Sector, the group developed their own scenarios for the sector, which were then subjected to a SWOT analysis. This is covered in Chapter 4.

The Working Group then identified the issues, drivers and trends that are relevant to the sector and worked these into a number of statements, which were tested on the broader stakeholder group by means of a survey. This is covered in Chapter 5.

The sector survey results are analysed and presented as direction for the future research and technologies relevant to this sector over the next 10 to 20 years. From this analysis, some key technologies and technology themes were identified, and strategies for their implementation were developed, together with some recommendations. These are covered in Chapter 6.

Chapter 2:
International Scan and Local Study

2.1 Introduction

Part of the Foresight process is, at the outset, to capture all the emerging issues, trends etc., both locally and internationally, that are likely to impact on the future wellbeing and competitiveness of the Mining and Metallurgical Sector in South Africa. In order to facilitate this process two reports have been produced by external contractors.

The first report, referred to as the International Scan, reviews international developments and trends relevant to the South African mining and metallurgy sector that are likely to impact on the sector over the next two decades. The report benchmark's South Africa's position against the international situation and identifies potential opportunities and threats for the mining and metallurgy sector.

The second report, called the Local Study, is a review of the current status of the sector in South Africa with a focus on research and technology, especially the strengths and weakness of the local industry.

The Mining and Metallurgy Sector Working Group considered both reports, and using their own understanding of the local and international market, generated the information given below, which gives a picture of where South Africa is in relation to other developed and developing countries in respect of four aspects. Firstly social, political and environmental issues, secondly economic trends, thirdly strategic plans and foresight studies, and lastly research and technological developments.

2.2 Social, Political and Environmental Trends

- As the world population increases from about 6 billion at present to an estimated 8,5 billion in 2025, with much of this increase taking place in the developing countries, overall energy and mineral demand will increase, although this will be offset by more energy-efficient processes, renewable sources of energy and the growing trend towards recycling.

- Global standards, international trade agreements, global regulations on social and environmental matters, inter alia, may dictate investments in future. For instance, there is a worldwide trend towards increasing emphasis on environmental protection. Partly as a result of this, many developed countries are transferring primary metal and mineral processing capability, traditionally referred to as heavy industries, to those countries where the minerals are mined provided the investment risks are acceptable. South Africa is well placed to take advantage of this trend having an abundance of mineral deposits, good infrastructure, liberal mining policies and access to fairly cheap energy. However, many investors are weary of the political instability in the region. Although it represents 20 per cent of the earth's land mass, Africa has attracted just 5 per cent of global expenditure on mining in recent years.

- Increasing international emphasis on environmental protection will also impact on the operation of the minerals industry in South Africa as there will be increasing pressure from developed countries for environmental responsibility in the developing countries. This will also extend to increasing international pressure on the mining industry to continue reducing the safety and health impacts of mining on the mining workforce in line with accepted international norms. South Africa's environmental legislation is becoming ever more stringent, in some cases more so than that in developed economies. Care must be exercised to ensure that a balance is achieved between environmental protection and economic growth. Poverty is the greatest cause of pollution.

- The environmental emphasis will also have major impact on the use of energy minerals. While the use of energy will improve in efficiency, global energy demand will continue to increase. While progressively greater use will be made of alternative non-polluting energy sources, coal will continue to be a major contributor. In particular, clean-burning uses of coal will be progressively sought. The net effect of these forces will be a relatively slow growth in overall demand, with good scope for South African coal to make an increasing contribution as there are substantial reserves of hard coal available.

- There is a trend for the world to be segmented into a smaller number of increasingly larger collective economic trading blocks. Increasing globalisation is being matched by increased emphasis on national individuality. This is likely to be reflected in increased international cooperation. South Africa as a member of the Southern African Development Community (SADC) can act as the engine for regional growth and the development of an integrated economy, with the mining industry playing a major role. However, for this to be achieved there must be political stability, non-restrictive mineral policies, favourable trade agreements, etc. Currently, mining contributes 60% of foreign exchange earnings in the region, while in South Africa it constitutes 8% of the GDP.

- The political changes that have taken place in the former Soviet Union have had a major impact on the worldwide supply patterns for several raw materials. In general, the states comprising the former Soviet Union have been depleting stockpiles of industrially significant materials, and this raises obvious opportunities for South Africa, particularly in commodities where the Soviet Union and South Africa together dominate the world mineral resource.

2.3 Economic Trends

- Africa has a low share of world consumption of minerals and products and there is a need to overcome the accepted tendency of exporting raw materials at low prices and importing manufactured goods at high costs.

- Although, over the last decade, the demand for most minerals and metals has grown steadily, commodity prices in real terms have remained fairly static and in many cases have fallen. As raw materials costs represent a diminishing share of the cost of producing finished goods, many of the developed countries have invested in primary and secondary metallurgical capacity in developing countries. The trend is towards mineral extraction becoming increasingly perceived as a chain of the process from exploration through to the end user, that is, towards a 'value-addition mindset'. South Africa has taken advantage of this thinking in the case of aluminium and stainless steel, but is well behind in adding value to other minerals, such as gold and platinum, in which it has a dominant world supplier position.

- South Africa is now one of the highest cost gold producers in the world. Competition from Australia and increasing amounts of gold produced by small-scale, low-cost operations, is threatening the industry. The problem is exacerbated by the fact that gold is losing its position as a 'store of national wealth', although there is increasing demand for jewellery in the newly industrialised (e.g. India) and developed countries.

- Australia is emerging as a major competitor to the South African minerals industry. The manufacturing growth in the developing world, particularly Southern Asia, is twice as fast as the developed world and Australia is seen as the 'minerals basket' for feeding these economies. In addition, the anticipated increasing demand from developing South American countries will lead to mining developments in that region. Appreciation and depreciation of currencies and freight costs are likely to play major roles in competitiveness in exporting minerals.

- Energy is becoming an increasingly important consideration, not only in the cost of mining and metallurgy, but also in the downstream manufacturing sector where improved processing efficiency is increasingly being sought. In South Africa, the comparative advantage of relatively low electricity costs are increasingly being exploited to produce value-added metals such as aluminium, giving producers a strong export advantage. There is a need to use this advantage for other minerals.

- With the worldwide concern for the environment, increased focus is being placed on lighter-weight, non-corroding and recyclable materials. This provides significant opportunity for increasing the demand for novel alloys incorporating base metals and light metals such as aluminium and magnesium. However, other non-metallic materials may substitute ferro-alloys in industrial and domestic applications. South Africa has considerable potential ore resources where mining and beneficiation could expand on commodities that have not been major traditional contributors to the South African mining and minerals sector.

2.4 Strategic Plans and Foresight Studies

A number of countries have conducted or have initiated foresight-type studies in recent years, most notably the United Kingdom, the United States of America, Japan, Germany, Korea, the Netherlands, Australia and New Zealand. None of these studies has specifically defined mining and metallurgy as a sector; nevertheless, a substantial amount of useful information has been derived from consideration of the outputs of these foresight studies. The UK, USA and Japanese studies are probably the most mature, and most information was obtained on their outcomes, with supplementary information being located in the German study.

- Energy trends occupied a prominent position in many of the foresight studies. Significant developments in energy generation technology are envisaged, with implications for the use of coal. Energy from waste products, from photovoltaic sources and from other natural renewable sources are anticipated to become significant contributors to energy supply. Parallel to this, energy utilisation is anticipated to become more efficient, while motor cars with extremely low fuel consumption due to reduced weight achieved by the significant introduction of new materials such as ceramics, aluminium and resins, and improved output achieved by near zero emission and higher engine efficiencies are also contemplated. These trends could have significant impact on the demand patterns for manufacturing materials.

- A longer term trend in most Foresight studies is the emphasis on biotechnology and nanotechnology, and developments in catalyst technology. As they develop, these technologies could have a significant impact on mining and metallurgy.

- Ever stronger focus on environmental issues with waste management and pollution control being emphasised on a worldwide basis. Parallel to this is a strong focus on materials development with lightweight, recyclable and environmentally friendly materials being used more substantially in industrial applications.

- Significant and rapid developments in information and computer technologies are envisaged, enabling both advances in automation through sensors and control systems, and more widespread application of simulation and modelling. Numerical modelling and simulation techniques have become routinely applied approaches in the fields of mine layout and design studies, ore value modelling, environmental engineering and metallurgical processing.

- Developments in sensors, communications and information processing have enabled applications such as automated vehicle route following, remote telecontrolled loading and tipping operations, remote control of mechanised rockbreaking and handling equipment, automated face mining systems and optimised ventilation systems to be introduced in overseas mines. Significant developments in finite element analysis and computational fluid dynamics have taken place or are taking place in most mining countries.

- Exploration costs have and will continue to rise as more locations are explored. Many mining countries are investigating the development of semi-quantitative prospecting technologies for mineral resources using artificial satellites. Others are examining the development of exploration technologies capable of estimating the economic feasibility of mineral deposits with virtually no drilling.

It is apparent from an examination of the above foresight studies that international strategic thinking on mining and metallurgy research has recently undergone a period of significant change. While much of this is in common with other research disciplines, the situation with regard to mining has been relatively extreme. There has been, in the last decade, an almost total demise of centralised research institutions in the major developed mining countries.

This situation has not been entirely without benefit as many of the research staff have established private, technology-based companies whose primary business has been to introduce new technology into mining. However the most serious consequences of these developments is an almost exclusive short-term focus, using current technological solutions, with little long-term development. The problem is exacerbated by the suggestion that the minerals industry of the twenty-first century will be dominated by a relatively small number of large companies; although much of the mining will be global in scope and internationally staffed, the holding companies will mainly be in the developed countries.

In the case of South Africa, it was recognised that mining and metallurgy had a key role to play in the future of the country and that there was a need to keep the industry competitive into the twenty-first century. In the **White Paper** entitled **'A Minerals and Mining Policy for South Africa'** dated **October 1998**, the government stated that research and development efforts would be needs-driven and directed to developing solutions in exploration, mining, processing, beneficiation and environmental conservation and rehabilitation of the environment, as well as to satisfying the needs of global customers and exploiting the value-adding potential of the country's minerals. This applies to large- and small-scale mining.

Furthermore, science councils and government departments will endeavour to establish joint-venture research and training programmes with universities and the private sector in order to produce the necessary technologies and skilled labour required for the mining and metallurgy sector. The results of the technology Foresight exercise being conducted by DACST will contribute to this endeavour.

In the case of **small-scale mining** the Department of Minerals and Energy (DME), would coordinate research and development by the science councils and ensure that the information and technology is readily accessible. This coordination function is being undertaken by the National Steering Committee (NSC) of Service Providers to the Small-scale Mining Sector under the umbrella of the DME.

In the case of **large-scale mining**, the strategic decision was taken to form two collaborative programmes of research involving science councils, organised labour, research institutions and the mining industry. The main purpose of the **COALTECH 2020** collaborative research programme is to address the needs of the coal mining industry while the **DEEPMINE** programme of work primarily concentrates on deep level gold and platinum mining operations. In addition, the government, through the **Safety In Mines Research Advisory Committee (SIMRAC)**, administers a levy on mines that is used in part to fund a research programme that addresses mainly those health, safety, and environmental issues that impact negatively on the well-being of the underground workforce.

