Foreword

The role of energy as a critical and essential precursor to both social and economic development is well established. This is particularly true for South Africa, where social and economic inequities were institutionalised over a long period. The energy sector is already playing a critical role in meeting equity and redress challenges in South Africa. The inclusion of energy in the foresight exercise will hopefully lend even greater momentum to this role, whilst identifying core research and technology strategies and priorities for the future. To this end the energy sector, if correctly positioned, will be able to continue underpinning the South African economy well into next century. This underpinning is not only based on low cost, high quality energy sources, supply, infrastructure and use, but also on environmental sustainability and the development of essential skills.

The development of energy foresight has been an exercise that tapped the collective wisdom of a wide variety of South Africans. I feel that this collective wisdom has resulted in a list of research and technology challenges and recommendations that can be used to focus activity in the energy sector — in both the public and the private domain.

The need for South African’s to focus efforts in a few key directions has never been stronger. The challenges of competing and achieving globally whilst developing South African Society are immense. We can only meet these challenges by pulling together, and learning from our pre-colonial, colonial and post-colonial heritage to produce African solutions to African challenges — as is so well captured in our President’s vision of the African Renaissance. Based upon the input received in the foresight exercise, I would say that the South African energy sector is more than ready to play a key role in this regard.

It has been an honour and a privilege to be in the Chair of the Energy Sector Working Group of Foresight over the last two years. The support for this process from Government, in particular the Departments of Arts, Culture, Science and Technology and Minerals and Energy, has been phenomenal, as has the personal commitment from the highest level in Government. The leadership and administrative and technical support of DACST has been a critical component in maintaining momentum and ensuring that we were able to produce this report. I would in particular like to thank the previous Director-General, Roger Jardine, the new Director-General, Dr Rob Adam, Foresight Manager Dr Phil Mjwara and Energy Sector Coordinator, Joe Strydom. This support, enthusiasm and commitment have produced this output.
Finally the Working Group of the Energy Sector can be particularly proud of the contribution they have made. Their innovation, hard work and continued dedication has been commendable, especially given the fact that, to a person, they had demanding high level full time occupations throughout the energy sector. The Working Group members are listed in Appendix B.

In conclusion, this document has been the outcome of a long and systematic process aimed at defining the Research and Technology opportunities for the energy sector. The true potential of this foresight will only be realised if practical action plans aimed at implementing the recommendations are established and applied.

The working group and I look forward to playing a role in this regard.

Dr S J Lennon
Sector Chairman
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Abbreviations and Acronyms

CSIR ................................................................................................................................. Centre for Scientific and Industrial Research
DACST ............................................................................................................................ Department of Arts, Culture, Science and Technology
DME ............................................................................................................................... Department of Minerals and Energy
DOE ............................................................................................................................... Department of Education
DTI ................................................................................................................................. Department of Trade and Industry
ESWG ............................................................................................................................ Energy Sector Working Group
HEI ................................................................................................................................. Higher education institutions
HR ................................................................................................................................. Human resources
ICT ................................................................................................................................. Information Communication Technology
IEA ................................................................................................................................. International Energy Agency
IPR ................................................................................................................................. Intellectual Property Rights
LPG ................................................................................................................................. Liquid petroleum gas
MCST ............................................................................................................................. Ministerial Committee on Science and Technology
Mintek ........................................................................................................................... Council for Mineral Technology
NGO ............................................................................................................................... Non–governmental Organisation
NIC ................................................................................................................................. Newly–industrialised Country
NRF ................................................................................................................................. National Research Foundation
NRTF ............................................................................................................................... National Research and Technology Foresight
NRTA ............................................................................................................................. National Research and Technology Audit
NSI ................................................................................................................................. National System of Innovation
R&D ............................................................................................................................... Research and Development
R&T ............................................................................................................................... Research and Technology
SABS ............................................................................................................................. South African Bureau of Standards
SACOB .......................................................................................................................... South African Chamber of Business
SADC ............................................................................................................................. South African Development Community
SAPP ............................................................................................................................... Southern African Power Pool
S&T ................................................................................................................................. Science and Technology
SETA ............................................................................... Skills Education and Training Authority
SMME ................................................................................................... Small, Medium and Micro-enterprises
STEER .................................................................................. Social, Technological, Environmental, Economic and Political
SWOT ...................................................................................... Strengths, Weaknesses, Opportunities and Threats
THRIP ........................................................................ Technology and Human Resources for Industry Programme
TRI ..................................................................................... Technology Research Investigations (now TSI)
TSI Technology Services Internationally (formerly TRI)
Executive Summary

The inclusion of the Energy Sector in the National Research and Technology Foresight exercise is an indication of the importance attached to this sector in the South African Economy. This report presents the results of an intensive exercise which was aimed at identifying those core Research and Technology opportunities that will position the energy sector as an enabler of both social development and economic growth in South Africa.

The report starts with a review of both the local and international situation in the energy sector. In particular, recent developments in the South African energy environment were highlighted. The focus of the White Paper on Energy was summarised, particularly the following main areas:

- Increasing access to affordable energy services
- Improving energy governance
- Stimulating economic development
- Managing energy–related environmental and health impacts
- Securing supply through diversity.

This environmental analysis was used to develop the following five focus areas for Energy Foresight with a time horizon of 20 years:

- Stimulation of economic growth by means of the energy sector.
- Socio–ecological sustainability related to the impact of energy activities on the physical environment and balancing it with the social equity pressures to ensure sustainability in the sector.
- Building on current competitive strengths by ensuring that focused, small future investments could realise large returns.
- Sustainable energy technologies.
- Implementation methodologies.

After a SWOT analysis, sector–specific scenarios were developed for the Energy Sector, based on an interpretation of the macroscenarios developed for Foresight as a whole. These scenarios were used to develop a wide range of statements that were regarded as sufficiently robust to be relevant under all scenarios. These statements were used as the basis of the survey that was used to develop data for the identification of Research and Technology priorities for the Energy Sector. The working Group used the prioritised statements from the survey to develop Research and Technology opportunities for the sector. Because the survey tended to average out any really innovative applications, the Working Group brainstormed additional wild–card technologies for inclusion in the final prioritisation process. In this way it was possible
to include both pragmatic short- to medium-term opportunities and long-term, high-risk, high-return opportunities.

The following list of priority Research and Technology challenges for implementation in the medium term were developed and rated in priority order:

1. Uses of coal discards
2. Low-cost solar water heating systems
3. Low-cost photo-voltaic solar home systems
4. Low-cost paraffin appliances
5. Knowledge-based energy information and energy simulation and modelling systems.
6. Low-cost electricity distribution, reticulation and metering technologies
7. Economic insulation for low-cost housing
8. Innovative energy applications for gas
9. Small-scale energy storage for stand-alone applications

The following list of priority Research and Technology challenges for implementation in the medium to long term were developed and rated in priority order:

11. End-use technologies to improve industrial competitiveness
12. Biotechnology for energy
13. Bulk solar thermal
14. High-efficiency power generation
15. Alternate energy delivery for rural SMMEs
16. Low-cost hydrogen production
17. Large-scale electricity storage

In addition to the technologies detailed above, there are three technological areas receiving considerable attention in South Africa at present. Whilst not part of the prioritised list, they were all in the ‘bubbling under’ category and therefore it was felt that they require further consideration. They are:

19. Wind energy — especially large-scale wind farms
20. Natural gas infrastructure
21. New nuclear technology such as the Pebble Bed Modular Reactor.

Detailed recommendations were developed for each of these areas. Typically, these tended to focus on the facilitation of an enabling environment for pilot programmes, financing mechanisms, capacity building, awareness development and research
programmes. The recommendations cover a variety of mechanisms ranging from the maintenance of current capacity and competitive edges, through the importation of technology to the development of new technology locally in partnership with international role players.

In addition to the technology–specific recommendations, the report includes a list of key success factors to support the recommendations in the following fields:

- Human resource development initiatives
- Business development initiatives
- Beneficiation initiatives.

Policy recommendations included in the report are based on the view that these conclusions and recommendations can be regarded as the implementation of Clause 8.5.4 of the White Paper on Energy Policy in terms of the development of a medium– to long–term energy R&T strategy. In addition, during the project it became abundantly clear that national energy policy and R&T strategies are linked, at times closely. The opportunity for the Department of Mineral and Energy to accept the responsibility to ensure the implementation of these results over time through the creation of the necessary systems, structures and bodies is stressed.

The report stresses the fact that no dedicated national funding for energy R&T exists, and that existing national funds are extremely limited. The situation is exaggerated by the fact that the allocation of energy funding by public sector (energy) bodies (DME, CSIR, Mintek, AEC, DACST, Eskom, CEF) are not coordinated or focused on national priorities. As a result it is recommended that medium– to long–term national funding be appropriately balanced over the main R&T challenges and that a Foresight energy fund be created and funding mechanisms developed to ensure that these R&T challenges are met.

General recommendations relating to the sustainability of the Foresight process through the continued activities of the working Group, as well as awareness development via a roadshow supported with appropriate communications material are also included.

The report concludes with a variety of lessons learnt. These include the positive experiences of continuity, strong leadership, good planning, strong support and commitment, as well as the negative experiences of an overlong and complex process that stretched participants to the limit of their technical and time resources.

Specific conclusions drawn from the exercise include the following:
• A mixture of medium- and long-term technological opportunities was identified across the full energy spectrum, albeit with a lesser focus on liquid fuels and transport. These opportunities represent a balance between supply and demand for both conventional and renewable energy applications.

• Technology development cannot be evaluated in isolation from policy. In particular, development and application of technologies are closely linked as addressed in the strategies detailed in this report.

• Whilst the National Research and Technology Foresight exercise has been a useful initiative, real added value will only be realised in the future implementation of the recommendations in this report.

• Lack of resources has been identified as a major constraint, thereby mandating a focus on the highest priority areas and excluding others. This emphasises the need for national technological capacity building if optimal value is to be realised from Foresight.

• Work in these areas is being undertaken by many role players. However, there appears to be a lack of coordination. A mechanism needs to be put in place to effect the coordination of foresight-aligned activities in South Africa.

• If South Africa is able to address most of the Research and Technology challenges identified in this process through the implementation of the strategies detailed in this report, then it will enable marked improvement in wealth creation and quality of life, whilst positioning South Africa strongly in the global energy sector.

• The recommendations are robust to accommodate all four energy scenarios and address projects that can be undertaken on a regional basis. Although the scenarios are equally plausible, the strategies support particular policies integrating South Africa with the rest of the world rather than inviting isolation.

In response to a strong belief that all information developed throughout the process should be captured, the report includes a number of detailed appendices which reflect the rough work of the Working Group. The purpose of these appendices is not only to capture these data for future national use, but also to encourage researchers and planners to use them for purposes of identifying alternative scenarios and opportunities in the energy sector in South Africa.
Chapter 1: Introduction

1.1 Background to the NRTF process

The National Research and Technology Foresight (NRTF) project is coordinated by the Department of Arts, Culture, Science and Technology (DACST). The Ministerial Committee on Science and Technology (MCST) commissioned the NRTF project. DACST initiated the project in 1996 and the Energy Sector Working Group (ESWG) conducted its work in 1998 and 1999.

Foresight’s mission is to promote technical innovation and deployment through a systematic process that identifies future opportunities for economic and social development for a given time horizon, which in the case of South Africa is twenty years.

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 will also inform the management of the innovation fund and research capacity-building programmes in the higher education sector as managed by DACST, the NRF, etc.

S&T has many stakeholders, including industry, government, academia, NGOs and society at large. Where possible all sectors were involved in the NRTF project and would also be involved in the implementation phase of the project.

An NRTF implementation plan is being developed to direct resources in accordance with the outputs of the project. An innovation fund from which identified projects can be supported will also be established. The private sector is encouraged to take up foresight outputs.

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

- 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.
• The methodological approach adopted employed a combination of techniques. These include strengths, weaknesses, opportunities and threats (SWOT) analysis, scenario analysis and survey of opinions on research and technology trends. Figure 1.1 shows a schematic representation of the Foresight methodology.

• The methodology also differs from that used in other countries in that, to contextualise sector work, macroscenarios for science and technology in South Africa were developed. These provided a uniform frame of reference for all sectors. The section on methodology addresses all of the techniques that were used in the South African foresight exercise in detail.

In an address to the first meeting of the Energy Sector Working Group the then Minister of Minerals and Energy, Dr Penuell M Maduna inter alia said the following:

'A nation that is energy-sufficient gains even greater independence. This, no doubt, is one of the objectives of any government. However, South Africa is, like any other modern economy, confrontted with an important question which concerns policymakers in the energy sector: What role, if any should the government play in the increasingly market-oriented energy sector? There are persons who maintain that government should have more influence over the market to curb carbon dioxide emissions, on the one hand. Governments are brought under extreme pressure to reduce their regulatory control over markets to increase competition and ostensibly make energy less costly to consumers.

It is my humble submission that in our case in particular, the public and private sectors are not mutually exclusive; they have a great potential to be mutually reinforcing instead. In the area of research and development in particular government has undoubtedly an important role to play in meeting some of the challenges that face us in the energy sector. It can for one thing, form partnerships with the private sector to ensure that our energy sector becomes more accessible to all and sundry on a non-racial and non-sexist basis. It should become more representative in its composition and begin to involve the direct victims of the ancien régime at levels higher than that of retailers of liquid fuels. It can also use a great deal of the scarce public resources at its disposal to promote research and development in the energy sector as envisaged in the Central Energy Fund Act, 1977...

The scene I have briefly sketched above suggests that a number of opportunities do exist for South Africa to exploit to the fullest. The challenges, though many and multifarious, are daunting. We need research and technology that will enable us to play and compete with the best in the world. I have no doubt that your working
group will rise to the occasion and develop the necessary strategies. This project requires the total commitment of each one of us; the government is fully behind it.

1.2 Energy sector

1.2.1 How the energy sector was identified to be part of the Foresight project

A total of eight sector selection workshops were conducted countrywide in the early stages of the Foresight project to determine which sectors were of national importance and should be part of the Foresight project. Delegates from 21 academic and research institutions, 34 businesses and 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 participated in this workshop process. Furthermore, meetings with a sector selection focus were held with representatives from an umbrella civic organisation, a provincial trade union confederation and a youth organisation. The outputs of these workshops were analysed and a profile of each sector was compiled using the available data.

The sectors that were finally selected by the NRTF advisory board reflect the goals of the exercise and have drivers that include social development, technological development and wealth creation. After the sectors were selected, sector-specific consultation was also carried out by each of the sector coordinators. The sectors are presented in Appendix A.

1.2.2 Sector vision and mission

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 achieved:

- The establishment of a system of technological and social innovation;
- The development of a culture which values the advancement of knowledge as an important component of national development;
- Improved support for innovation, which is fundamental to sustainable economic growth, employment creation, and equity through redress and social development.
The Foresight mission to promote technological innovation and deployment by identifying opportunities for economic and social development was used to direct the energy sector mission.

The Energy Sector mission as developed by the Energy Sector Working Group is as follows:

To identify strategic research and technology topics and strategies for the energy sector in South Africa that would realise sustainable economic and social benefits for the country over the next 15 to 20 years.

1.2.3 Energy sector focus

The working group used a number of tools and extensive information to identify priority sector areas. The following five areas of focus were identified by the working group to assist in the establishment of priorities during the Foresight process:

Economic growth

The following issues were identified as priority issues to stimulate economic growth by means of the energy sector:

• Exports of locally developed and adapted technology (e.g. pebble bed nuclear reactor, hypercar) on a commercial basis.
• The improvement of energy efficiency throughout the energy value chain. Lower-cost energy production, transport and usage will lead to lower-cost energy services to consumers.
• The stimulation of productive activities.
• Job creation and job retention in the sector.
• Sustainable and non-interruptible energy supply to customers.
• An energy mix available to customers that encourage choice, sustainability and competition.
• The development of appropriate energy technology that focuses on developing world needs ('African currency').
• The exploitation of Information Technology opportunities in the energy sector.

Socio-ecological sustainability

This area is concerned with the impact of energy activities on the physical environment and balancing it with the social equity pressures to ensure sustainability in the sector. The following important issues were identified:

• Sustainability of rural biomass.
• Management of emissions and waste.
• Environmental impact and resource exploitation.
• Political sensitivity of environmental issues.
• Affordable and appropriate energy to as wide a consumer base as possible, i.e. poverty alleviation.
• Rural and urban energy requirements for cooking, lighting, heating, refrigeration, etc.
• The impact of industrial development and waste management.
• Education.

Examples of technologies that could fall within this focus area are: smokeless fuels, low–cost electrification, distributed energy supply systems and low–cost appliances for the domestic and industrial markets. Financial instruments need to be developed to support the adoption and absorption of the newly developed technologies into the marketplace.

Building on current competitive strengths

If a current strength could be leveraged to the benefit of the sector it should be utilised fully. The investment to establish the strength has already been made and small future investments could realise large returns. The issues of importance are as follows:

• As a matter of priority, the local energy needs must be met and then external markets must be exploited.
• South Africa must have a strategic advantage to exploit. Current examples are:
  – Well–defined coal infrastructure and mining expertise,
  – Synfuel technology,
  – AEC nuclear energy technology,
  – Electrification technology, and
  – Lowest cost electricity.

Sustainable energy technologies

This includes the development of —
• energy–efficient technologies for energy supply and for domestic and industrial use;
• solar–power technology;
• hydro– and micro–hydrotechnology;
• wind, biomass and nuclear energy technology;
• human power (water pumping, bicycles, wind–up technology);
• emissions control for processing, transport, and petro–chemical industries;
• clean–coal technology; and
methods of economic assessment of different energy technologies taking account of full life cycle cost (this cuts across many other areas).

Implementation methodologies

The following issues are of importance for the implementation of the energy sector outputs:

- Funding mechanisms.
- Pilot projects.
- Private sector incentives.
- Improvement of efficacy.
- Protection of intellectual property.
- Social issue and community values.

1.3 Participation

1.3.1 The co-nomination process

A co-nomination, survey-based technique, which allowed the major stakeholders and the broad community to participate fully in an open exercise, was used to identify those individuals to participate in the sector working groups.