In the case of the **metallurgical industry** in South Africa, the investments off-shore, and the relocation overseas by several of the large mining houses has resulted in a significant decrease in local research and development over the past few years. Government funding of research in this field has also decreased. This has resulted at less longer term research at universities and organisations such as Mintek, one of the science councils which reports to the DME.

Mintek's strategy, on behalf of the government, is to serve the national interest through research, development, and technology transfer that promotes mineral technology and fosters the establishment and expansion of small, medium, and large industries. South Africa has begun to fall behind countries such as Australia, Canada and South America in certain research areas in the field of minerals and mineral products.

2.5 Research and Technological Trends

This section of the report examines the status of mining and metallurgy technology in South Africa compared to the rest of the world. It undertakes this comparison under the headings of the major minerals mined, namely coal, gold and platinum, industrial and base minerals.

2.5.1 Coal

South Africa is a major producer of coal for both the domestic market and export. Much of the technology for mining, both on the surface and underground, is imported and customised to meet local conditions. Similar technologies are applied in collieries overseas with Australia and the USA being the closest industries in terms of conditions, equipment used and productivity environment. Increasing competition from these countries, as well as emerging countries such as China, is likely to impact on the competitiveness of the local industry over the next 20 years.

In general, there has been a shift overseas towards research and development into massive and integrated bulk transportation systems. There has been a swing away from traditional road or rail transportation systems towards sophisticated conveyor belt transportation systems. Hydraulic and pneumatic conveying of bulk solids is increasing in popularity. More and more, transportation systems need to be as environmentally friendly as possible. High freight costs in South Africa negatively impact on the final competitive pricing of exported coal. In certain coal mines overseas, hydraulic or pneumatic conveying has been adopted successfully for vertical mineral transport.

The major, longer term programmes of research overseas are placing increasing emphasis on mechanisation, remote control and even automation of coal mining equipment, as part of an integrated mining system. This involved the application of advanced data acquisition and processing systems, networked into computer models that simulate the mining operations and allow real time management. The development and application of these technologies in South African mines is likely to be hindered by a lack of research and development capacity, and trained and experienced staff.

The main purpose of the COALTECH 2020 collaborative research programme is the development of technology and the application of research findings which will enable the South African coal industry to remain competitive, sustainable and safe well into the 21st century. The initial focus is on extending the useful life of coal mining in the Witbank/Highveld coalfield while sustaining job opportunities and utilising the available infrastructure to the year 2020 and beyond. One-third of the research funding will be provided by CSIR Miningtek, one-third by the NRF's THRIP programme and the remaining one-third will be divided between the participating mining groups. Other participants in the programme include organised labour, universities, government departments, etc. The overall programme of work consists of individual projects or tasks that address the seven technology or focus areas, these focus areas are geology and geophysics, underground mining, surface mining, coal processing and distribution, surface environment, and human and social aspects.

In parallel with the above collaborative programme of research (COALTECH 2020), the Safety in Mines Research Advisory Committee (SIMRAC) has a programme of research for coal mining that falls mainly into two categories: occupational health and safety, and rock engineering. While South Africa has a long history of coal rock engineering research and has been 2.5.2 Gold and Platinum

The South African gold mining industry is under threat from a low gold price, the increasing costs of mining gold from great depths, and the disproportionately high incidence of injuries and fatalities on gold mines compared to other mines e.g. coal, platinum.

The SIMRAC programme of research in the gold and platinum sector focuses on the critical safety and health areas of rock engineering, environmental engineering and hoisting of men and materials. The rock engineering issues in deep level mines leading to the problems of rockfalls and rockbursts with associated casualties, ore dilution, and delays to mining, are well defined. Research in South Africa over the past 35 years has been focused on these problems, and it could be said that South Africa leads the world in this type of rock engineering.

The way that South Africa has carried out its rock engineering research has been to develop a centre of experience and excellence and then to interact with relevant world authorities and institutions by means of collaborations, visits to and from South Africa and sponsoring sabbaticals. Currently, laboratory experimentation equipment is becoming outdated and as a result the level of expertise in younger researchers is lagging. A similar situation exists with in situ monitoring. In the field of underground geophysical monitoring, however, South Africa appears to be keeping pace with the rest of the world.

Although very significant progress has been made over the years in aspects of rock engineering, and research funding has been reasonably generous, the challenges, in particular with regard to rockbursts, are far from solved. The scope and scale of these challenges are considerable and will increase as mining proceeds deeper. Finding solutions is difficult and challenging and will require input from other innovative and specialised areas. For instance, ongoing developments overseas are likely to place greater emphasis on rock engineering systems that will integrate with automated or robotic mining systems. Thus research will be focused on remote monitoring of rock behaviour, expert system and neural network processing, analysing and interpreting the data to provide feedback and instructions to the mining equipment and support installation equipment. Research to develop such a mining system will be necessary. The driving force behind the development of these technologies would be an extreme concern for safety, the need for mechanisation to ease the lot of the miner, and to improve productivity and profitability.

In the area of **hoisting of men and materials**, South Africa's needs in the deep level mines are unique, with multi-lift shafts being commonplace, especially in the gold mining sector. For this reason, South Africa has recently developed some of the most advanced guidelines in the world for the design and operation of rope-based winding systems. In addition, there are stronger incentives than anywhere else in the world for the development of non-rope-based winding systems. Novel concepts for hard rock applications include linear motors and hydrohoisting coupled with underground comminution. Initial research on the latter approach shows promise. This area of research is being investigated as part of the DEEPMINE initiative, which is a collaborative research programme between government, research institutions and the mining industry. The programme of work is funded equally by government (FRD/THRIP), industry and CSIR Miningtek.

The DEEPMINE programme is designed to meet the needs of mining at depths of between 3 000 and 5 000 metres and is not designed to replace SIMRAC, but rather to complement it. Many of the productivity issues connected to mining safety at depth are covered in this programme of work. In the area of environmental **engineering technology** the main focus is on the management of heat through ventilation and refrigeration. The main thrust of current research efforts are in computerisation of environmental monitoring and control systems, the use of novel insulation materials research into practical use of water vapour refrigeration and research into ice as a cooling medium. The emphasis of these technologies and systems is on effective ventilation and cooling at worker locations. Consideration overseas is being given to remote control mining from the surface allowing a relaxation of environmental requirements.

Internationally, very little work is being done in improving the ventilation and cooling of deep mines. South Africa should be at the forefront of research in this regard. In many respects, research in South Africa stagnated owing to progressive reductions in funding. Experts performed consultative work in the implementation of existing technology, rather than extending relevant technologies. Environmental engineering is still not generally recognised as a potentially decisive problem area in the underground mining industry, and little time, money or effort have been invested in this research area over the last decade.

Comprehensive **geological interpretation and prediction** of economic ore values are techniques that are gaining in importance as the cost of exploration by drilling at ever greater depths and in remote areas increases. South Africa is a world leader in the delineation of ore bodies based on drilling, using technologies such as radio tomography. Remote satellite sensing and image processing is a major international growth area. Current research in South Africa focuses mainly on shorter-range, high-resolution geophysical techniques, such as radar, sonar, and seismic reflection and tomography systems. This usually involves the adaptation of overseas developments for local conditions.

In the area of the metallurgy or **mineral processing**, particularly of gold and platinum, South Africa is a world leader. However, there is a continual need for the industry to remain internationally competitive through improving process efficiencies and metal recoveries, especially as energy is becoming an increasingly important part of metallurgical operations. Improved capture of sulphur dioxide from the processing of platinum converter matte is becoming more environmentally necessary to achieve performance levels similar to those attained overseas. Future research is also aimed at economically unlocking metals from low-grade, difficult-to-treat ores using emerging and novel processes, such as bioleaching and molecular recognition technology. Apart from spending on advertising to promote both gold and platinum for various applications, including jewellery, there is limited expenditure within South Africa to develop downstream value-added products.

2.5.3 Industrial and Base Minerals

The challenges of the mining of **base minerals** is, in general, not as great as the challenge of the metallurgical treatment of the ores to unlock the base metals within. The mineral processing technology that has traditionally been used for the recovery of the base metals is undergoing fundamental change owing to cost, environmental, and mineralogical pressures (low-grade, difficult-to-treat deposits are becoming more important). Access to novel technology is seen to be of strategic importance in being able to compete successfully in a global industry, and the local industry has not been as active as in the past in supporting research and technology. For these reasons, South Africa is not as well placed in terms of its technological position as was the case previously.

The emerging new technologies that are positioned for the treatment of deposits of lower grade or high oxide content, include the flotation of oxide copper ores, sulphide heap leaching, tank bioleaching and pressure leaching. Because somewhat more limited research in base metal processing has been carried out in South Africa over the past 10 years, many of the recent advances have taken place in Australia, Canada and South America. The areas where South Africa has begun to make significant progress are in **nickel** and **copper** bioleaching, and the DC arc furnace smelting of both primary base metal concentrates and some secondary residues. Scope for implementing some of these technologies locally is limited, except with zinc, where South Africa has large but relatively low-grade deposits.

South African **nickel** refineries have developed world-class solvent extraction technology to produce cobalt from nickel liquors, and this technology is already being used elsewhere. Also, it is not commonly realised that this country is the largest producer of electrolytic **manganese** in the world, and that the locally developed technology sets the international benchmark. In general, South Africa research in the field of the major industrial minerals in the country is state of the art, and economically important processes have been developed locally.

While the iron and **steel** industry has been getting leaner and smarter in the industrialised countries, it has also been expanding in the developing countries. China, for example, recently became the largest steel maker in the world. The newly emerging steel-making countries have not yet harnessed the newest technologies. The trend recently has been to move steel production capacity to coastal locations and to develop and use newer steel-making technologies to overcome some of the local disadvantages. The development of gas fields both off the coast of South Africa and in the neighbouring SADC region could lead to a renewed growth in the local iron and steel industry. Most of the technology required can be sourced from overseas where much of the development work is carried out.

The demand for higher-quality steel continues to drive improved purity levels for stainless steel and **ferro-alloys**. South Africa has become a market leader in ferroalloys, in particular ferrochromium, largely because of the low cost of electricity and the adaptation of innovative solutions for dealing with the low cost and abundant, but lower quality, ore. The retention of this position will require a proactive research and technology stance.

Stainless steel in South Africa is still in a relatively early stage of development, which relies partly on proven imported technology. However, research and technology to utilise the raw material and energy advantage in South Africa should be more actively pursued. Domestic and foreign stainless steel consumption would benefit if the relatively expensive nickel and molybdenum additives used in the steels could be replaced by less costly metals. The direct use of molten ferronickel and ferrochromium could also reduce the cost of stainless steel production.

Aluminium research internationally continues on reduced energy consumption through improved process efficiencies, but improved product quality and wider applications are receiving ongoing attention. Magnesium research is still largely in the area of lowering production costs, and in this regard the local research community is in a good position to contribute to the development of an improved metallurgical process for magnesium metal production via the DC arc furnace expertise base that exists. The application of this smelting technology is gaining acceptance on a number of fronts based on its ability to accept lower cost ores with improved metal recovery. Considerable potential exists for the production of titanium alloys using this technology.

Chapter 3:
Situation Analysis of the Mining and Metallurgy Sector

3.1 Introduction

The work contained in this section of the sector report was as a result of a rigorous process, by the Working Group, aimed at an extensive situation analysis of South Africa's Mining and Metallurgy science and technology environment. The ultimate objective of this part of the process was to ensure that research and technology intervention in South Africa addresses both the internal weaknesses and external threats while taking advantage of our strengths to address the market opportunities that arise for the mining and metallurgy sector over the next twenty years.

3.2 Key issues

The South African Government's priority in the current context is the need to address the social imbalances of the past by alleviating poverty through education and job creation. The mining and metallurgy sector is an important job creator. However, the industry is under threat from low commodity prices, foreign competition, new and emerging regulatory reforms, etc. The relocation of the major mining houses overseas means that the South African-based operations will have to compete for investment from the parent company, not only in mineral resource development but also in research and development.

In order for the sector to remain competitive and meet the challenges of globalisation, there will be a need for the application of new mining technologies and for a more highly skilled, better paid and better trained workforce. Many developing countries are better placed than South Africa to develop their mineral resources, having better-trained labour using better technologies in a more cost-effective manner. In South Africa, there is a need to manage the introduction of these technologies with social responsibilities, such as minimal job losses.

However, the mining industry does not have a good public image with the youth and is not perceived as acceptable career-wise; mining is perceived as hostile and dangerous. There is also the perception that the industry is dying a natural death. Even the small to medium mining enterprises find that they not only have to compete with the larger ones, but also find it difficult to meet safety and environmental requirements. As a result there has been a steady decline in the teaching of mining-related subjects in institutions of education, which in turn has produced skills shortages.

The oversupply of unskilled labour and the general lack of commitment by, and collaboration between, both government and industry to promote mining, and science and technology in general, in schools, and to address the long-term tertiary education needs for the sector has led to a general decline in the quality and quantity of skilled manpower. In addition, there are a number of other national social uncertainties.

Increasing crime and corruption may not only impact negatively on investment in the country, but also on the speed at which change is taking place. Strikes may occur, as workers become frustrated at the slow pace of change. Social issues such as AIDS are also affecting the welfare of the workforce. HIV/AIDS in the mining industry is thought to be two to three times more prevalent than in other industrial sectors.

On the economic front there are many challenges currently facing the sector. A major challenge is addressing the issue of globalisation and the linkages to and inter-dependency on the economies of the dominant developed countries. The development of economic blocs is a major trend that will impact on economic competitiveness in future. Destabilisation of central and southern Africa as a result of regional political conflict is a major issue that is impacting negatively on the future of the sector as part of a SADC economic power bloc.

Even though world growth would be expected to act positively on the demand for minerals, commodity prices have remained fairly static and in most cases declined. Raw material costs represent a diminishing share of the cost of producing finished goods and the developed countries are expected to exert increasing control to keep costs low in the developing mining countries.

As regards technology, the developed countries are focusing primarily on developmental programmes that focus on value-added and high-margin products, while encouraging developing mining countries to remain primary producers of minerals. This 'value-addition' mindset, as opposed to a 'resource-based' mindset, has a significant impact on the rate of technological change in various countries.

The speed of technological change in developed countries is much greater than in developing countries. Scientific advances are now more quickly translated into technological successes than ever before. The developed countries have embraced the information society to such an extent that access to and integration of technology is rapid enough for the gap between the developed world and the developing world to be increasing. There is therefore a need to develop a downstream 'added-value' industry to offset this threat, and for an overall strategic plan to address this issue. Government policy should be aimed at encouraging such action.

The same can be said for the impact of international environmental policies and regulations concerning the mining and metallurgy sector. Increasing controls by the developed countries will result in improved waste management practices and the use of clean energy fuels. Also, the secondary recycling industry, and the increasing use of plastics, will play an increasingly important role in the supply of some metals. South Africa already has a healthy secondary recycling industry in copper, aluminium and lead.

As far as politics are concerned, the new democratic movement has had a positive influence on investment in the country. However, there is a need for government to maintain a healthy balance between overregulation and underregulation. Also, there is a need to increase access to mineral deposits for local and foreign investors, while at the same time offering incentives that reduce investor risk. The government recognises the need for increased productivity through new technology. However, there is concern that the government's focus on the funding of historic priorities may impact negatively on the need to develop technologies to remain internationally competitive. In any event, it is felt that increased government funding may also result in centralised control of collaborative research programmes.

A major **strength** of the South African economy is the well-developed mining and metallurgical industry and the associated infrastructure and higher level, commercial/technical expertise base. There are also very significant mineral resources that have, in addition to current operations, potential to be exploited given the necessary development. These include gold, platinum-group metals, chromite and manganese ores for ferroalloy production, titania minerals (ilmenite and rutile), base metals, diamonds and coal. The country has favourable energy costs and significant scope to generate a larger amount of electrical and fossils-fuel-based energy.

The wealth generated from this sector is one of the major cornerstones of the country's economy and many of the other areas of industrial activity are directly linked to it. Government has recognised this and government policy is therefore creating a more attractive climate for growth and development through the proposed metallurgical clusters in the various Industrial Development Zones (IDZs). South Africa currently has a strong scientific and technical capability in the area of metallurgical processing which lends itself to supporting the drive towards further added-value beneficiation.

Cooperation between industry and research and development organisations in South Africa is generally quite good and this favours the implementation of improved technology. The existing manufacturing industry that supplies the mining and metallurgical sector is also well placed to move into more added-value areas. The tripartite structure between government, industry and labour is well organised, and provides a solid basis for increased stability with regard to human resources and greater progress with safety and research issues.

One of the major **weaknesses** is that some of South Africa's minerals are not mined easily and operating costs, particularly in gold mining and platinum mining, are high because of the depth at which mining takes place. Also, not only is South Africa remote from main markets, but deposits in South Africa are often far from seaports and the local transport costs are excessively high compared to international transport costs, mainly because of poor management and excessive bureaucracy. The industry does not generally make a concerted effort to overcome such transport problems.

Mining is still the prerogative of 'big business' because of ownership of mineral rights and only in limited areas are SMMEs evident. Small-scale mining has a poor image in an industry dominated by the large mining houses. In the employment, surface and health and safety spheres, the industry is often vulnerable to criticism because it is sometimes perceived to be uncaring. The marriage between government and industry can be difficult at times, as each views the other with an element of distrust.

Tertiary education and training in the sector is fine from a quality point of view but poor at other levels. Technical training tends to be 'more of the same' and introduction of new technology for future development, especially for added-value opportunities, is limited. More generally, worker appreciation of the business process could be improved, thus avoiding confrontation between labour and management. Top management is perceived to be insensitive to anything but the 'bottom line,' while new technology is often felt to either threaten jobs or increase production costs. This impacts on the education system at the tertiary level where the high technical standards are perceived as good but where the difficulty of attracting quality academics and researchers is threatened by non-competitive salaries and a student body that is, initially, poorly prepared for the tertiary learning environment. While bridging courses are in place to some extent, the problems associated with attracting the youth to an industry perceived as dirty and dangerous remains. There is a perception that it is easier to import the skills required. Rising crime, however, is one of several reasons why such methods are becoming more difficult to implement.

In downstream development, there is still largely a lack of awareness of the advantages of and of commitment to fund, train for, and manage such initiatives. Although the opportunities exist, corporate inertia and lack of kick-start funding ensure that any development effort is difficult.

In terms of **opportunities** the South African Mining and Metallurgy Industry has fundamental strengths and many opportunities for growth and initiative. South Africa has an abundance of raw materials, energy resources, and skills in certain areas.

Existing resources can be exploited through new technology and training. However, unexploited mineral resources will need to be developed through the utilisation of even better technology, a better trained workforce and improved productivity. It is believed that there is scope for sustainable small and medium-sized mining operations which are currently not exploited and which would empower and stimulate growth and employment in small and medium-sized mining communities. Furthermore, the mineral base can be exploited by encouraging downstream development.

Adding value to our minerals will create wealth, jobs and foreign exchange earnings. The Foresight Beneficiation Cross-cutter report is an attempt to provide guidance on areas in which value addition should occur. In all these areas, new and improved technology must be developed, although existing know-how could be more widely used in existing mines elsewhere in Africa and to support smaller mining enterprises. Emphasis should be given to encouraging applied and more appropriate technology training at technikons and universities. More modern training technologies can be used for those in science, technology and information technology. Greater success and promotion of the mining industry will encourage the perception of it as providing economic, social and career benefits.

3.3 Summary

The original intention was to interpret the SWOT analysis by grouping and identifying how strengths interacted with opportunities and threats and also what needed to be done to overcome our weaknesses in the sector. However, because of the complexity of the various interactions, it was decided to discuss them individually as strengths, weaknesses, opportunities and threats.

Of note in this discussion are the strong interrelationships, as well as some possible contradictions, owing to the different viewpoints on some of the issues. Despite these contradictions, this analysis, together with the international and local studies, has proved to be valuable as a baseline study for the development of the sector-specific scenarios in Chapter 4 and the statements in Chapter 5.

Chapter 4: Macroscenarios and Sector-specific Scenarios

4.1 Introduction

Scenario thinking is part of the strategic planning exercise to assist in the activities of the Research and Technology Foresight Project. Scenarios are stories about possible futures, about what could happen, not what will or should happen. Scenarios are neither predictions nor forecasts, but rich, multifacted stories that capture the unpredictability, uncertainties and possibilities of the future. The purpose of scenarios is to encourage creativity, challenge mental models and conventional wisdoms, and generate or wind-tunnel strategies. Scenarios are useful if they are relevant, emerging, plausible and clear.

4.2 Macroscenarios

Scenarios referred to as macroscenarios were developed for South Africa, characterising the possible role of research, science and technology in South Africa's economy and social development in the next two decades. These macroscenarios were developed through an iterative process of interviews with high-profile role players in various organisations, and group participation in various workshops. The workshop outputs were refined by the Foresight team using external consultants in the field of scenario building.

Through the above process, four macroscenarios were produced, to be used by all 12 Foresight Sectors. Political, social, economic, and science and technology issues formed the basis of each of the scenario, which are summarised below. Further information about the scenarios is available in a separate publication from DACST.

Frozen Revolution: The non-implementation of government policy intended for socio-economic upliftment lead to policy paralysis; the masses are dissatisfied; the economy is gradually shrinking; key players are fragmented and individually focused.

Innovation Hub: South Africa's comparatively developed infrastructure creates opportunities for strategic regional investment. Building on human and national resources generates comparative advantage and a competitive edge regionally and globally; some national identity is lost, while regional identity is strengthened; initially, there is slow economic growth; finally, there is incremental social development towards a shared regional vision.

Global Home: In line with global trends and opportunities, government embraces global liberation, and facilitates private sector empowerment to respond to global market forces, which result in a 'hands-off' role for small government; initially, there is good economic growth; this scenario is fine for those who can pay, but there is little social development; and national identity and self-determination dissolve.

Our Way is the Way: South Africa believes in its ability to challenge the conventional route to globalisation by rallying developing countries' support for the development of a significant South-South economic bloc. This catalyses isolation from the developed world and results in a strengthened national identity, a focused development plan and, initially, a shrinking economy.

The above macroscenarios, or stories about the future, were used by the Sector Working Group to develop mining and metallurgy sector-specific scenarios. This process involved the identification, by the Working Group, of key uncertainties in the mining and metallurgy sector in order to create relevant, focused versions of the macroscenarios.