Four iterations of co-nomination were carried out. The response rate was above 30% and 2,573 names were generated. Most of the respondents were from higher education institutions (35.3%) and 88.2% were males. Few individuals from previously disadvantaged backgrounds and from labour organisations were identified via co-nomination. To make sure that the make-up of working groups was more representative, other individuals were appointed directly into these groups.

1.3.2 Working Group

A combination of two methods was used to identify working group members. These were:

- Co-nomination adapted to the RSA situation to identifying members of the sector working groups;
- Direct appointment by DACST in consultation with the Advisory Board and Project Management Team.

The Energy Sector Working Group (ESWG) was the operational arm of the NRTF project energy sector. The group was tasked to analyse the energy sector and to
identify issues as well as research and technology solutions to sector challenges. The names of the members are listed in the Appendix B.

1.3.3 Sector stakeholders

In addition to the ESWG members, there were other important participants in the Foresight project. They include —

- the 'pool,' that is, an expert group generated through the co-nomination process that participated in the postal survey.
- the 'stakeholders,' that is, individuals from organisations and institutions identified during the general Foresight and sector-specific consultation, which served as a reference group to the ESWG.

The involvement and participation of these role players were important to the project in that they acted as —

- a reference group to give feedback;
- participants in the Delphi survey;
- a source of expertise for specific issues; and
- part of the peer review process and thus participated in the evaluation of the project.

1.4 Process

1.4.1 Sector Working Group terms of reference

The sector working group investigated future socio-economic challenges facing the sector and identified the impact these will have on the sector. The sector was analysed within the South African context while recognition was given to its contribution to the global and regional economy. The sector working group identified market opportunities as well as research and technology requirements that will assist the sector in enhancing its performance and also addressed social issues. The responsibilities of the sector working group was as follows:

- To agree on proposed sector foci.
- To analyse the current status of the sector.
- To identify future research and technology challenges and market opportunities over the next ten to 20 years.
- To provide recommendations on the identified cross-cutting issues/areas.
- To compile a prioritised list of research and technology topics.
- To provide recommendations on an implementation strategy.
- To compile the Foresight sector report.
• To assist in identifying research and technology themes towards the design of appropriate research programmes.

1.4.2 Workshops

Altogether, eight workshops were held with the ESWG. The work programme and agenda of the ESWG meetings are given in Appendix C.
Chapter 2:
Local and international context

2.1 Introduction

This chapter supplies the local and international context that formed the background to this study. It starts with a description of South Africa’s energy systems, then lists the national energy policy objectives. These are followed by a description of the process as it unfolded and an overview of trends that could affect the energy sector.

2.2 Description of the South African energy system

2.2.1 Introduction

South Africa is a country endowed with abundant energy resources. Fossil fuels, such as coal, uranium, liquid fuels, and gas, play a central role in the socio-economic development of South Africa. This section, Description of the SA energy system, is a summary of the White Paper on South African Energy Policy. The description of the SA energy sector is divided into three sections, SA energy demand sectors, SA energy supply sectors and Cross-cutting issues.

2.2.2 South African energy demand sectors

Households

South African households consume some 24% of the country’s energy. By the end of 1997, about 60% of households had access to electricity. Yet this energy source contributed only 20% of household energy consumption. Most energy was obtained from fuel wood (65%). Other fuels used include coal (9%) and illuminating paraffin (8%), and a small amount from liquid petroleum gas (LP Gas) makes up the remainder.

Industry, commerce and mining

Industry, mining and commerce account for about 60% of commercial energy consumption in South Africa, at a cost of approximately R18 billion in 1995. The low price of coal and electricity in South Africa has contributed to the development of an economy with a large energy-intensive primary industrial sector. Mining and minerals
beneficiation were responsible for 11% of South Africa's GDP and over 50% of South Africa's foreign exchange earnings in 1995.

Transport

The transportation of people and goods is an essential social and economic service, and accounts for about 24% of total energy consumption. More than 90% of transport energy is derived from liquid fuels.

Agriculture

About three per cent of the total energy used in South Africa is consumed by agriculture, mainly by commercial farmers. Traction and transport tasks dominate this energy use, as evidenced by the fact that liquid fuels meet three-quarters of commercial agriculture's energy requirements. Stationary operations, such as lighting and refrigeration, are generally performed with electricity, although diesel is also used to power pumping and dehulling activities.

2.2.3 South African energy supply sectors

Electricity

South Africa produced 179 450 GWh of electrical energy in 1997. Ninety-six per cent of this amount is generated by Eskom and transported over its national transmission network to distributors countrywide. More than 400 distributors, mainly municipal electricity departments, supply electricity to end customers. Eskom is also the largest single distributor in the country in terms of energy sales for final consumption and number of customers.

Nuclear energy

Nuclear energy is a minor component of the South African energy sector. It contributed about 3% during 1997 of the national primary energy supply, and about 5% of the country's electricity. The main actors in the nuclear sector are the Atomic Energy Corporation (AEC), Eskom, the Council for Nuclear Safety (CNS) and the private sector Nuclear Fuel Corporation (Nufcor).

Oil and gas: exploration and production

Despite its generous minerals endowment, South Africa has no significant proven crude oil reserves, but it is believed that potential exists for offshore discoveries of both natural oil and gas and onshore coal-bed methane in South Africa.
Liquid fuels

Present crude oil refinery capacity is 455,000 barrels per day with the capacity of the Sasol synthetic fuels plant being 150,000 barrels per day and Mossgas 45,000 barrels per day of crude oil equivalent. About one-third of fuel demand is met by the synthetic fuels industry.

During 1997 South Africa imported approximately 23.6 million tons of crude oil and 21,300 Ml of refined product was consumed. Crude oil is South Africa's single largest import item. Approximately 15% of South Africa's primary energy consumption is currently met by imported crude oil. Taking synthetic fuel production into consideration, liquid fuels meet approximately 28% of South Africa's final energy needs.

Gas

South Africa has relatively small known gas resources of 30 billion cubic metres (bcm) off the south coast and some very small recent discoveries (3 bcm) off the west coast. However, the potential natural gas resources have not yet been fully investigated. To date, South Africa has undertaken limited exploration for oil and natural gas leading to twenty gas and nine oil discoveries.

Coal

South Africa has a coal resource of approximately 121 billion tonnes, of which about 55 billion tonnes are classified as economically recoverable reserves. Although coal's contribution to South Africa's total primary energy supply has declined slowly, at the current level of approximately 75% during 1997, it still dominates the energy sector. Approximately half the coal consumed in South Africa is used for the generation of electricity, and a quarter for the production of synthetic liquid fuels. A large number of urban households in the central industrialised area still continues to burn coal, even after electrification.

Renewable energy sources

Renewable energy resources provide approximately 10% of South Africa's primary energy. Biomass, in the form of firewood, wood waste, dung, charcoal and bagasse, accounts for close to 10% of net energy use at the national level (60% of household energy consumption). Hydro–electric power contributes less than 1% of electricity generation and most of that is pumped storage. Other renewable energy sources make up a small but increasing proportion of energy supply. These include biogas and landfill gas, which need to be promoted in order to address thermal energy needs.
Although more than 484 000 m² of solar water heater panels have been installed, this constitutes less than 1% of the potential market. The installed capacity of photovoltaic systems is approximately 5 MW peak, of which 50% is used for telecommunications. A total of 280 000 water-pumping windmills are in operation and the installed capacity of small-scale hydropower exceeds 60 MW.

2.2.4 Cross-cutting issues

Integrated energy planning

Integrated energy planning (IEP) is a process involving various technical functions to supply and use the information on energy demand and supply required to inform policy development in the South African energy sector. Such capacity does not currently exist within South Africa.

Statistics and information

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

Energy efficiency

Since expenditure on energy constitutes a large portion of the country's GDP (15%) and a particularly large proportion of poor households' expenditure, it is necessary to give attention to the effective and efficient use of energy. Significant scope for improved energy efficiencies exists within the industrial, commercial, domestic, and transport demand sectors.

Environment, health and safety

In common with most countries in the world, South Africa's energy sector has a significant positive and negative impact on the environment and on resources. These have given rise to a number of environmental challenges, many of which result from the lack of infrastructure investment in poor residential areas, while others result from the methods adopted to exploit the country's natural resource endowments. These environmental impacts vary widely in scale and severity, ranging from the local level where people's health is affected on a daily basis, to regional and global impacts where the effects are more difficult to identify and control. Because energy–related environmental issues affect many sectors of society, different government departments exercise functions that involve the management of these environmental issues.
Research and development

Energy research is currently supported by government, government agencies, parastatals and the private sector. The Department of Minerals and Energy manages a limited non-nuclear research programme, currently worth only R20 million per annum. It is focused on policy development and related programmes that are conducted by researchers at universities, research institutions and NGOs on a contract basis. Two other public sector organisations, the Atomic Energy Corporation (AEC) and Eskom, have significant research programmes. The activities of the AEC constitute the largest item on the Department of Minerals and Energy budget, although this is decreasing. These resources are used for institutional nuclear activities carried out for the government, nuclear enrichment research, high technology nuclear-based commercialisation activities and the decommissioning of uneconomic plants. The AEC spends approximately R30 million per annum of public sector funds on energy-related research. Research spending in Eskom, predominantly through the Technology Research and Investigations division (TRI), currently amounts to R123 million per annum and is increasing. Government spending on energy research, particularly in nuclear energy, has decreased steadily since 1990.

Human resources

Employment in the energy sector demonstrates trends similar to other economic sectors. A recent study of government energy institutions, as well as the electricity, petroleum and nuclear subsectors, showed that while 46% of staff were black, only 7% occupied managerial positions. Women were underrepresented in the sector, comprising 11% of the total workforce and accounting for 5% of total management. Black women were particularly underrepresented, comprising 1% of the total workforce and accounting for 1% of total management. This figure excluded petrol attendants at service stations.

Capacity building, education and information dissemination

South African energy consumers, from low-income households to business and industry, are poorly informed about good energy-use practices and options. This lack of consumer knowledge about the effective use of energy undermines economic competitiveness, the sustainability of development initiatives, the environment and people's health. That education and information can play a central role in addressing these problems is borne out by international experience.

International energy trade and cooperation
South Africa is actively involved in energy trade and cooperation with a number of countries in the region and further afield. Imports include crude oil and energy conversion plant and equipment and exports include coal for international markets and refined liquid fuels for regional markets. Active co-operation with a number of countries and organisations has developed over the years, particularly from 1993, and full official participation in Southern African Development Community (SADC) activities commenced in June 1994.

**Fiscal and pricing issues**

Government's current fiscal policies have many linkages with the energy sector, with five main categories of fiscal transfer, namely, value-added tax, income tax, special taxes and levies, tariffs, and implicit taxes.

**Governance and institutional capacities**

At present, parliament and its committees are responsible for energy legislation and the supervision of the executive arm of government. The executive consists of cabinet, the minister and the department, who are together responsible for formulating and implementing energy policy. Appointed boards or councils supervise a range of government-owned energy organisations, some created by means of a specific act, in order to provide them with strategic direction on their operational activities.

### 2.3 Objectives of the South African energy policy

This section summarises the contents of the White Paper on Energy Policy in South Africa.

#### 2.3.1 National context

Since 1994, the interests of the South Africa majority have found expression through new social and economic policies, particularly the Reconstruction and Development Programme (RDP). The government's new macro-economic strategy, Growth, Employment and Redistribution (GEAR), places emphasis on two core strategies:

- Promoting growth through exports and investment; and
- Promoting redistribution by creating jobs and reallocating resources through the budget.

The energy sector can contribute to economic growth and employment creation, as well as providing infrastructure for households. The RDP base document included a
number of policy proposals, especially the electrification of 2.5 million households by 2000, which the industry is well on its way to achieving.

2.3.2 Energy sector policy objectives

The following five policy objectives form the foundation for South Africa’s energy policy:

- Increasing access to affordable energy services
- Improving energy governance
- Stimulating economic development
- Managing energy-related environmental and health impacts
- Securing supply through diversity.

The main actions that form part of each objective with a short-term (1–3 years) and medium-term (4–10 years) horizon are as follows:

Objective 1 — Increasing access to affordable energy services

Short term

- Improve the delivery of household energy services, including electrification.
- Develop a national electrification policy, planning and financing system.
- Treat off-grid electrification in the same way as grid electrification.
- Facilitate the production and management of woodlands for rural households.
- Establish voluntary guidelines for the thermal performance of low-income dwellings.

Medium term

- Stimulate the development of new and renewable sources of energy.
- Promote improved combustion techniques and appliances for fuel wood and other traditional fuels.
- Support the development and implementation of capacity-building, education and information dissemination programmes.

Objective 2 — Improving energy governance

Short term

- Improve government’s capacity to govern.
- Improve energy policy formulation processes.
• Restructure the Department of Minerals and Energy’s budget to reflect the new policy priorities.
• Promulgate a new regulatory bill to consolidate the electricity regulatory regime.
• Maintain the liquid fuel regulatory system until a re-regulated system, based on competition, has been planned and implemented.
• Establish suitable energy information, statistical and database systems.

Medium term

• Facilitate the development of a research strategy to improve energy research and development.
• Develop and implement an appropriate system to co-ordinate energy research.
• Restructure state energy assets.
• Implement new regulatory arrangements within the nuclear sector.
• Clarify the mandate and role of the various nuclear energy bodies, including the separation of governance and implementation functions, by means of appropriate legislation.
• Establish suitable renewable energy information, statistical and database systems.
• Create appropriate institutional capacity to implement energy efficiency programmes.

Objective 3 — Stimulating economic development

Short term

• Encourage energy sector actors to facilitate economic empowerment through the creation of SMMEs and by assisting previously disadvantaged people to gain entry to the energy sector.
• Appoint an authority to oversee the restructuring of the electricity distribution industry.
• Restructure the state’s other energy assets.
• Develop and implement strategies to remove energy trade barriers, improve the availability of information and facilitate investment in the energy sector.
• Introduce special purpose levies to fund dedicated regulatory and energy development agencies in a transparent manner.
• Adjust electricity market structures to achieve effective forms of competition.
• Establish regulations that promote a cost-of-supply approach to electricity pricing for non-domestic consumers.
• Re-regulate the liquid fuels industry to achieve higher levels of competition and unrestricted market access.
• Promote energy efficiency in all sectors of the economy.
• Establish the necessary legislative and regulatory arrangements for the development of the up- and downstream natural gas industry.
• Develop standards and codes of practice for the correct use of renewable energy systems.
• Introduce a voluntary energy appliance labelling programme.

Medium term

• Adjust electricity market structures to achieve effective forms of competition.
• Establish regulations that promote a cost-of-supply approach to electricity pricing for non-domestic consumers.
• Re-regulate the liquid fuels industry to achieve higher levels of competition and unrestricted market access.
• Promote energy efficiency in all sectors of the economy.
• Establish the necessary legislative and regulatory arrangements for the development of the up- and downstream natural gas industry.
• Develop standards and codes of practice for the correct use of renewable energy systems.
• Introduce a voluntary energy appliance labelling programme.

Objective 4 — Managing energy-related environmental impacts

Short-term

• Improve residential air quality.
• Monitor the effect of electrification on the number and severity of fires caused by candles and paraffin.
• Introduce safety standards for paraffin stoves.
• Follow a no-regrets approach on energy-environment decisions.

Medium-term

• Develop a policy on nuclear waste management.
• Facilitate the monitoring, evaluation and demonstration of clean energy technologies.
• Investigate options for the use of coal discards.
• Monitor international developments and participate in negotiations on response strategies to global climate change.
• Investigate an environmental levy on energy sales to fund the development of renewable energy, energy efficiency and sustainable energy activities.

Objective 5 — Securing supply through diversity

Short term
• Develop the Southern African Power Pool to the mutual benefit of all of its members.
• Actively pursue energy sector cooperation with appropriate countries and international bodies.
• Stimulate energy research and development partnerships between local role players and international agencies.
• Actively facilitate regional co-operation on energy matters.

**Medium term**

• Utilise integrated resource planning methodologies to evaluate future energy supply options.
• Reappraise coal resources and support the introduction of other primary energy carriers as appropriate.

### 2.4 Process followed by the Working Group

The objective was to review the energy sector to identify areas of research, science and technology that are likely to yield economic and social benefits for South Africa in the long term (an approximate 15–20 year time horizon was considered). Firstly, a holistic review of the international and local energy sector was undertaken. This consisted entirely of desk research (a review of available publications and databases). At the same time account was taken of emerging opportunities on the one hand and internal strengths and weaknesses of the country on the other. Four main areas were assessed in the strategic analysis. They are —

• identifying the evolving economic and social needs and threats;
• identifying emerging scientific opportunities;
• identifying factors affecting the country's capability to exploit the potential economic or social benefits of the new technology including its comparative industrial strengths and weaknesses; and
• identifying scientific strengths and technological capabilities in order to take advantage of scientific and technological opportunities.

### 2.5 Trends that could influence the energy sector

Hunter and Simonson conducted a study examining current technological, market, policy and strategic trends of the energy sector internationally. A summarised review follows.

#### 2.5.1 Introduction
The world’s energy scene is changing rapidly. The oil crisis of the 1970s put energy at the top of the international political and economic agenda. Also, the collapse of oil prices in 1986, the Three Mile Island incident and the Chernobyl disaster all created an atmosphere of uncertainty in the world's largest industry. Added to this, rising concerns about and an increasing awareness of the environmental implications of energy production and use have complicated the situation. The enhanced greenhouse effect, tropical deforestation, acid rain, the problems associated with nuclear waste management, the destruction of habitats by hydroelectric dams, air quality in cities and other environmental fears have led societies to question the sustainability of a way of life based on high levels of energy use.

2.5.2 Social trends

Three major social trends, namely population growth, urbanisation and industrialisation, have had a direct impact on the per capita energy consumption of nations.

Population growth

According to the United Nations and the World Bank, the global population is projected to increase from 5,8 billion in 1995 to 8,3 billion in 2025. Most of the future growth will occur in the so-called 'third world' or underdeveloped countries. Worldwide, population growth alone will boost total world energy consumption from 13,1 TW in 1990 to 18,9 TW by the year 2025. The amount of energy used per capita in a developed country is, on average, six times greater than in a developing country. The relationship between energy, population growth, and sustainable economic development will be of critical importance during the next half-century. Pressures on the carrying capacity of the earth's ecosystems will become increasingly evident.