4.3 Key uncertainties

The Sector Working Group, initially in four small groups and then in plenary sessions, identified those key uncertainties or areas of concern that are likely to impact on the mining and metallurgy sector over the next 20 years. The 27 key uncertainties identified were further reduced by the Working Group to 15 as a number of them were conceptually closely related. The final 15 are as follows:

1. Government policies; economic, minerals, education, S&T funding, investment, etc.
2. Commodity prices
3. Global economy: financial, political, social challenges, exchange rates, stability
4. World growth and impact on the demand for mineral commodities
5. Regional stability
6. Scientific advances: new technologies, exploration, mining minerals, materials, environment, safety
7. Recycling: growth in materials recycling affects primary production
8. Discovery of alternative deposits
9. HIV/AIDS: incidence and cure
10. Regional conflict (war)

11. Beneficiation: added value and alternative materials
12. Crime and corruption
13. Human resources: costs, education and training, brain drain, health, safety, etc.
14. International environmental policy: climate change etc.
15. Global expansion of mining companies into SA.

The above 15 areas of concern (key uncertainties) were prioritised by the Sector Working Group. First, according to whether a small change in the key uncertainty or variable would have a big impact on the sector. Second, according to the possibility of predicting with any degree of certainty or confidence the value of this variable over the next 20 years. The results were plotted on an IMPACT versus UNPREDICTABILITY diagram shown in Figure 3 below.

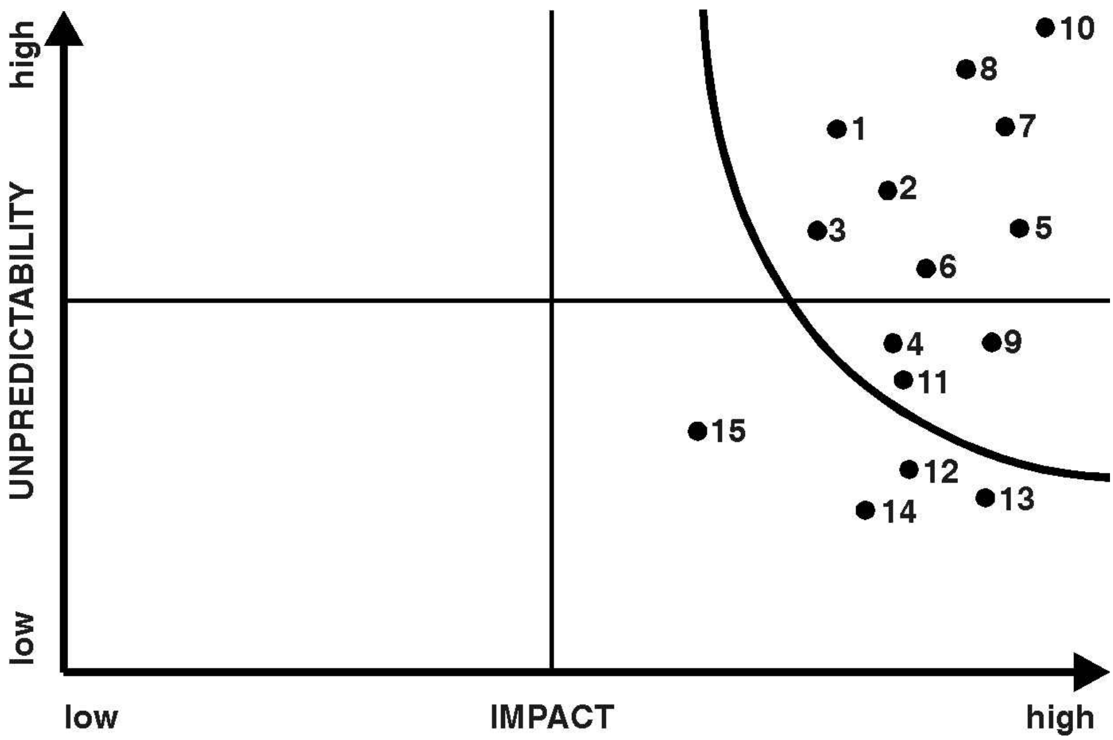


Figure 3 Unpredictability versus Impact of Key Uncertainties for the Mining and Metallurgy Sector

The first 11 key uncertainties 11 listed previously, and grouped as shown in Figure 3 had the 'highest impact' and the 'highest unpredictability'. The three uncertainties with the highest impact and the highest unpredictability were, in order of importance, REGIONAL CONFLICT (WAR) (NO. 10), DISCOVERY OF ALTERNATIVE DEPOSITS (NO. 8) and RECYCLING (NO. 7).

4.4 Mining and Metallurgy Sector-specific Scenarios

Using the above 11 prioritised key uncertainties as variables, the Sector Working Group, initially in small groups and then in plenary sessions, developed a mining and metallurgy sector-specific scenario for each of the four macroscenarios. The 'possibilities of the future' of the sector in each macroscenario were captured.

The Sector Working Group then undertook a SWOT analysis on each of the four sector-specific scenarios in order to identify possible market opportunities and external threats arising for the sector in each future scenario, and the strengths and weaknesses of the sector in dealing with them.

Although a SWOT analysis on the current environment in the mining and metallurgy sector had been undertaken earlier in the Foresight process (see Chapter 3), the thinking was that, by using the scenarios as a backdrop, a more expansive analysis of future market opportunities and threats would be achieved. A summary of the results of this analysis for each scenario is given below.

Frozen Revolution: In this scenario there would be no coherent government policies or plans and little control over the private sector mining and metallurgical operations apart from encouraging minimum extraction. There would only be fragmented influence in a few mining/metal commodities. The perceived high risk of investments would result in short-term financing only, and the industry would become more and more isolated from the global economy. This would mean little or no international integration of the mining and metallurgical industry, which would increasingly have to be self-sustained. The impact on economic growth would be limited to selected areas. Regional stability would be adversely affected and relationships between members of the Southern African Development Community (SADC) would suffer as the general economic stagnation drove the region into a survival-at-all-costs mode of thinking.

Science and Technology would become increasingly obsolete and would be driven by short-term, ad hoc government objectives and programmes. The region would be increasingly dependent on the sourcing of foreign technology, which might not always be available or affordable.

The investment climate would also be adversely affected by the lack of locally developed and supporting technology that would be required to give the industry a competitive edge. The region would be increasingly isolated from recycling/environmental technologies and opportunities and this would lead to some pressure on increased primary production. However, markets would become closed to us if we failed to comply with internationally accepted environmental/recycling norms.

There would also be less opportunity to participate in the exploration and exploitation of deposits off-shore and local prospecting would also suffer because less funding would be available. The occurrence of HIV/AIDS would have increased and the control of AIDS would suffer as medication would be more difficult to access.

The probability of local conflict would increase as the region would become more unstable with little prospect of outside intervention. The mining and metallurgical industry would continue to export largely in beneficiated minerals and metals and there would be little development of value-adding opportunities. Competition from imported materials would increase because of the perceived risk of supply shortages, which would put further pressure on the economy.

Innovation Hub: In this scenario, the mining and metallurgy sector would benefit from governmental policies promoting an emphasis on mining investment, beneficiation and normalisation of standards in the region. The development of larger markets and resources, given South Africa's regional leadership in development and technology, would boost the region's economy and competitiveness.

South Africa would experience an enabling climate for the development of new technologies, supported by proactive cooperation between industry and government. This climate would encourage optimisation of opportunities, from exploration for new deposits to beneficiation. The focus would be on the SADC region and the development of Small, Medium and Micro-enterprises (SMMEs) to exploit these opportunities would be facilitated.

Such policies would strengthen regional stability and cooperation. Although the focus would be primarily regional, more positive drivers for innovation, exploration, and downstream development with the wider impact of technology would facilitate integration into the global economy. There would, however, be some desensitising to global upheavals and conflicts. The incidence of HIV/AIDS would initially be high but would decline with focused effort.

Global Home: As the mining and metallurgy sector responds to global forces there would be increased markets both locally and internationally. The leading mining houses would move off-shore to the developed countries and the sector would become integrated into the global economy. South African organisations would participate in the discovery and exploitation of new deposits. Access to finance and technology would increase, but international competition would be more intense.

Government policies would facilitate private-sector investment with minimal interference and planning, but there would be adequate financial regulations in place to avoid global economic exploitation. Although there would be no special focus on regional alignment and cooperation, the issue of regional conflict would need to be addressed to encourage investment. The HIV/AIDS epidemic would initially impact negatively on the competitiveness of the industry until an international cure was found. Effort would need to be directed at a possible loss in national identity and lack of social development.

There would be little or no influence on commodity prices, as these would be dictated by the global market. However, greater access to foreign technology would enable the more effective use of mineral resources through downstream 'added-value' development, resulting in economic growth and job creation. To compete globally, the industry would adapt to more costly international best practices from the legal, environmental, and safety and health perspectives.

There would be a need to put in place an effective science and technology education system to ensure a sound technological skills base, mitigate in favour of the overdependence on imported technologies and encouraging local development. Meanwhile, deep-level mining expertise and technologies would be exported globally to exploit new mineral discoveries.

Competition from recycling and the use of alternative materials would be strong. However, global rationalisation would have optimised the most cost-effective production processes, favouring local production of probably fewer specific lower-cost metals. The local recycling industry would adapt to the challenges and develop innovative technologies, while at the same time new uses would be found for existing materials.

Our Way is THE Way: Government policies would emphasise the development of local capacities within the mining and metallurgy sector whilst developing South to South trade links and cooperation. Through these linkages there would be considerable opportunity for influencing commodity prices.

There would be limited integration into the world economy and, as a result, isolation from technological developments elsewhere. South Africa's go-it-alone policies would encourage self-sufficiency, such as import substitution. Low foreign investment would undermine competitiveness and limit economic growth. There would be no broad regional political alignment, but rather focused relationships with specific countries. South Africa would have a strong military presence in the SADC region. The incidence of HIV/AIDS would initially increase and then stabilise over time.

Government would be primarily responsible for driving science and technology programmes through joint ventures with strategic partners. However, technologies would not be benchmarked against world standards.

There would be intensive regional, South to South exploration and exploitation, but limited likelihood of discovering major new deposits. SMMEs would be encouraged and would, in general, make use of known deposits. Limited access to appropriate technology would result in less cost-effective recycling of materials. The use of alternative materials would not be pursued locally since this would not favour the local mining and metallurgy sector.

Chapter 5:
Survey, Analysis and Results

5.1 Introduction

The questionnaire-based survey is a core part of the Foresight process. It is a consultative process designed to assess and evaluate the various issues that have been identified by the Sector Working Group. It is a process to test the thinking of the future by the sector stakeholders. These stakeholders are knowledgeable people or experts in the sector, who have been identified by a co-nomination and consultation process supplemented by people identified by members of the Sector Working Group. All the people to whom the survey was sent, and who then returned completed questionnaires, are regarded as the 'Stakeholder Group'.

The expectation is that the responses to the survey questionnaire will make a major contribution to the identification of science and technology topics or issues in the field of mining and metallurgy. These topics or issues are considered likely to support an improvement in the economic growth and the quality of life of many of the people of South Africa over the next twenty years.

5.2 Survey methodology

The fundamental concept of the survey was based on similar work that has been done in countries such as Germany, Japan and the United Kingdom. In this process, a number of topics or issues are tested against a number of variables. The variables selected are the same for all sectors in the Foresight project and hence are not necessarily optimal for this sector.