The October 1997 census put South Africa's population at 37 859 million on a preliminary estimate. Fig. 1 shows the population growth since 1911. The high population growth rate and low population density in South Africa will lead to challenges for the energy sector to make affordable energy available to a growing market.

At a rate of 2,02% per annum, South Africa currently has the lowest population growth rate in the Southern African region, although still one that is higher than the world average, which peaked at 2,04% during the late 1960s and is expected to decline to 1% for the period 2020–2050. It is estimated that the annual South African population growth rate will decline to 0,96% for the period 2021–2026.

Urbanisation
The world’s urban population is growing at a much faster rate than its overall population. More than 80% of the population of industrialised countries live in urban environments and many developing countries show similar high rates. According to the UN, 2,2 out of 5,3 billion people (42%) lived in urban agglomerations in 1990, with a projected 60% expected to live in urban areas by 2025. Research has shown that per capita net energy consumption in urban dwellings is higher than in rural areas for developing countries. Underlying reasons are, inter alia, the following:

- The amount of energy required to satisfy a more modern (urban) lifestyle is reflected in the use of more commercial fuels, and the increased demand for services (including water), which entails increased transportation and other energy-using processes.
- Waste generation, which increases significantly with urbanisation and requires energy resources to suitably dispose thereof.
- Development of formal mass housing, which often occurs at a considerable distance from centres of economic activity, resulting in a further increase in the consumption of liquid fuel in transport from dwellings to work and back.

The overall urban population of South Africa was estimated to be 55,4% (up from 48,3% in 1994). This will have an impact on the energy sector from a rural and urban perspective.

**Industrialisation**

As a developing economy, South Africa has made substantial progress in the process of industrialisation (characterised as a progressive move away from primary sector activities such as agriculture and mining, to secondary sector activities, and finally, to tertiary sector activities). The manufacturing sector, today, constitutes the most important sector in terms of employment and income creation. South Africa has a relatively large, diversified and advanced manufacturing sector (within an African context).

**2.5.3 Political/institutional trends**

Innovation cycles of technology development are directly influenced by the rate of change in the world economy, which to a large extent is a function of the global political/institutional climate.

**Current global political/institutional landscape**

Geopolitical tensions have diminished somewhat in recent times. The agreement for further trade liberalisation and the formation of the World Trade Organisation (GATT, up to 1994) has advanced prospects for global economic integration. In the
next century, world trade is expected to be the 'engine of growth'. Regionalism in the
global economy is also rapidly reshaping world trade from an economic and political
perspective. The economic and developmental gap between the 'South' and the
industrialised world is widening.

South Africa's relations with the world

In the shorter term (i.e. over the next decade), South Africa's international position
will, to a large extent, be affected by its economic strength. South Africa is likely to
remain the strongest economic power in Africa (as the only country on the continent
classified as an emerging market), provided it can maintain political and economic
stability.

South Africa's current and future relations with Southern Africa

Within Southern Africa, South Africa has the largest population (39% of the total)
and by far the largest GDP (81% of the total). Inter-regional asymmetries of this kind
could lead to trade imbalances and, in addition, social conflicts may also emerge from
rapidly declining economic activity in some southern African states.

Fig 1  Growth of the SA population in the 20th century (Spies, scoping study for the
DACST Research and Technology Audit)

South Africa

South Africa has historically been politically divided and continues to be socially and
economically divided. Current strategies for development fit into an overall macro-
economic policy entitled GEAR, together with directly RDP-related projects for service
 provision and employment generation. Added to these is the development of
economic zones/nodes linked by corridors. Other factors that will also influence South
Africa are the rapid developments in communications and information technologies
that have converted the world into the metaphorical global village. Furthermore, the
trend toward increased privatisation and the emphasis on profitability will have a
profound effect on the developing world and how it plans for its sustenance. The
increasing influence of global institutions like the World Bank and the IMF become
another major factor in the equation.

2.5.4 Environmental trends

Current global trends

Evidence has been mounting over a number of decades that the current global
pattern of energy production and use is neither environmentally benign nor
sustainable. Environmental care has therefore become one of the most important
issues on the political agenda. At the heart of sustainable development lies the
objective of integrating the dual goals of economic growth and a healthy natural
environment. Economic growth offers the greatest potential for alleviating poverty and
for protecting the environment. Poverty is both a major cause and effect of
environmental problems. Economic activity depends on a healthy environment, and
good environmental behaviour makes economic sense.

Future trends

With the current negotiations surrounding international agreements on climate
change and biodiversity, the global community is involved in the collective
responsibility and management of global ecological issues. Trends point very strongly
to tighter global environmental regulation, particularly in the North. A suitable
international institution may have to be assigned the responsibility for enforcing global
environmental legislation.

The South African situation

In a global context, South Africa is the highest emitter of greenhouse gases on the
African continent. Studies indicate that South Africa is responsible for about 1,4% of
global carbon dioxide emissions (total CO₂ emissions are about 350 million tons
annually). Initiatives to formulate and implement environmentally sustainable
development practices, in the near future, remain one of the most pressing issues
facing government and industry.

2.5.5 Economic trends

The world economy has continued to expand at slightly less than two per cent per
annum. Regional experience, however, has been varied. The OECD countries
continued to grow at exactly the global rate. In the developing countries, average
annual GDP growth has been close to five per cent. Asia has seen the most impressive growth, whilst growth in Africa and the Middle East has been particularly low. Although the North and the South represent the top and bottom ends of the hierarchy, the ranks of the North are continually being widened to include the semi–developed nations of Southeast Asia and Latin America, also called the newly industrialised countries (NICs).

Global economic situation in the sector

The intensity of energy usage rises with increased economic development, particularly during the phase of primary industry development. The energy intensity of most developed countries started decreasing in the first half of this century. A number of important stages in energy use patterns can be distinguished. They are as follows:

- An initial stage characterised by energy demand elasticity (related to economic output) exceeding one. This is representative of most developing economies.
- A second stage with energy demand elasticity of approximately one. This is typical of most newly industrialised countries.
- A third stage with energy demand elasticity smaller than one. This reflects most industrialised countries.
- A fourth stage, in which increases in economic growth are associated with low or negative increases in energy use, because of environmental pressures and improvements in energy conservation and efficiency. Developing countries tend to have higher energy demand elasticities than industrialised countries, on average about two to one.

According to the International Energy Agency, world energy intensities decreased between 1971 and 1992 by approximately 0,8 per cent per annum, and according to their projections, world total primary energy demand is projected to increase by an average annual rate of 2,1% between 1992 and 2010. Total primary commercial energy demand in Africa is projected to increase by an annual average rate of 3,8% for the same period.

South Africa’s energy intensity is one of the highest in the world. The pattern of economic development in South Africa is expected to change direction over the coming decade. This is expected to affect, inter alia, the inter– and intra–sectoral composition of the economy, the physical infrastructure, the institutional structure, the technology of production, and the quality of manpower. A high–growth scenario will have substantial, but not necessarily proportional, effects on the demand for energy in South Africa.

South Africa is classified as a medium–sized, developing and relatively open economy. Compared to the OECD countries and most other developing countries,
South Africa's competitiveness is relatively poor. South Africa's annual population growth rate since 1980 has been higher than the annual growth in real GDP for the same period, resulting in a negative per capita GDP growth rate.

The growth potential for energy exports is significant in the form of coal, electricity and energy intensive products (e.g. aluminium and ferroalloys). The effect of regional interaction on the energy sector will become evident soon and it could change the established demand and supply patterns. Pressure on sustainable energy development and cleaner and efficient energy technologies is expected to increase in the medium term. The trends in increased use of liquid fuels, natural gas (especially important with Kudu and new gas to liquid technologies), LPG, biomass and nuclear could cause coal to be displaced as primary fuel in certain applications.

2.5.6 Energy research and technology trends

Introduction

The predominant global preoccupation in the field of energy technologies has become the search for environmentally more benign technologies, with the main focus being on energy efficiency, renewable energy and the decarbonisation of the energy economy. A major focus is on reducing the generation of greenhouse gases, with carbon dioxide reduction being of special interest.

Historical trends in energy technology

According to Energy Futures (1996, p. 4–5) the innovation of energy, roughly 200 years ago, provided the basis for economic growth through the use of steam, oil and electricity. At the present time, at a higher level of energy use, energy is transformed into information and knowledge. Further development in the technical fields of solar energy and hydrogen could have direct implications for the energy mix of the future. Likewise, further development in ceramics, composites, microelectronics, laser/glass fibre and gene technology could all considerably change the way energy is used.

South Africa's energy research and technology expenditure

South Africa compares poorly with other countries in terms of expenditure on energy–related R&D. South Africa is responsible for less than 0,1% of global research and technology development expenditure. According to Energy Futures (1996), South African expenditure on R&D lags behind the equivalent figures in major developed and developing countries. Total R&D expenditure was R2,6 billion in the financial year to February 1994. At 0,75% of gross domestic product, this figure was ahead of the equivalent ratios in Brazil, Mexico and Egypt, but well behind the levels in South Korea, Taiwan, Denmark and Canada. Approximately 54% of research expenditure in South
Africa was by the private sector. In the White Paper on Science and Technology, reference is made to South Africa's National System of Innovation (NSI) which is the enabling framework for science and technology.

Current international technological position within the Energy Sector

Primary energy resources

What is clear is that fossil fuel resources are still relatively abundant, and will continue to be the main source of world energy well into the 21st century. They will, of course, become scarcer and more difficult to extract, consequently becoming more expensive, but this trend will be gradual. Their use, however, has disturbing environmental implications, and international efforts to limit the growth of fossil fuel combustion are now a major focus of attempts to confront the threat of global warming. Despite this, it will be some time before fossil fuels become so scarce that their cost produces major changes in the way societies use energy.

Oil

According to Mannion and Bowlby (1992, p. 137), improved exploration technology has enabled oil reserves to be discovered at a far faster rate than they are used, and much of the world has yet to be properly explored. Consumption in the developed world actually declined, from about 1 900 million tonnes a year in the early 1970s to around 1 600 million tonnes in the late 1980s. The current 'best guess' for the future of oil is that supplies, and consequently prices, will not be under serious pressure until the end of the century unless political factors intervene (the impact of the 1990–91 Gulf crisis again shows how real that possibility is). After that, production can certainly be maintained at a constant level until the middle of the next century and will then gradually tail off. As such, oil will be a major source of energy for at least as many years into the future as it has been in the past.

South African imports in liquid fuels totaled R9 560 million in 1995. This is 8% of total national imports and the single biggest item listed. International companies own 65% of crude-oil refining capacity. Sasol has developed technology for the recovery of liquid fuels from coal. It is changing its research and development focus on higher-value-addition commodities such as chemicals and polymers. Paraffin distribution networks are generally good, but supply arrangements of paraffin and LPG to the poorest households could be improved, as excessive mark-ups are common.

Gas

Consumption of natural gas has grown rapidly over the last 20 years, and, like oil, the resource future is bright. Proven reserves, at 98 trillion cubic metres, are equal to
those of oil. Many geologists believe that ultimately the recoverable gas resource could be even greater than that of oil, enough to last for at least 100 years and probably far longer. A problem could arise with its distribution, however, with 43% of current reserves in the Russian Federation. Consumption of natural gas has been growing more rapidly than that of any other fuel. Gas has many advantages as an energy source. It is a high-quality fuel, is useable in many different sectors, and is particularly favoured by industry and by households in regions of the world with cold climates. It is often cheaper than competing sources of energy, and can be transported easily by pipeline. Above all, it is the cleanest of the fossil fuels, emitting lower levels of pollutants (including carbon dioxide) than either coal or oil.

South Africa produces about 1.8 billion cubic meters per year of natural gas (Trollip 1996) that is used by Mossgas in its liquid fuel synthesis plant. Gas manufactured from coal accounts for about 1% of total net consumption and liquefied petroleum gas (LPG) for about half a per cent. No significant research is being conducted in this field.

Coal

According to Mannion and Bowlby (1992, p. 138), the picture for coal resources is even brighter. The exact extent of coal resources is controversial, but there is without doubt the equivalent of several centuries at current consumption levels. Coal use has declined in many developed countries such as the USA, Germany and the UK, but it is growing rapidly in other parts of the world. It is particularly important in India, China and Africa, all of which have sizeable coal reserves and an urgent need to increase energy use. Coal is dirty to handle, has a low energy content proportional to its weight and is far more polluting than either oil or gas.

There are powerful arguments for alternatives to fossil fuels such as wind, solar, geothermal and even nuclear power. These arguments should be based on environmental and economic grounds (to show that the alternatives are cheaper and cleaner), and not some erroneous claim that the oil wells are about to run dry. Fossil fuels may not be renewable, but they are also not scarce.

Coal dominates the South African energy sector. The real output was R13 361 million in 1995. It is predicted to grow to R16 671 million in 2000 at a 4.5% annual growth rate. The number of employees in 1995 was 67 946, and it is predicted to decrease to 67 276 in 2000. The research is mainly focused on mining technology. However, some research is done on the combustion of RSA coals and the use of discard coal.

Fuelwood
The most important energy source other than the fossil fuels remains biomass energy (wood, charcoal and crop residues). These fuels provide 14% of the world's energy consumption and are the main energy source of the world's poor, providing an estimated 35% of all energy used in the developing world (Mannion and Bowlby 1992, p. 138). Biomass energy is consequently the fuel of the poor, but despite (or perhaps because of) this, these fuels have received little attention from energy planners. Biomass fuels present a number of unfamiliar challenges to those concerned with energy provision. The ways they are produced and used are very different from the more familiar international industries, which characterise fossil fuels. These challenges need to be confronted if some of the most pressing energy problems in the modern world are to be addressed. Fuelwood use will be important for the foreseeable future, whatever happens to energy resources and prices at an international level.

A total of 3.2 million rural households depend on fuelwood as a basic energy source for heating and cooking in South Africa. Women in the rural communities normally collect wood. Woodland denudation that leads to fuel shortages and soil erosion will damage the welfare of rural inhabitants. Because of cost and population growth it is not anticipated that electrification will significantly reduce the demand for wood over the next 15 years.

Bagasse accounts for nearly 5% of industry energy consumption. The low electricity price discourages industrial co-generation, though the situation could change over the next ten years as spare capacity is eliminated. No significant research is being conducted in this field.

Uranium

According to Energy Futures (1996, p. 3–32), limited exploration and the wide variety of settings under which uranium is found, imply that present estimates of uranium resources are poor. Uranium is contained in very diluted forms in different types of minerals. Prospecting has up to now been limited to deposits with a yield of more than 500g per ton of ore. There is about a 300-fold increase in recoverable uranium for each ten-fold decrease in ore grade on the basis of the ores at present being exploited. It is estimated that South Africa has 5% of the world's uranium reserves.

Renewable sources of energy

New and renewable sources of energy come in many forms. Wind, solar, hydro, tides and waves, biomass technologies, geothermal and others present a theoretical potential, which is almost infinite. Many of these resources are technically difficult and expensive to harness, are limited in their range of applications (most are best suited for generating electricity) and are highly dispersed. According to Mannion & Bowlby
(1992, p. 140), these characteristics all limit the use of renewables in the modern world, but their potential for the future is tremendous, and it is likely that these energy forms will develop to replace fossil fuels during the 21st century and beyond. The most widely used form of renewable energy is hydropower, which is important for electricity generation. The total amount of hydropower generated in 1989 was the equivalent of 526 million tonnes of oil, or over one sixth of total oil production. The present installed capacity is about 500,000 megawatts, and it provides about 23% of the world's electricity and around 6% of primary energy consumption. Other forms of new and renewable energy are of negligible importance in the modern world. In total, all of these schemes add up to a fraction of 1% of the total energy use. Within the category of geothermal systems are: hydrothermal systems, Hot Dry Rock (HDR), geopressed reservoirs, and magma (subterranean molten rock) systems. All geothermal systems involve drilling to great depths, usually boring holes over one mile deep into hard rock in order to tap steam for conversion into useful energy.

**Transformation technologies**

Electricity is taking an increasing share of final energy demand worldwide and this trend is expected to continue. Because a large proportion of the electricity generated comes from fossil fuels, it constitutes a large and growing source of CO₂ emissions. Other greenhouse gases, particularly N₂O, are also produced through power generation.

**Technology in the coal sector**

Advanced fossil fuel–fired technologies are widely available but the degree to which they are deployed depends upon the age of existing plant and the relative prices of fossil fuels. In general, however, the more conventional technologies dominate present electricity production. According to Energy Futures (1996, pp 4–43) coal–based power technologies include the following:

**Subcritical pulverised fuel technology**

Subcritical pulverised fuel is the predominant coal technology used all over the world although it has fallen out of favour in countries which put a high premium on efficiency and on reduced emissions (e.g., Denmark, the Netherlands, Sweden and Japan). Typical thermal system efficiencies range from 32% to 35%. Future development of this technology should, therefore, be focused on increasing thermal performance, which is best improved by increasing steam conditions, i.e., going to supercritical conditions.

**Pre–extraction of coal–bed methane**
Two alternative approaches for the collection of methane from underground coal seams are available involving, respectively, drainage through horizontal boreholes within the mine and vertical boreholes drilled from the surface. The latter approach may also be used, without subsequent coal extraction, to provide an additional source of methane. Further technical improvements are needed to in-seam directional drilling and hydraulic fracturing techniques to ensure that coal seams have a sufficiently high permeability for gas flow. Additionally, methods for increasing capture zones are needed to reduce borehole density and hence enable the technique to be extended to areas where premium agricultural land or population density currently precludes deployment.

**Atmospheric Fluidised Bed Combustion (AFBC)**

AFBC is a relatively new technology that is highly applicable to burning low-grade fuels. Its uptake by utilities has been limited however. Development needs to be done to reduce its ash and N₂O production.

**Pressurised Fluidised Bed Combustion (PFBC)**

PFBC is an even newer technology, with very few plants in operation. There is one outstanding technical issue regarding the further development of PFBC and that is the possibility of cleaning the combustion gases sufficiently to employ advanced gas turbine technology. Further developments are required in extending hot gas filtration techniques to temperatures around 850°C.

**Gas turbine technology**

Recent technological developments in the gas turbines industry have resulted in significant increases in thermal efficiencies of power plants utilising gas turbines for power generation. These advances were achieved through a combination of cycle innovations, increased firing temperatures and pressures, reduced cooling air usage, improved component efficiencies and improved material/coating systems. Among these, the increased maximum allowable gas turbine inlet temperature has been identified as the crucial element towards reaching thermal efficiencies as high as 65%. Consequently, the gas turbines are becoming an increasingly favourable choice because of their competitive edge in comparison with other types of thermal engines. However, the widespread usage of gas turbines has resulted in an increased level of scrutiny into the environmental impact of gas turbine power plants, mostly reflected in pollutant emissions concerns. Elevated flame temperatures in today's gas-turbine combustors have resulted in higher levels of nitrogen oxides formation, a major pollutant that contributes to smog formation and the depletion of the ozone layer.

**Nuclear power technology**
Nuclear power is of minor importance in global energy terms. It provides approximately 7% of the world’s total primary energy. Its use is mainly concentrated in a few developed countries. North America and Europe accounted for over 72% of the total nuclear power generated in 1996 (BP Statistical Review of World Energy — 1997). Less than 5% of all nuclear power was generated in developing countries. This is despite the huge sums that have been spent over the last 40 years on research and development for nuclear energy technology. In the period after the Second World War, nuclear power was presented as the energy source of the future, with claims that it would soon produce electricity that was ‘too cheap to meter’. During the 1970s however, because of, inter alia, public resistance to safety hazards, nuclear power was no longer regarded as the panacea for the world’s energy shortages. Further reasons for abandoning nuclear power are economic considerations and growing concerns over nuclear arms proliferation.

Existing nuclear power is based on four main reactor technologies, the most prevalent of which is the pressurised light water reactor (PWR) followed by the boiling light water reactor (BWR). Both designs are based on the use of a relatively high power density core, with water as a cooling and moderating medium. The CANDU design is a pressurised reactor using heavy water to cool and moderate a natural uranium core. These nuclear technologies have a good record in recent years for improving performance efficiency, for diversity, sustainability characteristics and cost stability. The Pebble Bed Modular Reactor (PBMR), a high-temperature reactor, was first developed in the early seventies, but was never commercially exploited. This reactor offers a number of advantages over conventional reactors, one of which is that it is intrinsically safer to operate. Renewed interest in the commercial exploitation of this technology has recently surfaced in South Africa. Eskom is proceeding with a feasibility study into the Pebble Bed Modular Reactor Technology as an alternative to current nuclear technology. (Trollip and the IEA document contain valuable information on the history of the South African nuclear energy industry).

Nuclear energy provides between 1% and 2,6% of South Africa’s primary energy supply.

Photovoltaic cells

Since the invention of the first solar cell at the Bell Labs in 1954, the technology has steadily improved with the development of high performance devices and modules based on a number of different photovoltaic (PV) materials such as crystalline silicon, amorphous silicon, cadmium telluride, copper–indium–diselenide and gallium arsenide. Moreover, as the performance of PV modules has improved, the manufacturing costs have been steadily reduced so that the average selling price of PV modules (for large purchases) has fallen from more than $20 per peak Watt (Wp) in the
mid-1970s to about $4/Wp today. Since 1980, the total world installed capacity has increased almost 20-fold, from 3.3 megawatts peak (MWp) to 61 MWp in 1994.

**Fuel cells**

A high electrical generation efficiency can be achieved through use of a high-temperature fuel cell in combination with a combined cycle. The primary fuel is processed to produce a hydrogen–rich gas feed to the fuel cell (e.g., natural gas is reformed to hydrogen and CO₂) and then reacted with oxygen in the fuel cell producing a direct current (DC) electrical output. Researchers in the US, Canada, Japan and Europe are of the opinion that fuel cells are on the verge of large-scale commercialisation. Currently, stand-alone, co-generation (combined electricity and heat) units in hospitals, hotels, office blocks, etc., with efficiencies of up to 80% are already being used. Electric utilities with localised shortages of capacity are also a potentially strong market for fuel cells. Hydrogen or methane can be utilised in fuel cells where between 35% and 65% of their energy potential can be converted into electricity for cars, homes and factories. Currently, their costs are $3 000 kW, in part due to their requirement of precious metals as the required catalyst.

**Power transmission**

Transmission and distribution systems (TDS) can be considered to comprise two main components: substations and transmission/distribution lines. The former allows for connection and disconnection of electricity users/generators and transformation between the various voltages, while the latter carry the electrical energy. The presence of an adequate TDS greatly enhances the security of electricity supply by allowing the output from several generators to be pooled. Most electrical transmission systems utilise high voltages (HV>200 kV) alternating current (AC) on overhead transmission lines, and most OECD countries have nationwide or large-area super-grid systems. An alternative method of electrical transmission is via direct current (DC), typically in underground cables. Such systems have several advantages over AC: DC cabling is cheaper and it can be used to connect AC systems which are not synchronised, e.g., the undersea link between the UK and France, but it becomes competitive with AC only for long cable lengths. All these technologies are mature and deployed.

**Energy service technologies**

**Road transport**

Motive power for road transport is provided predominantly by two principal engine types: the Otto spark ignition engine using petrol and the four-stroke diesel compression engine using diesel fuel (Energy Futures. 1996, p. 4–19). Considerable reductions in emissions and fuel consumption have been realised by improving
engines ignition systems, transmissions systems, reducing vehicle body weight and aerodynamic drag. Despite technological advances and the success of better fuel performance in some countries, on a global level, CO2 emissions from motor vehicles are growing at about 2.4% per annum. Reasons include increasing power of vehicles; increasing the fleet size; increasing mileage per inhabitant; low car occupancy; poor enforcement of speed limits; and growing traffic congestion.

Electric vehicles

Electric vehicles are of great current interest as zero-emission vehicles at the point of use, especially as 'urban vehicles'. Although the electric motor is more efficient than an internal combustion engine, the efficiency advantage is eroded by factors such as weight, and power losses in the generation, distribution and the recharging process. The key barrier to their implementation is the current state of battery technology, which results in high costs, heavy cars, sluggish performance and limited range (Energy Futures, 1996, p. 4–23). The Californian government revoked their zero-emissions standards in 1996 after an independent panel of US experts advised them that a new generation of advanced batteries would not be available until the year 2000 at the earliest. The large-scale introduction of electric vehicles would also require major infrastructure changes, not only in the energy distribution system and the car itself, but also in the electric power generation industry.

Rail transport

The rail sector is characterised by two broad technological categories: diesel traction (the most common) and electric traction. Reducing weight will have the largest impact on reducing energy use of rail vehicles. For diesel locomotives, turbo compression to recover some exhaust gas energy can reduce fuel consumption by about 5% in the short term. Other opportunities for reducing fuel consumption include drag reduction and the use of superconductors. In the longer term, the development of ceramic compounds and solid lubricants could reduce consumption by another 20%.

End-use applications in residential and commercial dwellings

Many countries have established 'major-appliance rules' setting a minimum efficiency limit residential and commercial end-use technologies, for example for new air-conditioners, dish and clothes washers, freezers, water heaters, gas ranges, refrigerators, furnaces, and boilers. In the United States for example, these new standards are expected to trim electricity consumption by 30 terawatt-hours (trillion-watt hours) during 1995 and reduce peak demand by 12 800 MW.

Domestic appliances
According to the Rocky Mountain Institute (website http://www.rmi.com # Cooking Appliances and Dishwashers) cooking food and washing dishes accounts for approximately 10% of all energy used in a modern home. Approximately 58% of United States households cook with electricity but gas cooking is making a comeback. The use of domestic appliances, especially of electrical appliances, continues to grow rapidly. There are ample opportunities for technological improvements in each of the following areas:

**Refrigeration** (e.g., incorporating CFC–free insulation that is more effective, using aerogels, gas–filled panels, and vacuum plates; high–efficiency refrigerators, especially equipped with better compressors);

**new types of stoves** (e.g., advanced microwaves, electromagnetic induction), and improved stove insulation, solar stoves, efficient wood heaters;

**washing machines** employing a range of improvements (require less water to heat, lower washing temperatures, and mechanical drying at high spin–speeds, which reduces thermal needs in tumble dryers);

**television sets and computers** (flat screens, power management systems, and lower energy consumption while in 'stand–by' mode);

**office equipment** (e.g., fax machines and copiers that feature power management and reduced stand–by losses).

Potentials for the reduction of energy consumption are large, in the order of 30% to 50%. It is in the usage habits of these appliances, however, through appropriate education, and not the improved technology per se, which represents the biggest potential for savings.

**Lighting**

According to the Rocky Mountain Institute (website http://www.rmi.com–Home Energy Brief # Lighting) lighting is responsible for about one fourth of all electricity used in the United States. Lighting is a field, which offers large potential for electricity savings (in the order of 60%). The more lumens produced per watt consumed, the more efficient the light source. The standard incandescent light bulb, used in over 90% of residential lighting, produces only 10–20 lumens per watt. More than 90% of the energy consumed by this bulb is given off as heat while only 10% is converted into light.

The most significant development in lighting technology for homes and commercial buildings in the past decade has been the development of the compact fluorescent lamp. These lamps produce three to four times the amount of light for each watt consumed, compared to standard incandescent bulbs, and last up to thirteen times longer. In the future, particular attention should be paid to integrating a building's lighting at its conception stage, especially in public and commercial buildings, which
are often constructed in such a way that artificial lighting is required when the building is occupied. Promising fields for technical improvements include high efficiency lamps and reflectors, daylighting (ways of bringing daylight into buildings such as skylights, improved window and glass technology), automatic control of artificial light as a function of daylight, building designs that enhance availability of light, sensors that control room lighting according to occupancy; and even more advanced light-control systems (combining some of the above techniques, providing individual availability of light only in immediate work areas, etc.).

**Water heating and air-conditioning**

Water heating is one of the largest consumers of energy in the domestic environment. Efficiency improvements can be achieved by improved water heating tank and pipe insulation, integrating renewable energy sources with the existing power supply and controlling the power supply by switching the electricity supply to the water heating tank on and off at appropriate times of the day. According to Energy Futures (1996, p. 4–53) the best opportunities for efficiency improvements in air conditioners probably lie in better controls and in better design of certain components, such as heat exchangers and fans.

**Current international research in energy technology**

The discussion presented makes it clear that there is no energy shortage in physical terms, and that some degree of energy efficiency has been achieved with the associated technology. There are, however, many places in the world, including southern Africa, where the cost of commercial energy is such that significant number of people cannot afford it. Furthermore, despite the progress made in energy efficiency, the current processes of energy generation and usage negatively impact on the environment at a local, regional and global level. These facts make a powerful argument for developing affordable energy, and achieving further energy efficiencies. A number of research initiatives aimed at achieving this objective, with commercial application likely within the next 10 years, are briefly discussed below.

**Primary energy**

**Coal technologies**

According to Energy Futures (1996, p. 4–30) a number of fossil fuel–fired technologies are being developed to reduce emissions and the unit cost of operations. They include the following:

**Underground coal gassification (UCG)**
UGC, if successful, has the potential to exploit deep coal reserves, which would not be economical to extract by conventional techniques. It could also open up the possibility of exploiting the considerable reserves known to exist offshore, which are inaccessible to conventional mining. Conceptually, the technology involves igniting and reacting the coal underground with a mixture of oxygen (or air) and water (or steam) introduced from the surface through an injection well. This converts the coal in situ into a low or medium-calorific value gas, which is brought to the surface through a production well. In addition, the coal ash and a significant part of the sulphur remain underground. Research needs to include further work on directional and in-seam drilling to allow the deeper, thinner, higher grades of coal to be exploited.

Coal and biotechnology

Micro-organisms may be used for the conversion, primarily of low-rank coal, into cleaner, more valuable fuels such as methane. However, the greatest potential may lie with the use of the enzymes isolated from such micro-organisms, as these avoid the microbial production of CO₂. Preliminary studies have demonstrated coal liquefaction in a single step using enzymes, which are applied to coal using an organic solvent. The product is a flammable liquid with potential as a fuel. Preliminary estimates suggest such processes could be developed in the medium term.

Transformation technologies

Coal technologies

(a) Integrated gassification combined cycle (IGCC) integrates coal and combined cycle technology. Significant increases in system efficiency can be achieved through further R&D in respect of the component technologies; specifically the gas–turbine and the hot–gas clean-up stage. These improvements are projected to increase system thermal efficiency from an initial level of 43% to 47% by 2010 (and 50% by 2025). Factors favouring the cost–competitiveness of IGCC technology are the differential between coal and natural gas prices, making IGCC more favourable, and the fact that manufacturers of the advanced combustion turbines (the heart of IGCC technology) are developing even more advanced machines with resulting lower capital costs.

(b) The hybrid cycle is a combination of fluidised bed and gassification technologies, which provide a system with a higher electrical generation efficiency than either of the individual technologies. Developments in gas–turbine and hot–gas clean–up technologies are projected to increase the thermal efficiency from an initial value of 44% in 2005, to 46% by 2010 (and 52% by 2025).
(c) Direct coal combustion gas turbines offer the potential for increasing the efficiency of electricity generation from coal, by directly feeding the energy released from coal combustion into a combined cycle system.

(d) Ultra-supercritical steam cycle offers significant increases in generation efficiency, which can be achieved by increasing the steam conditions under which modern conventional steam cycles operate to pressures greater than 30MPa. Operating under such conditions could increase the thermal efficiency of a new coal-fired steam cycle plant, equipped with flue gas desulphurisation (FGD) equipment, to as high as 45% from the 35–37% achievable in the most modern sub-critical plant without FGD equipment.

(e) Kalina cycle. Where the standard Rankine cycle used in power generation employs a single working fluid, namely water, the Kalina cycle operates by using a mixture of two or more working fluids, varying their ratio in different parts of the cycle, It is claimed that the only significant change required by a conventional generating plant is in the condensing process, where a system to change the composition of the working fluid before and after condensation is required. Significant increases in system efficiency are claimed (10% or more) by tailoring the cycle to suit the specific system.

(f) The humid air turbine (HAT) cycle employs a single gas turbine, in place of the gas and steam turbine elements of a combined cycle plant, to generate electrical power with an increased efficiency. The HAT cycle is suitable for use on natural gas or coal-fuelled plant Integrated Gasification Humid Air Turbine.

**Nuclear power technology**

Because nuclear technologies have such a long lead time, what is on the drawing board today will only be entering service around 2010. Utilities seem likely to favour evolutionary designs over this time frame. Current technology development activity is focused on improved reactor and fuel management systems. The goals for evolutionary designs are: to increase safety margins, to simplify and reduce the cost of construction/operation, to shorten lead times (primarily by addressing certification/licensing problems), and to reduce radiation doses to operatives. Attention is also being directed at raising proven output (both by increased rating and improved system availability) without adding significantly to the capital costs. Examples of these include the ABB System 80+, the Nuclear Power International (NPI, Framatome, Siemens, EDF) PWR design, the Tokyo Electric Power Company simplified BWR design, and the latest CANDU design. It is unlikely that fast breeder reactors will be deployed on this time scale because the surplus on the world uranium market makes it unlikely that uranium prices will increase sufficiently to make fast breeder reactors economically attractive.
Renewable technology (for electricity generation)

According to Energy Futures (1996, p. 4-36) the main renewable energy power generation technologies that could be developed to maturity or near-maturity in the next ten to 15 years are a variety of solar blend systems, on-shore wind generators, photovoltaics (PV), hot dry rocks (HDR), biomass and shoreline wave energy. The first three of these technologies have a large potential to reduce greenhouse gas emissions on a global scale (as assessed by their theoretical resource). In comparison, shoreline wave energy has only a small potential for reducing greenhouse gas emissions, but is seen as a precursor to the development of offshore wave energy.

The theoretical potential of renewable energy resources in South Africa is large. RSA has one of the highest solar radiation levels in the world, of which only a small part of the potential is realised. Wind power potential is good along the coast. About 300 000 wind pumps are in operation but wind powered electricity generation is negligible at present and likely to remain so in future. A small (estimated 8 360 MW) hydro-potential exists in South Africa, which is due to its low rainfall and few large rivers. Some research is being conducted at UPE and RAU with limited industrial support.

(a) Wind. Wind power is now the world's fastest-growing energy source. It increased by 33% from 1994 to 1995 (Flavin, 1996:56). On-shore wind energy schemes have been deployed in many countries with high wind regimes (8 m/s on average). Public acceptability, however, has proven to be a problem. One way of overcoming this is to mount wind turbines in offshore locations. Although this technology is approaching maturity, further R&D is required to reduce generating costs.

(b) Photovoltaics (PVs). At present, PV is still uneconomical except for remote applications, mainly because conversion efficiencies in the field are lower than theoretically attainable levels (more than 30%). In Australia, however, a team at the University of New South Wales has succeeded in coming up with a design breakthrough that will boost the efficiency of solar cells to 21.65%. This could cut costs by almost 80%, making solar power competitive with coal-fired electricity for peaking power applications. The team is working with the electricity utility of New South Wales to make this technology commercially available in five to seven years. A number of concentrating PV technologies are under development and showing encouraging results.

(c) Solar thermal. With solar thermal electrical technologies, sunlight is focused on to a receiving station to heat a fluid. This fluid can be used to raise steam for electricity generation. Existing designs are uneconomical but continuing R&D (especially on the heat engines for generating electricity and improvements in the
costs and reliability of tracking systems), together with the potential for economies of scale, could improve the competitiveness of the technology. One drawback is that solar power plants cover a large surface area and will therefore probably be limited to desert regions.

(d) **Hot dry rock (HDR).** In comparison with conventional hydro-thermal resources, the rock is dry and heat is extracted by the circulation of water through the rock after fracturing to provide flow paths between the production and injection wells. Government-sponsored work is under way in Europe, Russia, Japan and the US, but only small-scale prototype schemes have been developed to date. Research at Los Alamos National Laboratory has demonstrated that useful amounts of energy can be routinely produced and that HDR systems are reliable and resilient.

(e) **Biomass.** The technology is currently at a stage beyond basic R&D: the gassification, clean-up system, and gas turbine have all been proven to work. But the system as a whole has not yet been demonstrated on a commercial scale. The technology will have to be able to use a variety of fuels commercially. This will require significant development in many aspects of the system, namely the clean-up process, vessel sizes, the fuel-handling systems and the agricultural infrastructure needed to produce the energy crops. Potentially, developing countries offer a good market for biomass technology.