The respondents were asked to give their views on the range of topics selected by the Sector Working Group. This was followed by a second survey questionnaire in which the respondents were given an opportunity to review their responses in light of the collective opinions expressed in the first-round survey questionnaire. This enables greater significance to be attached to those statements that were given a high level of confidence by the respondents. This method has been in use for over 30 years and is the basis of successful foreign foresight programmes and other similar studies.

5.3 Survey process

5.3.1 Survey format

The Foresight project team, during the course of a number of workshops, developed the format of the survey and the variables to be used. The difficulty was to develop a standard list of variables that would have meaning in all 12 sectors involved in the project. The basis of the variables was an attempt to include questions that would provide a snapshot of where technology in South Africa stood at present and, at the same time, indicate how important it was for the country in respect of wealth creation and quality of life, and also through the development of strategies and timescales for acquiring these technologies.

The survey format made allowance for the respondents to add comments or even to formulate an alternative statement in a box at the end of each topic row. In addition the respondents were invited to propose new topics at the end of the questionnaire.

5.3.2 Development of relevant statements

The Sector Working Group developed the statements by working in four groups, one group for every two of the identified eight foci of the Sector. The groups went through the list of foci generated from the first workshop and for each made a sublist of the drivers, trends and relevant issues. For each topic identified on the sublist, possible opportunities, innovative solutions, products/processes, services and technologies, and research breakthroughs were identified. From the foregoing, the groups developed statements to test the relevant research and technology topics listed. These statements were subjected to further refinement before being incorporated into the survey document.

The statements were required to meet the following criteria:

- Each should test only one idea.
- They should have a futuristic element.
- They should be closed statements.
- Seventy per cent of them should focus on research and technology.
- About 30% of them should deal with generic and policy issues.
- They should answer questions like 'Why?' and 'Is it possible?'
- They should each have three components:
  - An idea (i.e. technology/research/market, etc.).
  - A specific issue/objective/use application to be addressed.
  - An indication of the 'state of development' of the particular research, technology, application or market, i.e. they should be made with the following 'lead words':
    - **Elucidation**: to scientifically and theoretically identify principles or phenomena;
    - **Development**: the attainment of a specific technological goal for a completed prototype;
    - **Practical use**: the first practical use of an innovative product or service;

- **Widespread use**: significant market penetration to a level where a product or service is in common use.

The survey statements were divided into two groups, namely 60 mining and metallurgy statements and 10 megatrend statements. The megatrend statements were general statements produced by the Foresight project to be included in the surveys of all sectors. Their analysis was also to be done across all 12 sectors.

5.3.3 Structure of the survey questionnaire

The mining and metallurgy sector on the survey questionnaire consisted of statements grouped into 11 mining and metallurgy, research and technology subsectors. They are:

Marketing and promotion (M&P)
Education and training (E&T)
Management of research and technology (MRT)
Social responsibilities (SR)
Health and safety (H&S)
Mineral resource development (MRD)
Mining operations (MO)
Mineral processing (MP)
Surface environment (SE)
Theft prevention (TP)
Downstream development (DSD).

The structure of the survey questionnaire is captured in Table 2.

An analysis of the above table shows that the majority of statements are in the subsector areas of mining operations (15 statements) and mineral processing (14 statements). The other major subsectors were health and safety, mineral resource development, downstream development and surface environment.

In addition, over 60% of the statements in the questionnaire are concerned with the 'development' of various technologies for the mining and metallurgy sector as opposed to 'elucidation,' 'practical use' or 'widespread use'. Many of the topics are 'development' in nature because of the slow implementation of new or emerging technologies in the sector. Less than 5% of the statements pertained to elucidation, i.e. 'blue skies research'.

It is recognised that at this stage, emphasis on development is appropriate for the sector. However, in a future foresight exercise, more attention ought to be paid to the longer-term visionary needs of the industry, i.e. more statements should have an 'elucidation' focus. This distribution of the different stages is a reflection of the current status of research and development in the mining and metallurgy sector.

5.3.4 Conducting the survey

More than 1 200 survey questionnaires were sent out to stakeholders and interested parties, including those on the mailing list of the South African Institute of Mining and Metallurgy (SAIMM). Prior to this distribution, a number of editorials on Foresight were captured in the SAIMM Journal. In addition, Mintek published an article in the Mintek Bulletin, which was distributed to over 5 000 readers. Furthermore, CSIR Miningtek developed a Foresight Mining and Metallurgy Internet website which was accessible to all parties.

The above 'awareness campaign' was aimed at sensitising people to the Foresight process. However, in hindsight and for future foresight exercises, more attention should be focused on a specific awareness campaign in sensitising the recipients of the survey questionnaire to the impending issuing of the survey questionnaire, the objective being to improve the response. It is also suggested that in future a broader and more inclusive stakeholder group be considered and the overall process publicised and made more transparent.

5.4 Survey results

5.4.1 Response

Of the 1 200 survey questionnaires distributed, 192 completed documents were returned, representing a response of 16%. The overall response figures are given in Table 3 below. It is internationally held that, considering the number of questionnaires distributed, a 10% response would be meaningful in terms of the survey and the subsequent analysis.

Table 2 Structure of the mining and metallurgy survey questionnaire

Mining and metallurgy subsectors	Status of development of technology				
	No. of statements	Elucidation	Develop-ment	Practical use	Widespread use
Marketing and promotion	1		1		
Education and training	2			1	1
Management of technology and research	1		1		
Social responsibilities	1		1		
Health and safety	9		5	4	
Mineral resource development	4		3	1	
Mining operations	15		11	3	1
Mineral processing	14		8	4	2
Surface environment	4		4		
Theft prevention	3		1	1	1
Downstream development	6	2	2	1	1
TOTAL	60	2	37	15	6
PERCENTAGE %		3,3%	62,7%	25%	10%

Table 3 Summary of overall response to survey questionnaire

Mining and metallurgy sector				
Overall response			Response method	
Sent	Received	Response	Paper	Internet
1 200	192	16,0%	91,7%	8,3%

5.4.2 Analysis of the overall results

The analysis of the results of the first survey questionnaire was undertaken by the Human Sciences Research Council (HSRC) according to internationally accepted norms.

The overall results of the first survey questionnaire are given in Table 4 below.

The following overall conclusions were based on analysis of the questionnaires in respect of the following variables.

- Importance to South Africa

Of the 60 statements, 63% were regarded as being of medium to high importance in terms of wealth creation, and 68% of the statements were regarded as being of medium to high importance in improving quality of life.

- South Africa's comparative standing

The overall impression from the respondents was that the South African mining and metallurgy sector, in most instances, was well ahead of other Southern African countries and equal to if not ahead of developing countries. In several cases it was not as far advanced as developed countries.

- Likely time frame for realisation

Most of the respondents felt that the time frame for realisation of the technology/capacity captured in the statements for the mining and metallurgy sector was typically between six and 15 years and mostly within five to 10 years. Very few respondents felt that the realisation time frame extended beyond 15 years.

- **Acquisition of technology or capacity**

Two-thirds of respondents indicated a preference for technology to be developed in South Africa or to promote joint ventures if international input were needed. Straight importation of technology was much less favoured. It would be relevant when South Africa was technologically behind developed countries in a particular field. Even then joint ventures are preferable to effect technology transfer.

- **Key constraints**

The two dominant key constraints in respect of the statements was the lack of appropriate technology and finance. The inadequacy of the research and technology infrastructure was strongly emphasised.

- **Confidence level**

In all of the 60 statements in the survey questionnaire, 66% of the respondents had a medium to high level of confidence in evaluating the variables for the statements. This is regarded as validating the results of the survey.

5.4.3 Analysis of the statements

The Foresight project team decided that Importance to South Africa would be the main variable for the analysis of the survey results from all sectors. A weighting process based on wealth creation and quality of life indices was used to develop a joint index.

An analysis of the 60 statements according to the Joint Index from 'All Respondents' is given in Table 5. The most important statements were selected on ranking according to the joint index[1], and the greater the joint index the higher the ranking.

In the deliberations of the working group it was decided to select, for further in-depth analysis, the top 20 statements and the bottom 10 statements according to the 'All respondents' joint index.

5.4.4 Analysis of the top 20 statements

The joint index

The analysis of the top 20 statements according to the joint index from 'All Respondents' shows that 35% fall into the category of mining operations, 15% fall under mineral resource development and 15% fall under mineral processing. It is worth noting that none of the top 20 statements fell under the following four subsectors, namely, management of research and technology, surface environment, social responsibilities and theft prevention.

Analysis of the statements indicates that, according to the joint index, nine of the 20 statements, that is 45%, have both a high wealth creation index and a high quality of life index, particularly the top five statements. Statement No. 13, ranked number 1 and dealing with a cure for HIV/AIDS, was felt to impact not only on quality of life but also on wealth creation. Statement No. 15, ranked number 2, was a fairly broad statement in the mineral resources development subsector, which encapsulated new gold-mining opportunities. This statement also had both a high wealth creation and a high quality of life index.

Mechanisation of mining operations, underground support, automation, robotics and control, as well as information technology, were seen as technologies that impacted strongly on both wealth creation and quality of life issues.

Analysis of the top 20 statements with regard to the state of the development of technology shows that 70% fall under the development category. None of the statements fell under elucidation. This would indicate that the development of technology for mining operations, mineral processing and mineral resource development are the major priority areas.

Wealth creation index

Statements considered important from a wealth creation perspective formed part of either the mineral processing or the mining operations subgroups. Analysis showed that five of the top 20 statements, that is 20%, were motivated primarily by wealth creation. Statement No. 15, which was concerned with an integrated low-cost mining system, had by far the highest wealth creation index, which elevated it to ranking position number 2 on the joint index.

The results suggest that the following areas have little immediate direct impact on wealth creation: education and training, management of research and technology, social responsibilities, surface environment and theft prevention.

Technologies that were considered important from a wealth-creation perspective included the development of downstream 'added-value' products, advanced 3D exploration techniques, and horizontal and vertical transportation systems.

The development of technology was again considered to be the dominant 'state of development' category in respect of wealth creation.

Quality of life index

In the context of the top 20 statements in the survey, mining operations, health and safety, and mineral resource development accounted for the majority of the statements having a high quality of life index. Analysis indicated that six of the top 20 statements, that is 30%, were motivated primarily by quality of life issues.

Statement No. 13, which addressed the HIV/AIDS issue, had the highest quality of life index and also a high wealth creation index. The statement came top in ranking for the joint index. This was also the case in other sectors in which this statement was tested. Theft prevention, social responsibilities and management of research and technology received zero ratings in respect of impact on quality of life.

Technologies with mainly a high quality of life index addressed issues such as improving the underground environment, in respect of noise, dust, heat, etc., the use of information technology in education and training, including hazard assessment techniques, and the avoidance of sulphate containing effluents.

In terms of the state of development of the technology or research, the need for development represented 75% of the statements, placing a major emphasis in this area.

Confidence level of respondents

The average confidence by respondents in the top 20 statements according to the joint index was 70% (see Table 6 below). This indicates that the top 20 statements are well supported by respondents who are very knowledgeable in these fields. It is felt, therefore, that the process for selecting the top 20 statements according to the joint index is validated.