(f) **Wave energy.** Prototype shoreline wave energy devices based on the oscillating water concept have been successfully deployed on a small scale in several countries. Further R&D is needed on the performance of such schemes at larger scale (especially on the turbines). A totally new concept designed by a Dutch group has been successfully tested. It differs from conventional wave energy technology in the sense that it is under the surface of the ocean where it is more protected and uses the huge swell of waves in the ocean. According to calculations, the world has 20,000 kilometres of suitable ocean coastline and each kilometre could generate 48 megawatts.

**Power transmission**

According to Energy Futures (1996, p. 4–39) there are two ways in which TDS technologies could contribute to greenhouse gas abatement: higher efficiency transmission (to reduce losses and to connect remote renewables) and the incorporation of embedded generation (renewables and combined production of heat and power (CHP)). Various technologies are being developed to achieve these aims. They include the following:

(a) **DC transmission.** DC overhead lines and underground cables are the preferred transmission option for long distances. In addition to avoiding reactive power
problems, DC transmission allows asynchronous connection between AC systems. All these features would be beneficial for remotely located generation such as renewables. However, further work is required to reduce the costs of terminals based on current thyristor technology.

(b) **UHV AC transmission.** A possible alternative to DC transmission for long distances would be the development of ultra–high–voltage (1 MV) AC technology. This would reduce resistive losses but increase the need for reactive power compensation.

(c) **Flexible AC transmission system (FACTS).** The automation of the grid with solid state, high–power electronic switching could provide much greater control and flexibility leading to a more efficient use of transmission lines. This would reduce losses in the system and facilitate the remote control of distant generating plant.

(d) **Embedded generation.** It is likely that future generating capacity will increasingly be in the form of smaller plant (combined heat and power units, renewables, fuel cells, etc.) some of which will have variable output (e.g., wind). Many national transmission grids were designed for relatively small numbers of large generators with steady output. The implications of such changes on the distribution system stability and reliability have yet to be thoroughly investigated.

**Energy service technology**

**Road transport.** According to Energy Futures (1996, p. 4–20) in terms of vehicle design, weight reductions offer the largest potential savings in fuel efficiency. This can be achieved through the use of lighter materials (e.g. plastics, composites, ceramics or aluminium) or alternative design techniques (e.g. the use of honeycomb structures for lightweight rigid panels). In terms of engine design, the two most important considerations are low cost and a high power-to-weight ratio. Several engine design concepts that could have major impacts are discussed below. While some of these engine technologies can have impacts by 2010, most of the technologies fit in better with the 2030 time frame.

(a) Lean burn technology improves fuel combustion and efficiency by increasing the air–to–fuel ratio. However, the exhaust gas contains too much oxygen for the currently available three–way catalyst to control the NO\textsubscript{x} emissions. This barrier may be reduced through the development of selective catalysts.

(b) Two–stroke engines are being intensively developed by engine manufacturers and may enter the market on a large scale by around 2005. Two–stroke engines have a higher power output and torque per unit of engine displacement than the conventional four–stroke engines, allowing for a corresponding downsizing of the
engine. In addition, they have lower friction and lower heat losses to the engine coolant.

(c) Diesel engine cars can reduce greenhouse gas emissions by 15% to 20% compared with petrol engine cars, but they are also more expensive. The diesel engine is noisier and dirtier (particulates and NOₓ) than a petrol engine with a catalytic converter, but these barriers may be reduced through the development of new technologies. A considerable improvement in the diesel engine is in the form of direct injection. Instead of having a central pump supplying individual injectors, pump and injector are combined in a single unit for each cylinder. This will offer up to 15% better fuel economy.

(d) Gas turbines are unsuitable for use in most cars because, below 100 kW, they are currently too expensive and inefficient. They are light in weight, low on noise and exhaust emissions (except NOₓ), and have multi-fuel capabilities and high efficiency.

(e) Stirling engines use a working fluid and could reach heat-to-work efficiencies of over 60%, but first the barriers of poor reliability and high engine wear must be overcome.

**Alternative fuels used for road transport**

Most alternative fuels (e.g. electricity, hydrogen and alcohols) are not primary fuels, but simply energy carriers. Their greenhouse gas emissions are directly related to their primary fuel source. Alternative fuels can be viewed as a means to the transition to renewable fuels, particularly aiding the development of the vehicle systems and the fuel infrastructure. Two particular fuels that may offer commercial and environmentally attractive alternatives to petrol and diesel are liquid petroleum gas and compressed natural gas, especially for captive fleet use in inner city areas.

(a) **Liquefied petroleum gas (LPG).** Liquefied petroleum gas has higher hydrogen to carbon ratio than petrol, emitting less CO₂ per unit of energy. No major infrastructure changes are required for LPG use. However, LPG supply is limited, making up only a small percentage of the output of a petroleum refinery.

(b) **Compressed natural gas (CNG).** Compressed natural gas has the same advantages as LPG over petrol (higher hydrogen to carbon ratio, higher octane number and lower fuel preparation emissions), but these are even more pronounced in the case of compressed natural gas. Some CNG vehicles are in use today, mainly as part of commercial fleets.
(c) **Methanol-powered flexible-fuel vehicles.** Conventional cars can be modified as 'flexible-fuel vehicles' to run on mixtures of gasoline and various types of alcohol, such as methanol, which is made from natural gas. All alcohol-fuelled vehicles (e.g. methanol and ethanol) produce less emissions of NO\textsubscript{x}, but greater emission of formaldehyde, methane (CH\textsubscript{4}), and CO (all greenhouse gases). However, catalytic converters can reduce some of these emissions and the amount of CO can be lower in the initial manufacturing process.

(d) **Hydrogen.** Hydrogen, like electricity, can fuel a point-of-use zero emission (or ultra-low emission) vehicle. Storage is still a problem because of its low energy density. The most probable source of hydrogen is from natural gas. To get significant greenhouse gas emission abatement, hydrogen produced from natural gas would require a fuel cell vehicle (see below). In future, hydrogen could be produced from biomass or non-fossil electricity. Electrolytic hydrogen vehicles would use three to five times the electricity of an electric vehicle because of the conversion process (electricity to hydrogen to automotive power). World leadership in hydrogen research is centred in Japan and Germany. Hydrogen fuel cells are two to three times as energy efficient as combustion engines.

(e) **Fuel cells.** Fuel cells produce power electrochemically, as opposed to combustion processes in conventional engines, and can potentially reach significantly higher conversion efficiencies — perhaps by a factor of two to three — compared to today's internal combustion engine. The proton–exchange membrane (solid polymer) is the leading candidate for cars because of cost, size, simple design, and low temperature (< 120°C) operation. The fuel cell requires hydrogen fuel, which may be generated onboard by reforming methanol or natural gas. Diesel is another possible source, but is not energy efficient or particularly clean. Fuel cells could help the move towards zero-emission vehicles after the only legislation that committed car manufacturers to producing them was modified.

**Electric/Hybrid super cars**

Advanced passenger car designs utilising electric/hybrid drive-lines, with an engine/generator or fuel cell, to generate electricity on-board the vehicle, and electrical energy storage (a pulse power unit, such as an ultra-capacitor) to load level the engine/generator, or fuel cell and to recover energy during vehicle braking, are being evaluated (Burke, Proceedings of the 30th Intersociety Energy Conversion Engineering Conference, Volume 2, 1995, p. 89). The hybrid vehicle simulations performed to date indicate that the use of hybrid/electric drive-lines is an attractive approach for greatly improving fuel economy and reducing emissions in high-performance passenger cars. These improvements were achieved using ultra-capacitors and modes of engine and system operation very different from that customarily used in conventional engine–powered passenger cars. However, the large-
scale introduction of electric and hybrid vehicles would require major infrastructure changes, not only in the energy distribution system and the car itself, but also in the electric power generation industry. It would also offer the potential of distributed power production by feeding electricity into the grid when the car is parked.

**Battery technology for the electric car and hybrid vehicles**

Batteries to generate energy for transportation must be capable of stable thermal operation, withstand overcharge, and require minimum or no maintenance. They should have an average voltage of 250V, a high energy efficiency, with a peak power output of 100 kW, an energy density of 50 Wh/kg, a high-rate charge/discharge capability and a life cycle of at least five years. For most vehicles their weight should be 100 kg, with an efficiency of 80% and a total cost of not more than $1 000. Current battery technology research includes the following:

Sodium–sulphur offers three times as much energy storage per unit volume compared to conventional lead–acid cells. They need to function at high temperature (350°C) so that both electrode components operate in a liquid state, which raises safety and convenience concerns. During discharge the sodium ions (negative pole) migrate to the positive where with sulphur they form sodium polysulphides and during charge the sodium ions travel to the negative to form metallic sodium. If the high temperatures are not maintained the molten sodium and sulphur inside them will solidify. They therefore need to be constantly in use.

Lithium–iron sulphide batteries with high energy capacity and high power output operate only at high temperatures (450°C) and use solid electrodes or LiAl or LiSi as the negative and FeS or FeS2 as the positive. Intensive research has only just begun.

Nickel–metal hydride batteries (Ni–MH) have high energy efficiency, energy density, high-rate charge/discharge capability and cycle life. They store hydrogen within a metal which when released is transported to the nickel oxide electrode. The United States Advanced Battery Consortium, a joint venture between American car producers and other companies, has awarded an $18.5 million contract to Ovonic (in Michigan) to develop nickel–metal hydride batteries which could double the range of electric cars.

One of the most promising storage devices now on the drawing board is the flywheel, a mechanical battery that stores energy mechanically rather than in chemical form. By the early 1990s several companies were working on advance flywheels with electromagnetic bearings, an internal motor/generator and the potential to release energy at an efficiency of more than 90%.

**Rail transport**
High-speed trains (including tilting trains) would not necessarily achieve greater fuel efficiency than conventional trains. However, they could encourage a modal shift from road and air traffic, as has been demonstrated in several OECD countries. Magnetic levitation (maglev), which uses computer-controlled magnets to propel the train, does, however, offer a fuel-efficient mode of transport. Although the maglev concept has been around for over thirty years, attempts to develop it have always run into technical and financial problems. In Germany, the proposed Transrapid Maglev line between Hamburg and Berlin has stalled because of difficulties with financing. In the US, a 20 kilometre maglev system was cancelled when it became too expensive. Maglev has a cheaper rival in an electromagnetically propelled train on conventional tracks, the segmented rail phased induction motor (the Seraphim train). On specially built rails the Seraphim would cost only a quarter of the price of a maglev system. However, the system is still very much in a development stage.

Transformation technologies

Technology in the coal sector

(a) Supercritical Pulverised Fuel (PF). This is the natural successor to subcritical PF. The use of higher steam conditions improves efficiency, which in turn inherently decreases emissions. Supercritical PF has had most success so far in countries where very high levels of efficiency and environmental performance are required. This is particularly true of the ultra-supercritical units.

(b) Magnetohydrodynamics (MHD). Early coal-fuelled MHD systems could have an efficiency of 45%. A key factor will be the availability/development of suitable high-temperature materials, a factor shared with a number of other technology options considered in this study. This technology therefore offers an increased efficiency for coal-fired generation compared to the alternative IGCC and hybrid cycle technologies.

Nuclear power technology

A number of reactor design concepts have been advocated for the longer term (approximately in the year 2030), the aim of which is to take the evolutionary path a stage further, with a greater use of inherent and passive safety features. The proponents of such concepts believe they can match current designs on cost, but this has yet to be demonstrated. All these small and medium-sized reactors have lower embedded environmental emissions. This is due to a reduction in the need for steel, concrete and engineered components in their construction. They are also designed to increase safety margins by virtually eliminating the possibility of a core melt accident and minimising the need for operator intervention. The designs are aimed specifically
at addressing the problem of public acceptability of nuclear power. If they are successful, these concepts could open up new markets for nuclear technologies.

**Fuel cells (triple cycle)**

Significant R&D is still required, with the triple cycle fuelled on natural gas projected to be available by the year 2025 with an efficiency of up to 60% and a goal of 65% by 2040.

**Renewable technology**

The main technologies with significant potential for reducing greenhouse gas emissions that could be developed in the longer term (with commercial application possible in 2030) are the following:

(a) **Wave energy.** Offshore wave energy schemes seek to exploit the more energetic wave regimes of deeper waters. The harnessing of this resource presents a more significant engineering challenge than shoreline or near-shore wave energy because of the hostility of the operating conditions. There are many designs proposed for this purpose, none of which are currently economical. Further R&D is needed on the hydrodynamics, power take-off systems and design optimisation to achieve the required reductions in generating costs.

(b) **Ocean thermal energy conversion (OTEC).** An OTEC system consists of a heat engine or power plant (operated by the temperature difference between the warm water on the surface of the ocean and the cold water below the surface), a water ducting system, an energy transfer system, a position-control system, and a platform to support the power plant (where deep water exists near the shore).

(c) Another, more long-term and theoretical technology, which could one day be a major source of pollution-free energy is the MegaPower concept coordinated by the Netherlands Agency for Energy and the Environment. A tower (five kilometres high) would use a chemical such as ammonia, which would be heated by warm ocean water and rise, evaporate and, when returning in the tunnel as a liquid, drive a turbine. A single station could have a capacity of 7 000 megawatts but would still need some technological breakthroughs to make it feasible.

**Power transmission**

Superconductors, which are poised to make a great impact on society in the next century, can touch every aspect of our existence that involves electricity. Although the full impact of high-temperature superconductors will only be fully experienced over a long time scale, companies are already declaring that the pre-competitive phase is
over. If successful, high temperature superconductors would allow low loss transmission over large distances, facilitating the development of a truly international market in electricity. In addition, this could generate the possibility of energy superhighways in which heavy gauge superconductors form a global network, linking the main areas of energy usage (e.g. Northern Europe, the US and Japan) with the main centres of renewable energy generation, e.g. PV stations in the world’s deserts.

Energy service technologies

Hydrogen technology

There is a distinct possibility that the hydrogen atom will replace the carbon atom as an energy source for transportation. Existing natural gas pipelines can be adapted in many cases for hydrogen transportation, allowing hydrogen to be cheaply transported across long distances as well as easily stored. Gaseous hydrogen has about 2.5 times the energy by weight of gasoline, and taking its efficiency into account, would cost only about $1.40 for the equivalent of one gallon of gasoline. With some mechanical modifications, all types of internal-combustion engines can utilise hydrogen gas. Texas A&M’s Centre for Electrochemical Systems and Hydrogen is researching hydrogen production from coal, natural gas, and the use of electrocatalysts to 'split' water using sunlight. Coal could become the cheapest source for the production of hydrogen, with its carbon dioxide by-product captured and utilised for industrial purposes or stored.

Bio-fuels

A number of plant-derived oils have also been considered for possible use as fuels in diesel engines including sunflower, soya, groundnut, cottonseed, rapeseed, palm oil and castor oil. Recent trials using modified vegetable oils have had more positive results than previous experiences. Significant technical progress would be needed if vegetable oils are to be utilised as a transportation fuel. The lack of emphasis on the efficient use of biofuels in the past could stem from the fact that biomass utilisation technologies are not mature enough in the commercial sense.

Future development of Thin Film PV Technologies

Two other promising thin film PV technologies are based on the polycrystalline materials, cadmium telluride (CdTe) and copper–indium–diselenide. Conversion efficiencies as high as 15.8% have been reported in small-area CdTe solar cells.
Chapter 3: 
Situation analysis of the energy sector

3.1 Introduction

This Chapter is the result of a rigorous process by the working group aimed at an extensive situation analysis of South Africa’s Energy Research and Development (R&D) environment. The ultimate objective of this work was to ensure that research and technology intervention in South Africa addresses both weaknesses and threats while taking advantage of the strengths in capturing social and economic opportunities for the next twenty years.

The SWOT analysis focused on socio-political, economic, technological and environmental factors in South Africa as they impact on the sector. This process consists of two iterations, the first analysing or scanning the current environment, while the second brought in futuristic thinking by using macrosenarios to cater for the uncertain nature and risks of the unknown future. The key issues that were identified through the situation analysis, as concerns to the social and economic development of the sector, were tested for research and technology implications and then prepared as statements for the Delphi survey discussed in Chapter 4. The results were as follows:

3.2 Strengths

(a) South Africa has a strong natural resource base and a variety of energy options are available. It has extensive coal resources and Eskom’s generation strategy and technology has resulted in one of the world’s lowest cost producers of electricity. The natural resources include —
   • abundant coal reserves of more than 200 years at the present rate of consumption, although the quantification of reserves versus grade is uncertain;
   • indigenous uranium reserves, also in Namibia; and
   • high solar radiation.

(b) A well-developed energy, rail, road, and grid infrastructure. An established research and educational infrastructure supports this.

(c) An electrification programme that is delivering infrastructure and electricity to previously disadvantaged communities. The following has been achieved:
- Grid extension to remote areas and regions.
- A rate of approximately 400,000 household connections per annum.
- Export of electrification skills and technology.
- Low-cost solutions that make it more affordable for low-income consumers.

(d) The benefits of economies of scale. Large companies with low-cost and appropriate technologies exist. Home-grown technologies such as dry cooling and synthetic fuel production have been developed successfully. This was partially due to the following:
- Large and strong institutions in the private and public sector.
- Finance that was available to these institutions at reduced cost because of their good credit rating.
- Large companies with access to resources that undertook appropriate R&D.
- A spirit of accepting challenges existed, with companies prepared to take risks that were supported by a national political will.

(e) South Africa has a well-developed core skills base. They are focused on the following:
- Operation and maintenance of sophisticated plant.
- Project management of large projects.
- Implementation levels.
- The supply side of the energy chain.
- The existence of multidisciplinary skills.

3.3 Weaknesses

(a) There is a limited national policy and vision for energy research and technology development.

(b) The energy industry has a supply side mentality and is not market-focused. The following are some of its characteristics:
- Energy suppliers are strong.
- There is no strong energy users group.
- Strong groups influence policy makers.
- Equipment is mainly imported and only limited local manufacture exists.
- Financiers, consultants and education are mainly focused on the supply of energy.

(c) The economy is dependent on polluting, primary energy sources (fossil fuels) that have a significant environmental impact. This leads to a poor international perception and image, which is mainly due to —
- coal being the largest polluter;
- leaded fuels still dominating the market;
• paraffin not always being used effectively;
• wood-fuel pollution, especially inside dwellings; and
• little attention being given to end-use energy efficiency and renewable energy development, especially matters relating to implementation.