Table 6 The Percentages of respondents that had a high and medium confidence level in the different indices

Confidence level of different indices			
	Joint index	Wealth creation index	Quality of life index
High and medium confidence	70%	68,7%	70,2%

5.4.5 Analysis of the bottom 10 statements

The joint index

An analysis of the bottom 10 statements, positions 51 to 60, ranked according to the joint index for 'All respondents,' indicates that, in general, the statements did not do well on either the wealth creation or the quality of life indices. Over 50% of the statements fall under the mineral processing and mining operations subsectors, which could relate to possible negative perceptions about the specific nature of the concepts contained in the statements in these two areas.

Although the statements do not represent poor ideas, there seems to be less confidence in the ideas being realised in the time frame six to 15 years, in spite of 70% of the statements being in the 'development' category. The overall perception, with which the Working Group agrees, is that the last 10 statements are regarded as less important to the prioritised needs of the mining and metallurgy industry. The statements also seem to capture ideas that are possibly too innovative and less plausible.

However, the results of the survey, especially the statements in the last 10, also illustrate the conservative nature of the sector. Statement No. 60, ranked number 52 and dealing with stainless steel production, is regarded as being of high importance in the Foresight Manufacturing and Materials Sector, and in the Foresight Beneficiation Cross-cutting initiative. This indicates that certain downstream 'added-value' opportunities are regarded by the respondents as being less important than the development of technologies for the immediate survival of the industry.

Wealth creation index

It is apparent that health and safety and surface environment contribute less to wealth creation than do other subsectors. In addition, the nature of the statements and the responses suggests that the technology is either not achievable or too futuristic.

Quality of life index

In general, 40% of the statements ranked in the bottom 10 are related to mineral processing and all have a very low quality of life index. This endorses the previous perception that this subsector does not significantly contribute to quality of life issues.

Similarly, theft prevention appears to make a minimum contribution, while the statements pertaining to health and safety, such as advanced miniaturised communications systems, are regarded as possibly 'too futuristic'.

Confidence Level of Respondents

The average confidence level for respondents in the bottom 10 statements according to the joint index is 58%. The lower confidence levels for these statements suggest that either the respondents are less certain about the subject matter captured in the statements and/or their importance to South Africa, or some of the statements were less plausible.

5.4.6 Comments by respondents

A number of useful comments were received from approximately 50 respondents and they were taken into consideration in the selection and in amendments to the wording of the statements for use in Round 2 of the survey.

A whole range of divergent and often conflicting viewpoints were received. In general, the comments fell into four categories, namely those that supported the statements, added value to the statements, questioned the statements or strongly disagreed with the statements. The comments on the top 20 statements were more complimentary than those on the bottom 10 statements. These comments will be captured in the composite report for all 12 Foresight Sectors.

5.4.7 Statements for Round 2 of the survey

The Sector Working Group decided that, for greater representivity, the list of statements for the second questionnaire would include the top 20 statements according to the Joint Index. These would be supplemented by adding additional statements from the top 20 statements in the individual wealth creation and quality of life indices that were not already accounted for in the top 20 of the joint index. This resulted in a total of 33 statements (an additional 10 from the wealth creation index and an additional three from the quality of life index) being selected for the second survey questionnaire.

As an example of this selection process, statement No. 2 in the survey questionnaire is ranked number 7 in the joint index and for this reason is included, although in the wealth creation index it is only ranked number 28.

Similarly, in the quality of life index, statements 9, 51 and 49, although in the top 20 of the quality of life index, are excluded because statements 58, 1 and 22, which fall outside the quality of life top 20, are included in the top 20 of the joint index.

5.5 Summary

Analysis of the survey results indicated that the top ranked statement according to the joint index dealt with finding a solution for the HIV/AIDS issue. This was also the case in the survey results for other Foresight Sectors in which this statement was tested.

The analysis also indicated that nearly half of the top 20 statements had both high wealth creation and high quality of life indices. This was particularly true of the top 5 statements. The technological issues addressed by these statements included integrated mining systems, mechanisation, automation, robotics and control, and information technology.

The remaining statements were divided equally between, statements primarily with high wealth creation indices and statements primarily with high quality of life indices. In the case of wealth creation, technological issues addressed included 3D exploration technologies, low-grade ore processing and DC smelting, bulk transportation methods, and information technology. In the case of quality of life issues, the technologies included heat and dust control in mines, technologies for education and training, including hazard assessment, and impacts on the surface environment.

The majority of the respondents (over 60%) considered that in most cases the above technologies could be achieved in 6-15 years. About two-thirds indicated a preference for technology to be developed in South Africa, or to promote joint ventures if international input was required. Also, this view was common to both the top 20 statements and the bottom 10 statements. Similarly, there was an overall view for all statements that financial, technological and infrastructural factors represented the major constraints on the implementation of the projects.

An examination of the survey results indicates that some of the statements, and the associated technologies, have a capacity-building perspective, while others offer business development opportunities. These issues are dealt with in the three cross-cutting initiatives, namely Human Resource Development, Business Development and Beneficiation.

Although the current economic downturn, particularly the gold crisis, is likely to impact to some degree on the viewpoints of the respondents, it is felt that it has not unduly influenced the overall result. However, experience from foresight surveys undertaken in other countries suggests that results differ markedly depending on the current reality and social issues.

Chapter 6: Identification of Key Research and Technology Areas and Recommendations

6.1 Introduction

In this section of the report the consolidated survey outputs from Chapter 5 are used to address the Foresight Mining and Metallurgy Mission Statement, which is **'To identify strategic research and technology topics and strategies for the mining and metallurgy sector in South Africa that could realise substantial economic and social benefits for the country over the next 10 to 20 years'.** The process followed is given below.

6.2 Methodology

As discussed in Chapter 5, Item 5.4.4, the Sector Working Group agreed to select for analysis the top 20 statements according to the joint index ranking from 'All respondents,' plus additional statements high on the wealth creation index and high on the quality of life index. Each of the 33 statements was analysed according to the underpinning key technologies and end-use applications that were assessed as being significant for the statement.

In order to simplify the process, the key technologies were then clustered or grouped into common 'themes' as shown in Table 7 below. Those statements in brackets are the remaining 27 of the 60 statements in the survey questionnaire that have been ascribed to the various themes. In many instances a specific technology could be ascribed to more than one theme, and in this case only the dominant statement containing that specific technology issue was recorded against a particular theme.

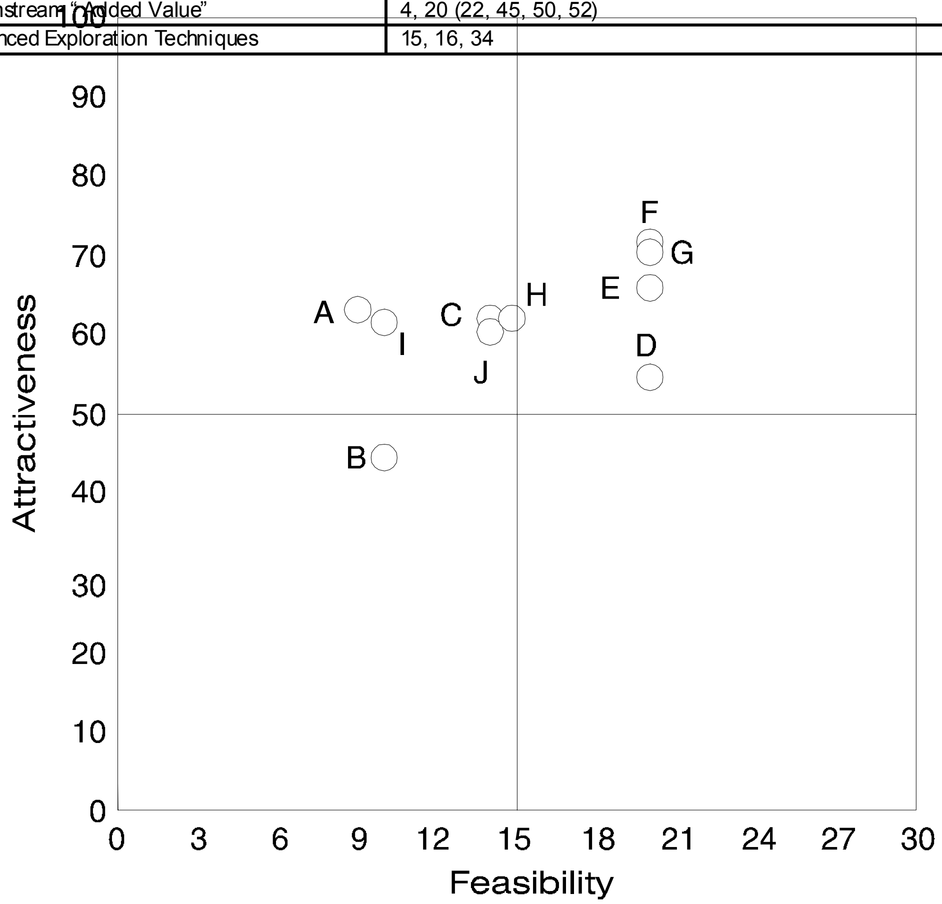
Each of the 10 themes (Themes A to J) was evaluated by the Sector Working Group according to their **ATTRACTIVENESS**, and according to their **FEASIBILITY** in respect of achieving the Sector's Mission Statement.

Attractiveness is an assessment of the impact of the theme in terms of international competitiveness, government policies, benefits such as job creation in both small and large enterprises, etc.

Feasibility is an assessment of the constraints to achieving the technologies, and these constraints include issues such as cost, size of technology base, R&D knowledge required, etc.

Theme	Relevant statements according to ranking position
Theme A: Automation Robotics and Control	5, 10, 40 (21, 32, 43)
Theme B: Refrigeration, Cooling and Insulation	6, 18
Theme C: Mining Equipment and Methods	2, 3, 11, 27, 33 (23, 36, 55)
Theme D: Transportation	12, 13, 24 (48, 54)
Theme E: Information Technology	7, 9 (30, 35, 42, 44, 46, 48, 60)
Theme F: Mineral Processing	14, 17, 19, 25, 26, 28, 37, 41 (31, 47, 49, 51, 53, 56)
Theme G: Health and Safety	1, 8, 39 (59)
Theme H: Surface Environment	29, 38 (57)
Theme I: Downstream "Added Value"	4, 20 (22, 45, 50, 52)
Theme J: Advanced Exploration Techniques	15, 16, 34

The above two assessments were recorded on an Attractiveness/Feasibility diagram as given in Figure 4 below.



The themes were prioritised in terms of attractiveness and feasibility and, as can be seen from Figure 4, these themes fell naturally into three main groupings. For ease of discussion, they are referred to as **Group 1 (Themes D, E, F and G), Group 2 (Themes C, H and J) and Group 3 (Themes A, B and I).**

An analysis of these three groups shows that certain characteristics predominate within each group. In addition, contrary to conventionally held views that highly feasible technologies require shorter time frames for development and implementation, this does not, in general, hold true within the mining industry, where technologies can require medium to long time frames irrespective of their feasibility.

Characteristics of Group 1

The key characteristics of Group 1 include high feasibility, that is, development costs are not a constraining factor and the requisite R&D knowledge exists together with a superior technology base. The attractiveness of Group 1 is high as well, which means that the themes will increase our international competitiveness, and, with the exception of Theme D, there is generally an enabling government policy and infrastructure in place. There is also good potential to exploit and commercialise these themes which will impact significantly across a broad spectrum of industrial sectors.

Characteristics of Group 2

The feasibility of Group 2 is lower because of the increased knowledge that needs to be generated for all themes in this group and the higher development costs involved, particularly for Theme C (Mining Equipment and Methods). Attractiveness is generally lower throughout the group owing to less enabling government policies and implementing infrastructures, although the impact on international competitiveness and on the broad industrial sector remains high.

Characteristics of Group 3

The feasibility of Group 3 is also lower. However, the reasons are not consistent across the themes. For example, Themes A and B require higher development costs, Themes B and I have a lower technology base, and Themes I and A require considerably greater knowledge to be generated. In terms of attractiveness there is a lack of an enabling government implementation structure (this is common to all themes within this group). In addition, Themes B and I indicate a lack of supportive government policies, while Theme B also shows a lower impact on the secondary downstream industrial sector.

6.3 Recommendations

The individual themes in the above three groups have been analysed further in order to identify the overall impact on wealth creation and quality of life. This process also permits greater focus on the attractiveness and feasibility characteristics in order to **develop recommendations** concerning future programmes of work.

Group 1 Themes D, E, F and G

In general, the development of technologies that are highly attractive and highly feasible, such as those in Group 1, usually involves greater private-sector involvement, as the technological risk is low. Government intervention, often through the science councils, can take place especially if the technologies impact on health and safety, environmental issues, or other matters that are deemed of national importance.

Characteristics of Transportation (Theme D)

Improved transportation both underground and on surface is aimed mainly at wealth creation through the reduction of operating costs and increasing productivity in mining operations, with the added benefit of improved safety. In terms of international competitiveness, the development of technologies underpinning the theme would marginally improve South Africa's competitiveness.

The government enabling policy to reduce the cost of transportation is not as supportive as it could be, while the supportive infrastructure is not in place. Interaction between various government departments and industry in order to address the optimisation of the transportation of ores, concentrates, intermediate and finished products, both regionally and nationally, is strongly recommended.

The commercialisation of these technologies could have a wide-ranging, positive effect, in terms of employment, on both large organisations and small supplier organisations in the downstream added-value sector, including cluster industries.

It is felt that the key technologies are highly achievable within a reasonable time frame without excessive expenditure on research and development. In addition, the existing technology base and research and development knowledge appear satisfactory to achieve this goal. This could be a niche area for a focused, coherent programme of work between government and the private sector.

Recommendations: We recommend a significant improvement of both the underground mining transportation systems and the national surface transportation network in order to maximise the cost-effectiveness of the production and export of mineral and metallurgical products.

To achieve this, government should collaborate with the private sector to —

- set up a task group to look at the cost and optimisation of the surface transportation of ores, concentrates, and intermediate and finished products that impact on the competitiveness of small, medium and large operations, both regionally and nationally; and
- accelerate activities in the DEEPMINE and COALTECH 2020 collaborative research programmes to identify those technologies that will ensure an integrated solution to

the rapid and safe transport of labour, and the efficient transport of material and minerals between the surface and the underground workplace.

Key technologies:
- Techno-economic modelling.
- Neural networks.
- Real-time information processing.
- Bulk horizontal and vertical transportation systems, e.g. hydraulic conveying.
- Simulation modelling.
- Underground milling.
- Sensor technology.

Characteristics of Information Technology (Theme E)

The sector would benefit enormously, in terms of international competitiveness, from greater access to and use of information technology (IT). However, because South Africa is only moderately well placed in respect of its own technology, it will be necessary to pursue joint ventures with international partners, with whom local organisations are particularly well placed.

Government support policies generally enjoy a very high priority in this area and the implementation structures within government are favourable.

In terms of the exploitation and commercialisation of technology it would have a significant effect across the broad industrial sector, from large corporations to SMMEs and even cluster industries.

There does not appear to be any fundamental constraint on the transfer and implementation of information technology solutions to the mining and metallurgical sector, although a limited research and development capacity will be required in support of a strong implementation competency. The overall emphasis will be on ensuring that adequately trained resources are available in the IT field.

The results of the survey confirmed the emerging importance of this theme, which impacts on both wealth creation and quality of life issues.

Recommendation: We recommend the establishment of 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, to support the creation of new opportunities, to improve current activities and to support education, training and R&D in the mining and metallurgical industry.

To achieve this, government in collaboration with research institutions and the private sector should —

- develop information systems to enable more effective exploitation of mineral resources and added-value products for both large, medium and small operations, taking into account existing facilities;
- promote a practical and more widespread application of IT in the education and training of personnel for the sector; and
- develop and apply real-time management systems to the simulation and control of mining operations, both underground and on surface.

Key technologies:
- Real-time information processing.
- Neural networks.
- Sensor technology.
- Control systems.
- Simulation modelling, including virtual reality.

Characteristics of Mineral Processing (Theme F)

The industry is well placed in terms of international competitiveness, and the general enabling environment in South Africa is becoming more conducive to the exploitation of under-utilised mineral resources.

Government policy and the implementation infrastructure are reasonably supportive in this area, but greater emphasis needs to be placed on progressing from the mineral processing stage to the inclusion of added-value operations.

There are many opportunities for improved efficiency and cost reductions through the development and implementation of new and emerging mineral processing technologies. It is felt that the impact would not only benefit existing operations but also promote downstream industries.

Increased synergy between the mineral processing and downstream value-added stages needs to be developed to gain greater competitive advantage from processing local raw materials such as iron, chromium, vanadium and titanium ores and concentrates based on the optimal use of energy resources.

Recommendation: We recommend improvement in mineral processing technologies to enable the more cost-effective and wider exploitation of our mineral resources taking environmental requirements into account.

Government and industry should jointly support further research and development in the following fields:

- Non-toxic solubilisation of gold in underground/in situ mining operations;
- Advanced bioleaching of gold and base-metal sulphides;
- Improved recovery of platinum-group metals from chromite containing ores;
- Zinc extraction from lower grade deposits by leaching/smelting;
- Direct smelting of stainless and alloy steels from feed materials (chromium, iron, nickel and vanadium);
- Titanium and titanium oxide production from local raw materials; and
- Aluminium production with less energy usage and from local feed materials.

Key technologies:
- Mineral processing.
- Hydrometallurgical techniques.
- Pyrometallurgy.
- Electrotechnology processes.
- Materials engineering.

Characteristics of Health and Safety (Theme G)

The international competitiveness of the mining and metallurgy sector will be strongly influenced by the impact of HIV/AIDS on the workforce and the need to improve occupational health and safety in mining operations. In some occupational health and safety areas, local technology is on a par with, if not better than, that in the rest of the world, while in other areas, such as HIV/AIDS, it is not as far advanced. However, the industry is reasonably well placed to take advantage of alliances with foreign organisations and companies to supplement local technology.

Government policies in particular, but also supportive infrastructure, are among the most advanced in the world and are highly supportive of and conducive to the development and application of technologies that greatly enhance the health and safety of the workforce. However, a lack of skilled personnel has limited the rate of implementation of government policies.

The exploitation and commercialisation of appropriate occupational health and safety technologies could have a wide-ranging effect on industry, from large corporations to SMMEs and even cluster industries. It would be expected that the impact on sustainable development could be significant.

There does not appear to be any major fundamental constraint on the development of technology to address the HIV/AIDS issue and occupational health and safety issues, provided the existing technology base and research and development knowledge are used as a platform for acquiring complementary technologies through international interaction.

The majority of respondents to the survey questionnaire felt that the HIV/AIDS issue would impact negatively not only on quality of life issues but also on the wealth creation capability of the sector. It is also apparent that the impact of HIV/AIDS on the occupational health diseases and safety issues of the underground workforce cannot be ignored.

Recommendations:We strongly recommend that the HIV/AIDS issue be vigorously addressed as it is impacting negatively on the health and safety of the workforce and on the competitiveness of the mining industry.

To achieve this, government in collaboration with research institutions, industry, labour and other stakeholders should —

- develop a coordinated, national programme of work to address the HIV/AIDS issue;
- evaluate the impact of HIV/AIDS on the occupational health diseases and safety issues of the underground workforce (this could form part of either the SIMRAC programme of research or the DEEPMINE and COALTECH 2020 collaborative programmes of research); and
- develop technologies to allow for the improved interactive training of mine workers that will influence occupational health and safety issues on mines.

Key technologies:
- The collaborative programme of research into HIV/AIDS will require a wide range of technologies ranging from information technology, through preventative measures and treatments.
- Information and interactive communication skills such as virtual reality and simulation modelling will be required.
- The physiology of the impact of the working environment on performance and health will have to be studied.

Group 2 Themes C, H and J

In general, technologies that are of high attractiveness but are only of moderate feasibility, such as those in Group 2, are usually developed jointly by the private sector and government through institutions such as the science councils. In this instance, the technological risk is higher than for Group 1, but it is shared among the parties involved.

Characteristics of Development of Mining Equipment and Methods (Theme C)

The industry is strongly placed to take advantage of new and emerging technologies, while the exploitation of these technologies would give the South African mining industry much greater international competitiveness in both shallow and deep-level mining. Although there is a reasonable level of local technology, this would have to be reinforced through alliances with foreign partners, with whom industry is well placed.

While it is recognised that some government support is received from DACST and the DTI, there is a need for increased effort to develop and implement technologies that will ensure the long-term well-being of the sector.

The exploitation and commercialisation of this technology will have a significant impact on the development of higher levels of skill for underground operators. Furthermore, the development and manufacture of mining equipment will not only be beneficial to the mines as primary users, but will also encourage the development of the secondary and downstream manufacturing sector and service-orientated industries. The benefits would be considerable, and include increased productivity and improved safety and health on mines, a longer life for operating mines and the facilitation of the exploitation of new and underutilised mineral resources.

At present, the main constraint on the acquisition of the necessary technology is the high cost of developmental. However, it is felt that the technology base and the research and development knowledge required are in place and that it is merely a matter of harnessing local and international resources in a focused manner.

There was strong emphasis in the results of the survey on the fact that mechanisation, and even automation, of underground mining operations would be of significant benefit to both wealth creation and quality of life issues. However, it is necessary to address the need for the industry to be internationally competitive through mechanisation, while at the same time preserving jobs.

Although mechanisation will lead to fewer, but more highly qualified and skilled workers in mining, it is strongly felt that science and technology have a major role to play in re-shaping the mining industry so that it will cause minimal disturbance for humans. New employment opportunities can be created by innovative government policies and incentives that encourage the creation of new mines and the manufacture of mechanised mining equipment on surface for use underground. Where there is a lack of capacity for the redeployment of staff, retraining for work in other sectors in which labour shortages have been identified must be a consideration.

Recommendations: We recommend that only through the mechanisation 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.

Government in collaboration with the mining industry and research institutions should —

- develop an integrated, low-cost mining system for the economic exploitation of low-grade ore bodies at shallow depths;
- form a task group to explore the development of a collaborative programme of work that addresses the mechanisation of deep-level mining operations in the medium to long term, and this should be considered for inclusion in the DEEPMINE collaborative programme;
- ensure that automation, robotics and control, as well as information technology, integrates closely with the programme of work;
- explore opportunities for the development of government policies that encourage mechanisation while at the same time preserving jobs; and
- explore the labour needs of other sectors to maximise employment opportunities and minimise national unemployment.

Key technologies:

- Rockbreaking.
- Underground support.
- Seismic technologies.
- Ore-body delineation.
- Hydraulic conveyancing.
- Engineering design.
- Control systems.