(d) Insufficient local energy related R&D expertise exists that leads to a dependency on imported technologies. This is evident from —
• the low number of scientists, engineers and technologists (SET) in the energy and related fields;
• a shortage of skilled manpower and the incorrect application of the few SETs in the energy sector; and
• institutional inefficiencies in the system.

(e) A lack of knowledge about the needs and technologies in the energy environment. The statistics and information in the sector is poor or lacking in detail. Some of the characteristics are the following:
• Awareness of energy and appliance options by users is low.
• The level of competitiveness in the sector is low.
• The dissemination and capturing of appropriate information is ad hoc.

(f) Limited or low value-addition to resources takes place. The low beneficiation is evident from —
• a focus on raw material and semi-processed materials production;
• the fact that the economy has a high energy intensity;
• the fact that the economic efficiency of production is low;
• the fact that limited export of refined products takes place.

(g) Governmental capacity in the energy sector is limited. Some of the characteristics are the following:
• Low S&T capacity.
• Lack of sufficiently quality people.
• Lack of process knowledge.
• Lack of strategic thinking and prioritisation in the energy sector.
• Policy gaps and poor implementation of policy in parts of the energy sector.

(h) There is a lack of progress in restructuring the energy sector in the following areas:
• Electricity
• Liquid Fuels
• Lack of regulation that stimulates competition and higher efficiency such as in some other countries
(i) Huge barriers to entry for new entrants and entrepreneurs in the energy sector. This is mainly due to the following:
- Lack of suitable and reliable information
- High cost and knowledge that is required to enter the market.
- Lack of technology and technology transfer being available to entrepreneurs.
- Structure and regulation effectively prohibiting new entrants.
- High cost of capital.
- Uncertainty of future policy.

(j) Energy prices are not cost- or market-related, which leads inter alia to non-sustainability of the national electrification programme because of —
- hidden cross subsidies, across and within the electricity sector;
- the fact that the planning and funding process is not transparent;
- wrong technology choices that could be made.

(k) Barriers to large-scale implementation of new, renewable and efficiency technologies because of vested interests of organisations, cost structure and cultural acceptability.

(l) Infrastructure in rural areas is not well developed.

3.4 Opportunities

(a) The availability of natural resources to add value to in the country and the region exists. This could also apply to energy resources such as coal, uranium, sun and wind.

(b) The improvement of quality of life can be achieved by utilising energy technologies for job creation, rural development, equity improvement and SMME development.

(c) Energy efficiency improvements can be achieved throughout the energy chain i.e. conversion, transport and end-use technologies. Integrated energy planning with a focus on economic efficiency will lead to more efficient housing, transport, appliances, manufacturing, etc.

(d) Renewable energy technologies such as solar and biomass have significant growth potential in South Africa and the region.

(e) Environmental pressure for pollution reduction internationally could lead to funding and technology transfer opportunities for South Africa.

(f) New distributed generation technologies and opportunities will become available.
(g) The regional and international integration of markets, R&D, etc. would increase access to funds, technology, etc.

(h) The development of a national and regional gas infrastructure is anticipated.

3.5 Threats

(a) The level of poverty is high and it could worsen if the low economic growth and a low rate of development continue.

(b) The spiral of non-payment and non-delivery could continue. Ongoing non-payment for services, rates and taxes places a question mark behind the potential success of electrification, housing, water provision and other programmes.

(c) Slow technological development in South Africa and a lack of appropriate technological skills would have a significant impact on the energy sector. A lack of a sufficiently trained workforce to produce globally competitive manufactured goods would also lead to lower growth in the country. The situation is exacerbated by —
   • a small pool of skills in the country; and
   • a brain drain of many skilled people.

(d) The low level of funding and a lack of appropriate incentives for research and technology development. A declining trend has emerged in an already small R&D expenditure.

(e) Taking into account the limited resources, a lack of focus exists in technology development. A continued dependence on external sources may continue as limited technological development is done in critical areas.

(f) The costly delivery of energy to some consumers because of inappropriate policies. In rural areas, supply could become very uneconomical for certain energy types. This is caused by costly infrastructure development, low population densities, low consumption and affordability of certain energy types, incorrect pricing policies, etc.

(g) There is a poor perception of the characteristics of renewable energy sources by consumers and a resistance to change.

(h) The environmental burden of the current energy system is high and this should influence future energy decisions, i.e. comparing the impact of coal, nuclear, renewables, etc. Indoor pollution due to coal burning still has a major impact on
the health of a large number of South Africans and must be addressed. Stricter environmental legislation by South Africa's major trading partners could lead to carbon taxes being placed on manufactured products utilising fossil fuels as a source of energy.

(i) Poor policy, strategy and legislation lead to overregulation of industry. The lack of policy and policy implementation in the energy sector continues. A policy framework for rapid economic development has been put in place in the form of Government’s macro-economic strategy called Growth, Employment and Redistribution (GEAR), but this is not implemented rigorously.

(j) Mass urbanisation and overpopulation lead to high population densities that cannot be serviced because of limited resources. Rapid population growth accompanied by poor rates of economic growth, or even civil unrest in the Southern African countries, could lead to large-scale migration to South Africa.

3.6 Additional SWOT issues from the scenario process

As described in Chapter 4, four energy sector scenarios were developed. This was followed by a cursory SWOT analysis for each of the scenarios. The results are given in Appendix E.
Chapter 4: Scenarios

4.1 Introduction

Imagine the year 2018. What would the Energy Sector in South Africa look like and how would decisions that were made in the past be viewed? The working group used scenario methodology to look at future energy markets and trends to make more robust decisions today. The NRTF project developed four macrosenarios. These are diverse, plausible pictures aimed at identifying the key uncertainties, including socio-economic and political environments, that could affect the South African research and technology systems in the longer term. The aim is not to predict future events, but to understand the key factors that are likely to have the most impact on the future of science and technology.

The analysis of macrosenarios can be viewed as an open-minded, systems-based approach to future planning that will provide a basis for building sector-specific scenarios. Long-term strategic planning and sound decision-making are based on the realisation that in times of change, the future is highly unpredictable. A systematic and imaginative way of thinking is crucial to prepare for the future. These scenarios at least make easier to recognise the possibilities of change in the socio-economic environment of a country. Besides helping nations or communities see the future with different eyes, scenarios have managed to position leading corporations of the world, such as Royal Dutch Shell, favourably in terms of strategic thinking and planning. It is in this light that the NRTF found it necessary to incorporate scenario planning as a crucial part of efforts to position South Africa’s research and technology at the forefront of strategic development.

A set of four macrosenarios depicting four possible roads that South Africa could take to 2020. They are—

- The Innovation Hub describes how South Africa’s comparatively developed infrastructure creates opportunities for strategic regional development.
- The Global Home is about government embracing global liberalisation and facilitating private sector empowerment to respond to global market forces, in line with global trends and opportunities.
- The Frozen Revolution highlights the effect of the non-implementation of government policy towards socio-economic upliftment that leaves the masses dissatisfied and key players fragmented and individually focused.
- Our Way is the Way depicts South Africa’s perceived ability to challenge the conventional route to globalisation by rallying developing countries' support for
the development of a significant South–South economic block. This approach results in isolation by the developed world.

The macroscenarios are national scenarios of the science and technology system in South Africa in the 20-year term that was developed by a high-level cross-sectoral DACST team. They provided a futures frame of reference for the sector specific scenarios. These scenarios are published in a separate report obtainable from the DACST and are described in Appendix D.

4.2 Energy sector scenarios

Four energy sector scenarios were developed by the ESWG and are summarised in the text boxes that follow. They were informed by the macroscenarios as described above.

Narratives of the energy scenarios

Innovation Hub Scenario (with SADC focus)

This scenario explores South Africa’s comparatively developed capacity for scientific and technological (S&T) innovation. This capacity creates opportunities for regional investment to build on the S&T skills base. It explores indigenous technology capacity, excellence in scientific research and discourse, human resources development and policy instruments geared towards socio-economic problems of the region. Background information: An invitation to tender article in the Southern African Business Times February 29, 2018 follows.

Invitation to tender for a New 5000 MW power plant in Pietersburg, for electricity supply to the SADC Zone 7 main grid.

Preferences will be given to the utilisation of available Southern African energy resources (e.g. wind, solar etc.).

Recently developed demonstrated technologies are favoured, and the following additional SADC tax subsidies will apply to capital investment:

- Nuclear Fusion ................................................8%
- Combined solar and wind .........................6%
- Hydro.............................................................5%
- Natural SADC Gas .................................4%
- Coal ............................................................3%
- Nuclear Fission ............................................2%
- Oil................................................................1%
Applicants will comply with the SADC council directive EE218 of 2009, for integrated pollution prevention. Rebates for locally developed environmental technologies will be given.

Power will be purchased in terms of a 10-year power purchase agreement after which time the Independent Power Producer Corporation will compete via the power pool market. Standardisation of power delivery specifications, quality of supply and other technical aspects will be in accordance with SADC council directive TT002 of 2015, SADC regional transmission and distribution specifications. The local content and the amount of indigenous resources to be used needs to be specified.

The prices quoted in the tender will be in the SADC Imali currency and include the following subcomponents:

- SADC Energy R&D Council 0.5%
- SADC Educational Fund 0.5%.

The Independent SADC Centre of Excellence Energy Directorate has been appointed to review the submitted tenders. Their recommendations and evaluation results will be supplied to the SADC Regional Regulator Council for final approval.

Tenders must be submitted to the SADC Power Corporation head office in Luanda before 31 May 2018.

Global Home Scenario (global development with national focus)

In line with global trends and opportunities, government embraces global liberalisation and facilitates private sector empowerment to respond to global market forces. This leads to —

- a ‘hands-off’ role for small government;
- initially, good economic growth; and
- a tendency towards global identity.

It is a dark and stormy night, Winter 2018, Thandi and Sifiso are sitting at the fire in their global home...

Thandi (an International Hindsight Planning Facilitator):
Sifiso, you supported the takeover of National Electricity by Amalgam Energy Inc because of their international expertise, reputation and links to investment. You said the government would reduce its role by outsourcing, and the market would ensure we get quality supply. So why is this our third day without power?

Sifiso (an Amalgam employee):
After the 2010 elections the market outran economic and social regulation. South Africa had moved down the privatisation track. With complete deregulation, Amalgam gained control of the electricity industry. We had our problems keeping pace with change. They were made worse by the loss of local technical knowledge through both emigration and AIDS. We had to stay competitive to sustain local industry based on low-cost energy. So we cut operating and maintenance costs. Technology was intended to make us more efficient. Notwithstanding all the biotechnology and new materials, the ever-advancing technology applications use more power, increasing system demand. Eventually the needs exceeded our capacity.

**Thandi**

What stopped Amalgam from keeping pace with demand?

**Sifiso**

Our choice of supplies was limited by the extreme competition in the ESI. Our nuclear facilities are only slowly coming on stream after the approval delays. Amalgam also felt the effects of international environmental controls, following the extension of the Kyoto protocols in 2012 to include developing countries. We had to refurbish with expensive clean coal technologies, and buy green power at high cost from Inga and Cahora Bassa.

**Thandi**

John is coming home tomorrow from his workshop exchange. How will I get to the airport to fetch him? The car motive batteries are flat.

**Sifiso**

Transport has really changed! Sasol, and the whole petroleum industry, now produces high value chemical products and exotic synfuels only (no longer used for ordinary transport). The high-cost catalytic converters are mandatory in other countries, and provide the basis for strong export earnings, but never took off in this country. All we ever do is adapt imported R&D for local use. And since Bill G took control of the multi-national electric vehicle companies, reliability has been terrible.

**Thandi**

I often wonder if John's studies at the Chinese Peoples' Private International University in town are relevant to Africa. How will his lunar base feasibility research overcome our present problem — in fact what use is it to SA anyway?

**Sifiso**

His education is only possible because we're both working. You know, the rich get richer and the poor get poorer. You'll have to get one of the older (petrol)
cabs to the airport. They will be in demand now, so you'll have to make a booking. At least I can telecommute from home tomorrow.

Thandi
Good thing MTacom is powered by an independent energy provider.

Sifiso
They use distributed generation to meet their special customers' needs — it isn't our niche. Tomorrow we buy a PV distributed energy system. Even if they are the opposition!

Conclusion: Having identified the world's need for greater energy diversity, Thandi and Sifiso spend an old-fashioned romantic evening by the wood fire.

Frozen Revolution Scenario (reactionary)

The Frozen Revolution scenario depicts a situation where the government is trying to address social and economic upliftment through endless policy formulation processes. From policy paralysis, manifested in non-delivery, the masses are left dissatisfied. This ultimately leads to stagnation, a widening gap between the elite's and the masses. For Science and Technology this means 'hobby horse' projects, vote-catching projects with continued reduction in resources leading to the demise of the S&T system.

An article in the Southern African Business Times February 29, 2018 reads as follows:

Another multinational Oil Company, today announces its disinvestment from SA.

The MD, Mr NoOil blamed the sluggish economy, minimal margins and governments ad hoc response mechanisms, for the decision. NoOil contends that the lack of implementation after the release of the 14th strategic energy plan was the final straw. Furthermore, the spiralling AIDS crisis has lead to exorbitant medical costs, loss of investment in deceased staff, new staff training costs and loss of work time. All these have further exacerbated the financial strain experienced by the company.

Comrade Ndiza representing labour criticised industry for pretending to build local capacity while in fact utilising expensive imported skills and technology. This
is seen as a significant factor contributing to the poor financial performance of companies in the energy sector. He also expressed his gravest concern about 5000 jobs that are expected to be lost in this move. The economic ramifications are staggering he claims!

The minister of energy and science responded to NoOil's allegations, saying he was not particularly bothered by the state of affairs. He felt that this is anticipated in the 15th strategic energy plan where these assets will be placed under state control. He commented that there is currently no money in the budget for extravagant technology developed as proposed by the green lobby. He emphasised that funding would only be channelled to maintaining the current energy systems. He believes that the low cost environmentally friendly and energy efficient hydrogen vehicles that are so popular in the developed countries, are totally unsuitable for SA.

In response to the allegations of non-delivery to the African Renaissance commitments, he said that as soon as the World Bank loan was received, it would be used to create new jobs but declined to specify how and where these jobs would be. The linking of environmental penalties to the loan would see it materialise later rather than sooner was the opinion of a well known academic and energy monitor that wishes to stay anonymous. He said that government was naive in their expectations, as the World Bank would pressurise us as a result of the poor environmental practises common in SA. Government needs to be more decisive, avoid vacillating environmental polices, avoid spending funds on 'political' agenda items and avoid rhetoric if the tide is to be stemmed.

Our way is the way scenario (developing national self sufficiency)

Our Way is The Way highlights South Africa's belief in its ability to challenge the conventional route to globalisation by rallying developing country support for the development of a significant South–South, Non Aligned Movement (NAM) economic bloc. This catalyses isolation by the developed world. In terms of S&T it means skills base development, focused towards development and self-sufficiency, government focuses on innovation investment and less focus on science base and gathering of scientific information by all means.

Background information: Extracts from the keynote address in January 2018 to the Non-Aligned Movement, Foresight study, Energy Sector Working Group.

1. Energy and natural resources

As you know we have extensive resources of coal and renewable energy in South Africa. Coal still supplies the major part of our energy needs, including 60% of
liquid fuels. Because of our self-sufficiency policy, developed countries did not want to deal with us over the last ten years, and most new and clean energy technologies were not available to us, except for the ones we developed ourselves as determined by our own agenda.

2. Effect of global issues
Although we understood global developments, we deliberately decided to pursue our own interests first and aligned ourselves with the developing countries in the Non Aligned Movement (NAM). This led to our isolation from western capital, skills and technology. In response we developed our own appropriate but, of times, expensive technology and have developed markets for them in other developing countries.

3. Environmental Concerns
The overwhelming emphasis of the government was on development rather than on so called 'sustainability'. We ignored irrelevant international environmental protocols such as those on greenhouse gases that were of no immediate concern to South Africa. The international community imposed sanctions, such as imposing extra environmental duties on SA coal exports. Conventional coal technologies, without flue gas scrubbing, were simpler and cheaper than clean coal and were used extensively. Our locally developed cleaning technologies took longer to implement than anticipated.

The South African government formed trade agreements in primary energy and technology with like-minded governments of developing countries. The economy became partly closed and there was trade in beneficiated products with developing countries. Energy, especially electricity, was brought to the poor by cross subsidies at a small cost to the economy. Unique low-cost technologies were developed by this policy that benefited the poor and lead to jobs being created in the manufacturing industry.

5. R&T in the Energy Sector
We keep our eyes open for opportunities to adapt overseas technology for our own local conditions. Fortunately we have good relationships and common energy programmes with other developing countries and we are able to survive economically and technologically. Development of communities is a national priority and as such it has lead to the rapid development of appropriate technologies.

6. Education and R&D
In Research and Development (R&D) we are co–operating with the NAM such as our joint nuclear programme with India. Our limited R&D effort has become more
appropriate and is coordinated at national level. University professors research what government policy requires. The focus is on developing appropriate energy technologies. Nowhere in the world do they have our clean burning coal stoves, solar sewing machines, paraffin water heaters, centrally switched gas space heaters, or mixed heated refrigeration.

7. General developments:
The development of solar villages, wind farms, low-cost appliances and the commissioning of Mossgas subsidiaries along the coast.
Our electricity is expensive today because we have increased the level of electrified homes in SA from 50% 20 years ago to 90% now.
Health and Education services have become more accessible, but the general standard has deteriorated.