Characteristics of Surface Environment (Theme H)

The need to be environmentally compliant with international norms is becoming increasingly urgent if the mining and metallurgical sector is to continue to export minerals and mineral products and remain internationally competitive. The sector is not only very well placed with regard to local technology but it has developed the ability, through close links with international parties, to supplement any deficient technologies.

The government-support policy is one of the most stringent in the world, and it is becoming increasingly more difficult for industry to comply with such policies and remain competitive. This has resulted in limited implementation of such policy, a situation that is further exacerbated by protracted evaluation and approval of new projects by government departments. This creates uncertainty with regard to identifying appropriate technologies to address environmental issues.

The judicious use of appropriate technologies to overcome environmental issues could result in positive financial rewards as well as the exploitation of new and waste resources in an environmentally-friendly way. This can impact on both large and small companies.

It is highly feasible to evaluate current and emerging technologies available in South Africa. However, a key issue is to prioritise the technological areas in which to concentrate the research and development effort. Interdepartmental government policy on environmental issues will need to be streamlined, while government itself could offer incentives for technology to be applied in identified areas.

The majority of respondents to the survey questionnaire concurred with the viewpoints of the Working Group that the technologies captured in this theme impacted primarily on quality of life issues and that the following action needed to be implemented:

Recommendations: We recommend that longer-term, internationally acceptable solutions be found to the surface environment issues that affect the mining and minerals industry; this should be done through support for research into and the development of technologies that minimise the impact on both capital and operating costs and the environment.

To achieve this, government in collaboration with research institutions and the private sector should —

- obtain greater clarity on the regulatory framework, especially between government departments, and the development of environmental policies that offer regulatory incentives;
- find more cost-effective and centralised ways of handling environmental issues, such as those in proposed metallurgical clusters; and
- find technologies for the economic treatment of mining and metallurgical wastes, including water, on-surface, and sulphur-dioxide emissions.

Key technologies:
- Desalination processes.
- Bioleaching.

- Sulphur emission control technologies.
- Clean-air technologies.
- Waste stabilisation and vitrification technologies.

Characteristics of Advanced Exploration Techniques (Theme J)

The benefits, in terms of international competitiveness, of advanced exploration techniques would be considerable, especially in making exploration more effective and affordable. It is believed that South Africa is well placed not only with regard to its own technologies, but also with supplementing technological deficiencies through foreign alliances and joint ventures.

Government support in terms of policies and supporting infrastructure could be better developed and some measure of incentives put in place to encourage technological development.

Although the main beneficiaries of the exploitation and commercialisation of these technologies are likely to be the larger corporations, there will also be some benefit for smaller mining operations. The benefits to industry are significant, not only in terms ofmaintaining employment by extending the life of existing mines, but also in the development of new mines and the creation of employment in downstream, secondary industries.

The feasibility of the development and implementation of those technologies is dependent on the establishment of a larger research and development expertise base, together with the necessary funding for a programme of work between government and the private sector.

Recommendations:We recommend the development of advanced exploration technologies for use underground and in remote areas on 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.

Key technologies:
- Remote sensing.
- Seismic techniques.
- Electromagnetic techniques.
- 3D simulation modelling.
- Image enhancement techniques.

Group 3 Themes A, B and I

In general, technologies that are attractive but are of lower feasibility are often deemed to be of too high a risk by the private sector. In this instance, government, usually involving science councils and universities, are the primary movers for technological development. However, the mining industry as the end user of the technology developed must be an integral part of the development process.

Characteristics of Automation, Robotics and Control (Theme A)

The majority of respondents felt that the key technologies captured in this theme would impact on both wealth creation and quality of life issues facing the mining and metallurgy sector in South Africa.

It was felt that the sector would benefit greatly from the development and implementation of automation, robotics and control technology, especially in underground mining operations but to a lesser extent also in mineral processing. This would considerably enhance our international competitiveness. Currently, the majority of technologies in this area would have to be acquired through international associations and adapted to meet specific local conditions. In this regard, local industry is reasonably well positioned for the development of commercial linkages with foreign organisations.

In general, the government policy needed to encourage this development is in place. However, the government's implementation infrastructure is not as well advanced, and should be developed through a government/mining industry task group. This group should look at the impact of automation and robotics on the socio-economic benefits to the sector and the country in general.

The exploitation and commercialisation of this technology would have a significant impact on the development of higher skill levels for the operation of underground mining equipment and surface metallurgical plant. In addition, it would be expected to result in improved safety and health conditions on mines and in metallurgical plants. Additionally, the development and manufacture of more advanced automated equipment will not only be beneficial to the mines as primary users, but will also encourage the development of the secondary and downstream manufacturing sector and service-orientated industries.

The feasibility of achieving the significant benefits that automation, robotics and control would bring, is constrained mainly by a lack of major funding support in order to transfer and adapt the necessary technology from foreign countries to meet local conditions. Furthermore, locally it would require the establishment of a supportive research and technology base to facilitate the transfer of technology into practical engineering solutions and the implementation thereof.

Recommendation: We strongly recommend that competency be developed 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 metallurgical sector.

To achieve this, government in collaboration with research institutions and the mining industry should—

- evaluate the current competencies in this field and examine how best to utilise the resources to address the longer-term development and implementation of automation, robotics and control technology in the mining and metallurgy sector;
- implement new collaborative research programmes that are integrated with current and emerging research programmes addressing the mechanisation of mining operations; and
- develop postgraduate courses at identified higher-educational institutions to support the collaborative research programme.

Key technologies:
- Sensor technology.
- Image enhancement techniques.
- Control systems.
- Real-time information processing.
- Simulation modelling.

Characteristics of Refrigeration, Cooling and Insulation (Theme B)

An important technological area underpinning the issue of health and safety in mining operations is the cooling and insulation of the underground workplace. In this area, especially in deep-level mining operations, South Africa's international competitiveness is considerable, but it is based on a balance of a reasonable level of our own technology supplemented by technologies acquired through joint ventures with foreign equipment suppliers.

Supportive government policy and structures facilitating research and development in this field are available, but they require reinforcing. This would include such things as a consolidation of the current DEEPMINE research programme between government and the mining industry. This programme addresses some of the issues captured in this theme. The findings of the survey confirm the importance of Theme B and the fact that failure to implement research and development in this area will negatively impact on the operation of existing mines and delay the opening of new mines.

It is felt that the development of appropriate technology, beyond that currently existing, will impact positively on deep-level mining operations, enabling mines to access new reserves at greater depth, reduce health risks to the workforce, and extend the operating lives of mines. In addition, the supply of technologies will, to a moderate extent, contribute towards the development of medium-sized downstream enterprises.

It is apparent that a major constraint on the development of technology is primarily financial, with lesser constraints being the development of a technology base, and the expansion of our research and development knowledge in this area.

Recommendation: We strongly recommend the development of more cost-effective solutions for the cooling and insulation of deep-level mining operations.

To achieve this, government in collaboration with the mining industry and research institutions should—

- accelerate activities in the DEEPMINE collaborative research programme to identify those cooling and insulation technologies that will ensure a safe working environment.

Key technologies:
- Sensor technology.
- Real-time control systems.
- Simulation modelling.
- Operations management.
- Materials engineering.

Characteristics of Downstream 'Added Value' (Theme I)

In general, the results of the survey questionnaire endorsed the view that the technologies underpinning this theme primarily impact on wealth creation issues. Furthermore, it is recognised that in most instances raw-material costs will represent a diminishing share of the cost of producing finished goods.

The overall opinion is that the sector is theoretically well placed to benefit from a mineral resource base but is poorly placed in terms of its own technology to develop an improved international competitiveness. There is a need to develop better relationships with overseas partners from both a technology and a market point of view, as most added value enterprises would have to be truly internationally competitive.

While it is recognised that some government support is received, e.g. from the DTI, a more cohesive and entrepreneurial support policy needs to be implemented by government to create a climate thatis more conducive to the 'added-value' initiative. The scope of these policies could be much wider than simply the well-recognised cluster enterprises.

There are enormous opportunities in this area, through 'added value' initiatives, to exploit and contribute towards South Africa's large and diverse mineral resource base. It would support primary producers by the 'pull through' of their products into larger markets and encourage smaller and medium enterprises into new products and manufacturing activities. This type of activity will have a multiplier effect on wealth and job creation. Exploitation of the technologies lends itself to clustering.

However, feasibility is somewhat inhibited by the locally available technology base. This situation is understandable in view of the diverse and more internationally competitive character of downstream industry. Government in collaboration with the private sector would have to carefully select these added-value products where it stands to gain the maximum benefit, rather than spreading its limited resources too thinly.

Although qualitatively there were ample indications in this sector of the potential importance of downstream developments, the Sector Working Group did not fully explore these. For example, the substantial existing and possible investments in South Africa were not clearly identified in respect of important industries such as stainless steel, aluminium, gold, zinc and magnesium. These are expected to be featured in the reports of the cross-cutting Beneficiation initiative and in the report of the Foresight Manufacturing and Materials Sector.

Recommendation: **We strongly recommend the commercial implementation of added-value opportunities where South Africa has, or could develop, a competitive advantage through the further processing of local and in some instances imported feed materials into intermediate and finished products.**

To achieve this, government in collaboration with research institutions and the private sector should —

- develop an information system to facilitate the exploitation of existing and new markets, and increase the opportunity to develop downstream, added-value, manufactured products;

- develop a collaborative programme of research that focuses on prioritised minerals in the first instance, but also integrates downstream from mining to finished product; and
- recognise and actively promote the concept of research into new and innovative technologies by improving the framework for added value and by providing the necessary sustainable incentives.

Key technologies:
- Beneficiation technologies.
- Manufacturing processes.
- Information technology (marketing).
- Database management.
- Materials engineering.

6.4 Summary

The following recommendations are based not only on the results of the survey questionnaire, but is the culmination of a process that has involved the knowledge of individuals within the Sector Working Group, together with an analysis of the sector from both a current and future perspective.

In the **short term** it is recommended that government in collaboration with research institutions and the SA mining and metallurgy sector should concentrate on the development of technologies that are captured in the themes of **Group 1**. Detailed recommendations are captured in the individual themes given previously.

The technologies in **Group 1** are perceived as having immediate impact on either wealth creation or quality of life issues or both, and ensure the competitiveness of the industry. **Information technology** impacts equally on both wealth creation and quality of life issues, while **transportation** and **mineral processing** technologies primarily impacts on wealth creation. **Health** and **safety** technologies are primarily related to quality of life.

However, it is felt that 'Theme D', namely **Refrigeration, Cooling and Insulation**, which is part of Group 3, needs special attention. It requires technological solutions that, although specifically for use in deep-level mining operations, do not impact greatly on the broader industrial sector but are nevertheless critical to the immediate future of the industry.

In the **medium term**, effort should be directed at the development of technologies captured in the themes underpinning Group 2 and given in detail previously. **Mechanisation** of underground mining operations is seen as a key technology for maintaining the competitiveness of the sector in the future, as is the development of

advanced exploration techniques and finding solutions to the **surface environment** issues.

In the **longer term**, it is apparent that **automation, robotics and control** of mining equipment and metallurgical plants, together with an **downstream, 'added-value'** secondary industry, as captured in Group 3, are seen as crucial to maintaining the competitiveness of the industry into the 21st century.

It is recommended that the above three programmes of research and technology be run in an integrated fashion and in parallel with one other, having different time frames for the outputs.