Were the decisions made in 1998 the correct ones? I hope the members of the working group will decide on the NAM's R&T future for the energy sector learning from our past experiences, good and bad.
### 4.2.2 Key Aspects of the Energy Sector-specific scenarios

<table>
<thead>
<tr>
<th>KEY UNCERTAINTY</th>
<th>STATUS QUO</th>
<th>INNOVATION HUB</th>
<th>GLOBAL HOME</th>
<th>FROZEN REVOLUTION</th>
<th>OUR WAY IS THE WAY</th>
<th>OUR WAY IS THE WAY</th>
</tr>
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<tbody>
<tr>
<td>1. Extent and availability of energy and natural resources. (including external influences on availability)</td>
<td>1. Energy and natural resources are plentiful but water is limited. Coal is primary energy source and plentiful. Liquid fuel is produced via synfuel and mainly imported. Gas is emerging. Nuclear energy is small in power generation and ore is exported. Renewable is mainly non-sustainable biomass and small solar installations. External influences are minimal (only on oil supply). SAPP is developing. Oil products are subject to the variable international oil price. Coal and oil use produces pollution.</td>
<td>1. Wider choice of energy supplies depending on political stability within SADC (especially access to gas, hydro and oil) Access to water of the region.</td>
<td>1. Better water opportunities exist. International issues have an adverse influence on energy carrier choice. Although there is more opportunity for energy and natural resources imports/exports, adherence to international visions and agreements will restrict the options. Environmental protocols e.g. reactive supply options but more participants.</td>
<td>1. Water, reactive to needs. Ad hoc government influence that leads to difficult long-term planning, slaves to international investment and restricted development.</td>
<td>1. Local external energy and natural resources trade. Inward focus will alienate trading partners and lead to expensive home-grown technology.</td>
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<tr>
<td>2. The extent to which global issues affect supplies and markets. Competition opportunities.</td>
<td>2. Limited impact except in oil supply sector (significant). Not perceived to be investor friendly.</td>
<td>2. Limited external influence owing to innovative use of indigenous resources and attractions of investment.</td>
<td>2. Significant impact – all sectors will experience volatility of free market systems. Coal opportunities/attractive for investment/coal threats.</td>
<td>2. More sensitive – more dependent on imported resources – local resources decrease owing to fragmented approach.</td>
<td>2. Extent of impact will be variable depending on selection of issues. Domination of coal, vulnerable market and isolation potential market opportunities in developing countries. Demand limited by affordability.</td>
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<tr>
<td>3. Impact of environmental issues on the energy sector.</td>
<td>3. Lip service to environmental sustainability, poor implementation, desirable principles included in policy but not followed through.</td>
<td>3. Environmental sustainability dictated by regional priorities and opportunities, e.g. SAPP, South African grid etc. Favours PBNR, Hydro, Gas etc.</td>
<td>3. Compliance with international treaties and protocols. Encourage renewable energy development and clean coal technology. Carry a cost that may be difficult to recover and allocate. Energy price could come down or go up?</td>
<td>3. Vacillating environmental policy. No local initiative and implementation, only under duress. Carry on with coal.</td>
<td>3. Ignore international protocols and environmental pressure. A case of development opposed to sustainability. Redress of demands will result in a backlash.</td>
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<tr>
<td>KEY UNCERTAINTY</td>
<td>STATUS QUO (current reality)</td>
<td>INNOVATION HUB (SADC focus)</td>
<td>GLOBAL HOME (global developments with a national focus)</td>
<td>FROZEN REVOLUTION (reactive)</td>
<td>OUR WAY IS THE WAY (developing national sufficiency)</td>
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<tr>
<td>5. Influence of the African renaissance vision on the energy sector and related areas.</td>
<td>5. Limited to SADC at this stage. Too new for Pan African impact yet</td>
<td>5. Collaborative position in global markets. African renaissance dwindled to be replaced by SADC focus – no overall energy impact, but SAPP flourishes. SADC gas, grid region not a focus.</td>
<td>5. Totally subjugated to global forces</td>
<td>5. Rhetoric. Sporadic projects if aid is available</td>
<td>5. African Energy Technology Institute up and running. Critical strategy for channeling expertise into Africa – African power, gas and LNG grid.</td>
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</table>
Table 4.1 lists the key uncertainties for the energy sector and how they could change in each of the scenarios.

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<tr>
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<tr>
<td>8. Extent and rate of development of technology.</td>
<td>8. Dominated by mature technologies, wide spectrum of development, but relatively slow rate of absorption into practice.</td>
<td>8. Increased rate of development regionally. South Africa focuses on technologies specifically for regional needs. Appropriate technologies for remote energy systems e.g. windup TV's.</td>
<td>8. Slower extent and rate of technology development in SA, except small niches for global markets, e.g. Sasol coal to gas technology. More participation in international state-of-the-art R&amp;T.</td>
<td>8. No energy sector technology development, only for maintenance of current systems, survival.</td>
<td>8. Increased rate of energy technology development in SA, very focused on specific strategic energy projects e.g. Mossgas.</td>
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<tr>
<td>9. Extent and rate of uptake and implementation of technology.</td>
<td>9. Conflict between uncompetitive job creation and value-added imports.</td>
<td>9. Extent depends on regional economic development, high uptake of appropriate technology.</td>
<td>9. Environmental technology transfer initially high. Uptake determined by affordability Energy efficiency and end-use opportunities.</td>
<td>9. Intermittent, opportunistic uptake and limited implementation.</td>
<td>9. Opportunistic use of technology for end use to reduce cost of imported energy. High uptake but from a reduced and limited base.</td>
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<tr>
<td>10. Extent of impact of AIDS and population growth. Economically active population affected and disruption of social structures. Changing occupational modes, environmental and economic drivers.</td>
<td>10. High population growth and urbanisation places demands on pension planning. AIDS spread demands increasing medical costs.</td>
<td>10. SA and SADC drive effective AIDS programmes. Technology used for population education. Urbanisation and skills loss controlled.</td>
<td>10. SA imports expertise and products. Potential exists for export of human resources. Urbanisation follows global trends. Lower benefits lead to loss of local skills.</td>
<td>10. Use is made of cheap and available skills and products (from SA or elsewhere). No plan to solve local problems, only to contain. Internal focus. High impact of urbanisation.</td>
<td>10. Use what is known and available (in SA only). No import and export of skills and technology. Can build on relationship with other developing nations (joint programmes).</td>
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Chapter 5: Survey

5.1 Introduction

The aim of the Foresight exercise, through its Working Group, is to assess emerging market opportunities and technological trends and inform decisions on the balance and direction of publicly-funded science and technology for the next twenty years. It was recognised from the outset that it was not possible to have all the necessary expertise within a Working Group of a manageable size especially considering the broadness of the sector. To gain the necessary commitment and consensus needed to make decisions and implement the Foresight product, it was crucial to conduct wide consultation with most stakeholders in the energy sector. A substantial amount of consultation was done through the Working Group members, associated individuals and the reference group. However, a much more structured dialogue with a cross-section of stakeholders was required to test preliminary strategies developed within the Working Group. This intensive and continuous consultation process makes the Foresight relevant to South Africa, where science and technology systems have functioned in fragmentation. The method chosen to achieve this objective is the questionnaire-based Delphi Survey, a process in two iterations aimed at broader consultation of the stakeholders in the sector. The reasons for the second iteration were —

• to give feedback to the respondent on the results of the first stage;
• to provide the respondent with the opportunity to refine his/her own evaluation;
• to provide the opportunity to give reasons for differences from the aggregate results where these existed.

The main objectives of the survey were —

• to access views on future developments in markets and technologies from business, civil society, and science and technology communities;
• to achieve commitments to results and consensus development; and
• to inform stakeholders at large about major issues being addressed by the Foresight project.

The Delphi was used in other, international studies in countries such as Japan, Germany, the UK and Hungary, either alone or in support of other Foresight tools. The same principles underlying these international Delphi studies were also applied to the South African Delphi. The Delphi approach in its classic form obtains people’s opinions in an iterative fashion, usually by bringing them together in a discussion. In the modern age the opinions are often gathered remotely. The Delphi approach in the
foresight context obtains the opinions of various knowledgeable and interested individuals on technologies and technological trends and the most appropriate options for their countries, usually using a futures frame of reference of between ten and 20 years.

5.2 Methodology

The Working Group members worked in subgroups around themes that were formulated from the SWOT analysis (Appendix F). The topics that were identified in these areas were rated in each of the scenarios to establish their relative importance to South Africa for the long term (Appendix G). This prioritisation methodology was used to reduce the number of topics for the survey. The Working Group then formulated Delphi statements. These had to be concise statements of event, achievements or other phenomena upon which views are sought, an unambiguous expression of what the questioner felt had to be achieved, incorporating any key conditions but excluding separate issues that warranted additional topics. Sixty-nine statements were formulated for the first round of the survey. The Sector Working Group was encouraged to be even more precise in their formulations through the use of quantitative representations in the statements. The results of the first round were analysed by the Working Group and the statements were reduced to 49 for the second round of the survey.

5.3 Survey statements

The refined statements and the results from the second round of the survey are presented in Appendix H.

A list of R&T challenges emanating from the second round of the survey and augmented by the SWG is presented in Appendix I.

5.4 Survey results

The survey results reflect the perceptions of the stakeholders in the sector at large about the statements as represented by the respondents of the survey. The results were analysed according to confidence levels claimed by the respondents, for e.g. High, Medium or Low, and in combinations of these three. It was evident from the data that a high degree of variability between the 'High' and 'Low' levels of confidence existed, while those between 'High' and 'Medium' were almost minimal. The Sector Working Group based its analysis on the responses of the respondents claiming high or medium knowledge of the topic.

The results of all the respondents are attached:
• Frequency Table Bars — indicating the response patterns or the distribution of responses (part of Appendix H);

• Table 5.1 indicating the Top Twenty Topics according to the descending aggregate index (WC+QL), derived from the indices Wealth Creation (WC) and Quality of Life (QL). These indices are used as a measure of the respondents perceived ultimate potential for the topic.

Also included on these tables is respondents' perceived significant constraints associated with the topics. E.g. F = financial; T = technological, M = market, HR= Human Resources, P = Policy; SC = Social or Cultural. Please refer to the questionnaire for these.

• Table 5.2 indicating the Bottom Ten Topics according to the descending aggregate index (WC+QL), derived from the indices Wealth Creation (WC) and Quality of Life (QL).

• A graph indicating the correlation between the WC and QL.

The Bottom Ten Topics are also provided for comparison. It is evident that the futuristic technologies such as super conductors and airships did not solicit support in the South African environment. There could however be certain markets in which these and other technologies could play a significant role.

5.4.1 Statements considered important to South Africa

Although the top 20 statements have been sorted according to the joint index reflecting the aggregate importance of the topic, the topics should be interpreted also by evaluating the wealth creation and quality of life indices independently. For example, statements 39, 1 and 36 would have a significant effect on quality of life issues, and statements 10, 8, 43 and 19 on wealth creation.

5.4.2 Spread of results

Figure 5.1 illustrates the position of the statements on the WC and QL axes. The right-hand top quadrant shows the statements with the largest potential for creating wealth and improving quality of life. These topics formed the core of the subsequent analysis and development of technology priorities.
Table 5.1: Top twenty topics identified in the Energy Sector Delphi Survey

<table>
<thead>
<tr>
<th>No</th>
<th>Topic</th>
<th>Joint Index</th>
<th>WC Index</th>
<th>QL Index</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>08</td>
<td>A technically reliable Southern African electricity grid enables low-cost electricity delivery for 30% of South Africa's electricity needs.</td>
<td>70</td>
<td>72</td>
<td>69</td>
<td>P, T, M, HR</td>
</tr>
<tr>
<td>10</td>
<td>Widespread application of more efficient electricity delivery technology reduces capital and operating costs by 15%.</td>
<td>69</td>
<td>77</td>
<td>61</td>
<td>T, R&amp;D, P</td>
</tr>
<tr>
<td>36</td>
<td>New advanced mass public transport (including rail, tram) systems will provide cost- and energy-efficient alternatives to 1998 practices.</td>
<td>64</td>
<td>47</td>
<td>81</td>
<td>P, M, SC, T</td>
</tr>
<tr>
<td>39</td>
<td>As a result of energisation (a mixture of electricity and thermal fuels) programmes, low-income household air pollution and the related health problems have been reduced by 80%.</td>
<td>58</td>
<td>30</td>
<td>87</td>
<td>SC, P, T, M</td>
</tr>
<tr>
<td>43</td>
<td>Widespread electrical equipment manufacturing in SADC stimulated by regional electrification and standardisation.</td>
<td>48</td>
<td>67</td>
<td>28</td>
<td>M, P, T</td>
</tr>
<tr>
<td>26</td>
<td>Nearly all new houses in South Africa with piped water are built with solar (thermal) water heating systems.</td>
<td>46</td>
<td>18</td>
<td>73</td>
<td>M, P, SC, T</td>
</tr>
<tr>
<td>19</td>
<td>South Africa's average efficiency in the combustion of coal to generate electricity is increased to 50% from our current 34% level.</td>
<td>43</td>
<td>48</td>
<td>39</td>
<td>T, R&amp;D, P</td>
</tr>
<tr>
<td>01</td>
<td>Two million households and cottage industries in remote areas of South Africa obtain cost-effective electricity from photovoltaic (PV) sources for low power energy services e.g. lighting, TVs, refrigeration.</td>
<td>38</td>
<td>-6</td>
<td>82</td>
<td>SC, M, T, P</td>
</tr>
<tr>
<td>33</td>
<td>Widespread application of Demand Side Management (DSM) reduces the need to invest in additional generating capacity.</td>
<td>27</td>
<td>19</td>
<td>35</td>
<td>P, T, M, SC</td>
</tr>
<tr>
<td>09</td>
<td>The development of robust high-voltage transmission and enabling technologies for bulk power/energy transfer in South Africa.</td>
<td>27</td>
<td>33</td>
<td>20</td>
<td>T, R&amp;D</td>
</tr>
<tr>
<td>29</td>
<td>The increase in rural Liquefied Petroleum Gas usage has facilitated an increase in the development of the rural local delivery services and small businesses.</td>
<td>25</td>
<td>13</td>
<td>37</td>
<td>M, SC, P</td>
</tr>
<tr>
<td>30</td>
<td>Widespread use of remote pre-payment metering technology for electricity in South Africa.</td>
<td>23</td>
<td>5</td>
<td>40</td>
<td>M, SC, P</td>
</tr>
<tr>
<td>46</td>
<td>The development of technologies to add value to indigenous materials in energy applications such as catalytic converters.</td>
<td>22</td>
<td>33</td>
<td>12</td>
<td>T, R&amp;D, HR, M, P</td>
</tr>
<tr>
<td>31</td>
<td>Development of appliances (e.g. lighting) with a 20% energy efficiency improvement to reduce household energy costs.</td>
<td>22</td>
<td>19</td>
<td>24</td>
<td>T, M, P</td>
</tr>
<tr>
<td>35</td>
<td>Widespread use of traffic management systems reduces energy consumption considerably.</td>
<td>21</td>
<td>19</td>
<td>24</td>
<td>P, T, SC</td>
</tr>
<tr>
<td>44</td>
<td>South Africa's manufacturing facilities, which are based on its local solar photovoltaic panel requirements, export 50% of its production.</td>
<td>20</td>
<td>27</td>
<td>14</td>
<td>M, T, P</td>
</tr>
<tr>
<td>27</td>
<td>70% of homes with solar power in South Africa have TVs.</td>
<td>20</td>
<td>-13</td>
<td>52</td>
<td>M, SC, T</td>
</tr>
<tr>
<td>18</td>
<td>The development of high-efficiency, low-emission technologies for burning discard coal in South Africa.</td>
<td>19</td>
<td>13</td>
<td>26</td>
<td>T, P, R&amp;D</td>
</tr>
<tr>
<td>12</td>
<td>The development of customer-side power quality technology, especially for remote areas, allows use of less expensive distribution networks.</td>
<td>19</td>
<td>8</td>
<td>31</td>
<td>T, P, R&amp;D</td>
</tr>
<tr>
<td>42</td>
<td>Widespread exporting to the SADC region of South Africa energy sector technology based on local expertise (also health and safety etc.).</td>
<td>15</td>
<td>26</td>
<td>3</td>
<td>M, P, HR</td>
</tr>
<tr>
<td>Rank-order position</td>
<td>Topic No</td>
<td>Topic</td>
<td>Wealth Creation</td>
<td>Quality of Life</td>
<td>Joint Index</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
<td>The expansion of internationally recognised, fossil fuel technologies, skills base, in South Africa</td>
<td>-3.28</td>
<td>-22.95</td>
<td>-13.11</td>
</tr>
<tr>
<td>41</td>
<td>14</td>
<td>Ninety-five per cent of South African paraffin users and potential users have access to paraffin within a 5 km distance from their dwelling</td>
<td>-59.68</td>
<td>20.97</td>
<td>-19.35</td>
</tr>
<tr>
<td>42</td>
<td>38</td>
<td>Widespread application of heat pumps that have been developed and built in South Africa</td>
<td>-21.67</td>
<td>-18.33</td>
<td>-20.00</td>
</tr>
<tr>
<td>43</td>
<td>2</td>
<td>Fifty per cent of South Africa’s electricity is generated by medium-scale (500kW–5MW) renewable energy sources, e.g. wind, solar and wave</td>
<td>-29.23</td>
<td>-13.85</td>
<td>-21.54</td>
</tr>
<tr>
<td>44</td>
<td>15</td>
<td>Practical use of Liquefied Natural Gas (LNG) technology for imported gas, which is used in industry and power generation</td>
<td>-17.74</td>
<td>-36.07</td>
<td>-26.90</td>
</tr>
<tr>
<td>45</td>
<td>6</td>
<td>Practical recovery of coal-bed methane for in situ gasification in deep-level coal fields in South Africa</td>
<td>-34.38</td>
<td>-33.33</td>
<td>-33.85</td>
</tr>
<tr>
<td>46</td>
<td>41</td>
<td>Development of knowledge-based systems to provide access to public-domain South African energy information for future research, planning and training</td>
<td>-28.81</td>
<td>-48.28</td>
<td>-38.54</td>
</tr>
<tr>
<td>47</td>
<td>11</td>
<td>Practical use of super-conducting cables in power systems</td>
<td>-25.81</td>
<td>-51.61</td>
<td>-38.71</td>
</tr>
<tr>
<td>48</td>
<td>16</td>
<td>Practical use of Compressed Natural Gas (CNG) for transport vehicles that make a contribution to the reduction in emissions</td>
<td>-54.69</td>
<td>-32.81</td>
<td>-43.75</td>
</tr>
<tr>
<td>49</td>
<td>37</td>
<td>The practical use of airship technology for low-cost transport of goods, recreation, tourism, etc.</td>
<td>-66.13</td>
<td>-70.97</td>
<td>-68.55</td>
</tr>
</tbody>
</table>

Figure 5.1: Scatterplot of the indices of importance to South Africa (for all second-round topics). All second-round topics in the scatterplot are shown as

Wealth Creation vs Quality of Life
Chapter 6: Working Group recommendations

6.1 Introduction

Future research and technology challenges and market opportunities over the next 10 to 20 years for the energy sector were identified and strategies developed around them. The outputs will be crucial to the economic and social development of the energy sector in South Africa over this period. The following are the outputs that form the long-term research and technology plan:

1. Long-term research and technology objectives for the energy sector and a strategy for achieving them;
2. A prioritised list of research and technology topics for the energy sector; and
3. Recommendations on implementation strategies for the energy sector.

6.2 Process followed

The top twenty statements identified in the second round of the survey and the technology challenges emanating from the survey and augmented by the Sector Working Group were used as input for this part of the NRTF process. The aim of this part of the process was to identify the most important medium- and long-term R&T issues for the energy sector in South Africa and formulate recommendations around them. The Working Group linked the R&T challenges to different themes. These themes were derived by logically grouping statements together. The linkages to themes were done to determine the effect of the R&T challenges on them. The number of linkages to an R&T challenge was an indication of its relative importance in supporting the statements. The collective knowledge of the Working Group was used to reduce the R&T challenges to a manageable number. These R&T challenges were then positioned on an attractiveness versus feasibility diagram (see Figure 6.1).

The high attractiveness and high feasibility quadrant in the diagram shows the medium-term priority areas, which present immediate implementation or technology transfer opportunities.

The high-attractiveness and low-feasibility quadrant in the diagram shows the long-term priority areas, which present R&D opportunities.

In addition, the Working Group identified technologies that display potential for South Africa. However, their potential for implementation is currently uncertain.
6.3 Key research and technology areas

Recommendations were then developed for all of these areas.

Research and technology challenges were grouped according to two criteria, namely attractiveness (what are the benefits/rewards?) and feasibility (is it possible or the converse of the required effort, risk and time to develop?), as indicated in Figure 6.1.

Eighteen challenges were selected according to their ranking on the two axes. For each of these challenges constraints and recommendations were listed. Those challenges located at the lower end of the feasibility axis (top left-hand quadrant of Figure 6.1a) represent the longer-term technology possibilities, while the challenges at the higher end of the feasibility axis (top right-hand quadrant, Fig. 6.1b) represent the medium-term possibilities.

6.4 List of priority R&T challenges for implementation in the medium term

(These were developed from Figure 6.1 and rated in priority order by the ESWG.)

a) Uses of coal discards
b) Low-cost solar water heating systems
c) Low-cost photovoltaic solar home systems
d) Low-cost paraffin appliances
e) Knowledge-based energy information and energy simulation and modelling systems
f) Low-cost electricity distribution, reticulation and metering technologies
g) Economic insulation for low-cost housing
h) Innovative energy applications for gas
i) Small-scale energy storage for stand-alone applications
j) Energy-efficient buildings.

6.5 List of priority R&T challenges for implementation in the medium to long term

(These were developed from Figure 6.1 and rated in priority order by the ESWG.)

a) End-use technologies to improve industrial competitiveness
b) Biotechnology for energy
c) Bulk solar thermal
d) High-efficiency power generation
e) Alternate energy delivery for rural SMMEs
f) Low-cost hydrogen production
g) Large-scale electricity storage
h) High-efficiency electrical transmission.

6.6 List of technologies requiring further investigation

In addition to the technologies detailed above, there were three technological areas receiving considerable attention in South Africa at present. Whilst not part of the prioritised list, they were all in the 'bubbling under' category and therefore it was felt that they require further consideration. They are as follows:

a) Wind energy — especially large-scale wind farms.
b) Natural gas infrastructure.
c) New nuclear technology such as the Pebble Bed Modular Reactor.

6.7 Recommendations for each of the challenges for implementation in the medium term

6.7.1 Uses of coal discards

Mainly because of coal exports, South Africa produces large volumes of discard coal. More than 500 million tonnes are stored in dumps, mainly in Mpumalanga. This material is a useful asset that is not utilised at present, but it could become an environmental problem. Some typical constraints on the use of discard coal are the following:

- 'High' cost of use
- Lack of supporting policy
- Lack of/constraining environmental legislation or policy
- No IPP policy or mandated purchase of electricity at system avoided cost
- Excess capacity of existing system
- Low energy and high sulphur content of the discards.

Recommendations

- Stimulate the development of a centre of excellence in coal discard utilisation.
- Explore means of creating an enabling environment for discard coal use.
- Obtain international funding for research application of clean coal technologies.
- Seek cleaner utilisation of coal and innovative methods for discard coal use.
- Conduct pilot projects.
- Fund local research and development in respect of discard coal utilisation beyond power generation.
6.7.2 Low-cost solar water heating systems

The country has high levels of solar radiation but the use of solar water heating is relatively low. Many reasons for this situation exist, one of them being the relatively high cost of solar water heaters, especially when used in low-income applications. Some typical constraints on the use of solar water heating systems are the following:

- Current low volume of production and commercialisation, which lead to high costs
- Lack of products appropriate for low-income housing
- Lack of a national policy with tangible incentives
- Lack of piped water in many cases
- Lack of standards.

Recommendations

- Conduct a techno-economic study of South African low-cost systems, to be used to develop strategies for implementation.
- Determine the characteristics of and requirements for piped and non-piped systems.
- Monitor what is happening in other comparable countries, especially in India, China and South America.
- Research and develop appropriate materials, storage approaches and minimisation of losses.
- Develop cheap anti-freezing technique/method.
- Analyse hybrid systems, especially the control strategy for an electrical backup heater.
- Formulate appropriate incentives and/or requirements.

6.7.3 Low-cost photovoltaic solar home systems

South Africa has high levels of solar radiation that are ideally suited for the application of photovoltaics. Some typical constraints on the use of photovoltaics are the following:

- Low level of PV technology activity in South Africa
- Lack of trained human resources and manufacturing infrastructure
- Financing mechanisms for end users not developed.

Recommendations

- Purchase technology, establish JV to develop local applications.
- Promote/establish centres of academic excellence in this area.
• Evaluate potential for South Africa to be a major user and participate in world market.
• Support initiatives to develop low-cost energy storage for PV technology.
• Monitor technology and application progress in other developing countries.
• Investigate applications for PV energy — rural households, low-cost appliances
• Develop institutional and financial mechanisms to improve accessibility.

6.7.4 Low-cost paraffin appliances

Paraffin appliances are widely used by a large part of the population. Cost, safety and performance are major considerations that are not satisfied in many cases. Typical constraints on the use of paraffin appliances are the following:

• Poor safety of some products
• Lack of appropriate standards and methods of enforcement
• Lack of user education
• Affordability.

Recommendations

• Establish and implement safety and performance standards.
• Develop and institute an effective method of enforcing the marketing of appliances that satisfy this standard.
• Investigate the techno-economic feasibility of multifuel appliances.
• Develop an effective user education programme.
• Encourage regional application of the standard and education programme.
• Achieve/promote economies of scale for manufacturing, including the region and African countries as component suppliers and markets.

6.7.5 Knowledge-based energy information and energy simulation and modelling systems

South Africa's capacity and skills with regard to the collection of disaggregated energy supply and use data are limited. This results in questions about the accuracy of available data, limited analysis of energy economic trends and very slow progress in long-term energy modelling and the quantification of national energy scenarios. The energy sector requires national data for economic analysis of additions to installations and new plant/products and the capability of 'micro' economic analysis related to the national situation. Typical factors that have an impact on the development of knowledge-based energy information systems and energy simulating and modelling are the following:

• Limited resources for data collection and system development
• A lack of skills in information systems development
• No policy in respect of integration and application of such systems
• A lack of models to process the available data.

Recommendations

• Follow internationally established formats for data models.
• Demonstrate public accessibility of data by also applying such data in education.
• Identify the major public needs, develop appropriate systems and create the required resources.
• Relate data collection and simulation to the environmental impact of the energy sector.

It needs to be stressed that this challenge consists of two discrete components that are linked but require separate approaches:

• The collection and analysis of data.
• The modelling of energy demand and supply at both the macro- and micro-levels.

6.7.6 Low-cost electricity distribution, reticulation and metering technologies

South Africa has world-class manufacturing facilities in low-cost electricity distribution, reticulation and metering technologies. Technology development attitudes have changed and extensive markets exist for the implementation of improvements to these systems. Typical factors that have an impact on the future development of these systems are the following:

• Policy to promote innovation
• Commercial structures
• Uncertainty in electricity distribution industry (EDI) institutional structures.

Recommendations

• Retain world status in metering technologies and protect intellectual property.
• Support joint-venture activity between utilities and manufacturers for distribution and reticulation.

6.7.7 Economic insulation for low-cost housing

Because of cost constraints, low-income dwellings are not insulated. The most important component for thermal comfort and winter energy use — a ceiling — is generally not installed. The life-cycle cost of low-cost thermal insulation is very low.
Typical factors that influence the use of insulation in low-cost houses are the following:

- No funds are available for insulation and it does not form part of the subsidy policy.
- Housing policy and standards do not address insulation as a priority area.
- A need exists for suitable product and system development to achieve low-cost insulation systems.
- There is a lack of attention to and knowledge of the life-cycle cost of no insulation by user and housing bodies.
- Energy consumption is not a priority in South Africa.
- Lack of a suitable awareness policy.

Recommendations

- Scan for international and local developments.
- Analyse the implications of no/limited insulation versus suitable insulation on national energy use, cost, future demand and pollution.
- Develop suitable products and systems for application in different housing types and climatic regions, including the use of recycled materials and products.
- Conduct pilot projects, also for retrofit and on a do-it-yourself basis.
- Develop concise standards related to climatic region.
- Develop and implement implementation programme.

6.7.8 Innovative energy applications for gas

Pipeline gas is used to a limited extent. Resources existing in South Africa and its neighbouring countries can contribute to the diversity of energy supply, reduction of pollution and economic competitiveness. It is expected that this gas can be effectively used in a variety of innovative applications but much of the analysis and development have not been undertaken. Typical factors that have an impact on the energy applications of gas are the following:

- Limited local natural gas resources
- Lack of infrastructure and knowledge base
- Little or no academic focus.

Recommendations

- Develop a centre of excellence.
- Scan developments in this area.
- Analyse innovative applications.
- Buy technology and customise for the Southern African environment.
• Implement pilot projects.

6.7.9 Small-scale energy storage for stand-alone applications

Stand-alone energy systems require some form of energy storage. Some of these are used in conventional applications and are well-understood, for example batteries connected to solar panels. No experience exists with regard to other potential systems, like large-scale superconducting storage devices for low-cost power. The optimal use of these applications requires a suitable and cost-effective storage system. Typical factors that influence the application of small stand-alone energy storage devices are the following:

• Lack of knowledge and technology
• High costs
• Little or no academic focus
• No support by the tax system

Recommendations

• Scan developments in this area to identify potential partners.
• Joint venture(s) with centre(s) of excellence in other countries.
• Support research and development infrastructure development.
• Identify areas with potential for focused attention.
• Support policy analysis and development.
• Promote pilots and disseminate information.

6.7.10 Energy-efficient buildings

Energy efficiency is not necessarily implemented in the retrofits of existing and the design of new buildings. Much of the knowledge exists internationally but it needs to be adapted and applied locally. The potential for large cost and energy savings exists. Typical factors that have an impact on energy-efficient buildings are the following:

• Lack of awareness, policy and standards
• Lack of focused education in energy-efficient building design in architecture, building and engineering systems design
• Lack of understanding of the implications of orientation at town planning level
• A fragmented building industry
• Professional fees linked to capital costs.

Recommendations
• The housing subsidy must be linked to criteria regarding the orientation, window size and thermal resistance to satisfy minimum standards.
• Develop and implement energy-efficient building regulations and standards.
• Residential town planning guidelines along zonal (N/S) lines.
• Develop local focus in this area.
• Build demonstration centres in various climatic areas and conduct pilot projects.
• Sponsor energy audits in existing large buildings.
• Promote life-cycle costing.
• Introduce industry into study programmes of associated disciplines.

6.8 Recommendations for each of the challenges for implementation in the medium to long term

6.8.1 End-use technologies to improve industrial competitiveness

Much of the end use of energy in industry involves less efficient technology and a lack of skills to operate these systems at peak efficiency. Extensive developments have taken and are taking place in other parts of the world with large efficiency and cost improvements that will make local industry more competitive. Typical factors that impact on end-use technologies are the following:

• Lack of knowledge and skills
• Lack of detailed information and data on energy use
• Production technology is old and replacement with efficient technology slow because of low growth in economy and surplus production capacity
• Limited choice regarding energy carrier and end-use technology
• High cost of capital versus low cost of energy
• No culture of energy awareness
• No clear signals from government of what is required.

DME has recently dropped energy efficiency as a line function.

Recommendations

• Develop a disaggregated information collection and dissemination programme, including the relevant regulatory mandate.
• Create a centre of expertise/excellence, linked to appropriate industry associations and units in SADC countries for —
  – training (also as part of SETA);
  – culture change, including publicity, information dissemination, development of an active Web page;
  – subsidised demonstration projects; and
- development of a user-friendly technology database, including overseas links such as the IEA and Caddett.
- Appropriate R&T development, also in coordination with other industry research bodies (Mintek, CSIR, TRI/TSI).
- Channel international environmental funding.
- Organise competitions and awards to reward organisations that have achieved excellent results/improvements and give publicity to results achieved (the activities of this centre is similar to the Energy Efficiency Agency that is described in the Energy Policy White Paper as a medium-term priority).
- Financial support:
  - Remove financial disincentives (e.g. import tariffs on low-volume energy efficiency equipment).
  - Tax incentives for the installation of energy efficiency equipment and processes.
  - Low-interest funding.
  - Pricing of energy to reflect actual or market cost, including the internalisation of external costs and benefits when our trading partners do so.
- Support the creation of Energy Service Companies (Escos).

6.8.2 Biotechnology for energy

Biotechnology offers potential for large breakthroughs in energy use and supply, often in unexpected ways. Local biotechnology research for energy applications is limited. Some work in biotechnology for mineral extraction is taking place in South Africa. Chemistry and biotechnology skills are available and the typical factors that impact on biotechnology for energy are the following:

- Low involvement of biotechnology research in/for energy.
- Existing skills are not focused.
- Fundamental research is required.
- Because of a wide range of new technology possibilities the risk of no or limited investment return on research exists.

Recommendations

- Conduct a scan and study to identify preferred focus areas. Redo study on a five-year cycle.
- Include gassification of biomass and waste, such as tyres, by biotechnology.
- Support fundamental research at a small number of centres of expertise at universities and refocused research institutes.

6.8.3 Bulk solar thermal
The solar resource in South Africa is one of the best in the world but this topic has received very little attention because of the low cost and large resource base of coal. Solar technology that is being developed in other parts of the world has the potential to compete with conventional forms of power and energy generation in the medium to long term, especially for peak requirements, with zero greenhouse gas emissions. Typical factors that affect the development of bulk solar thermal are the following:

- Solar radiation is available on a diurnal cycle.
- Storage facilities are required to be part of the supply system.
- High cost of these installations at present and sophisticated materials required.
- Requires resources to operate, clean and maintain.
- Sophisticated control systems are required.

**Recommendations**

- Obtain government support for international funding and World Bank subsidies.
- Create a joint venture with the US and/or EU to obtain their experience and knowledge.
- Select a suitable site where all the requirements and constraints will be evaluated in a demonstration project that will form the basis for strategic planning for large-scale commercialised use.
- Implement a research programme on the durability of materials, improved efficiency in absorbing solar radiation and reducing costs.

**6.8.4 High efficiency power generation from coal (including coal gassification)**

Existing power generation technology has a technical thermal system efficiency limit of about 35%. New technologies are available that have efficiencies of up to 50%, but no R&D experience exists in South Africa in this regard, and in many cases, for e.g. heat and power, these technologies are not applicable. This is an area where value can be added to local coal resources. Many countries are busy with a variety of new developments and demonstration projects for improving efficiency and lowering environmental impacts that will produce results in the medium to long term. The larger countries or groups of countries have linked these developments to clean energy/coal programmes. These technologies include the entrained gassification of coal linked to combined cycles of various types. Current constraints are the following:

- These technologies are very specific regarding the characteristics of the coal that is used. This means that local coal will have to be studied and tested in order to link to or adapt available technology.
- Large investments for demonstration plants are required.
- The private sector may have the know–how to operate these new technologies but will not invest in technology that is not proven or cost–competitive.
• High costs.
• Regional applications.

Recommendations

• Form an alliance with relevant technology partners, such as the US-DOE and the IEA, to get access to experience and know-how.
• Obtain a licence to implement the most appropriate technology.
• Carry out a medium-scale demonstration project.
• Develop a clean-coal policy and strategy.

6.8.5 Low-cost energy supply and alternative delivery for rural SMMEs

Many issues still need to be understood and developed in this regard. Some of the constraints are the following:

• A lack of knowledge, information and choice.
• A lack of physical infrastructure, resources and finance for energy delivery.
• Long and expensive energy delivery chains.
• Low population density and long transport distances.
• Existing approaches are too expensive and new approaches are not proven or known; costs and risks are high.
• Development agencies do not address effective energy delivery per se and do not have the knowledge or suitable experience.
• No integrated development plan exists.
• Constitutional authority/responsibility of central, provincial and local government is not clear.

Recommendations

• Carry out well-planned and monitored pilot projects in a number of different applications and parts of the country, including the exploration of the social acceptance of the technology.
• Develop joint programmes with rural development agencies (DBSA, Khula Enterprises, Ntsika, the provinces, the Rural Development Trust, etc.) and with SADC countries.
• Implement R&T development in specific areas of real potential and need (mainly electrical, therefore the focal point for such efforts could be TRI/TSI).
• Expand the rural electrification programme to include the developmental, information, and training and support functions.

6.8.6 Low-cost hydrogen production
Low-cost hydrogen is an important alternative energy source. The importance is the fact that hydrogen is a clean and efficient energy source that can be efficiently transported and used in a variety of end-use devices, including fuel cells. Typical constraints are the following:

- The cost of producing hydrogen
- The storage, transport and production of hydrogen
- Very new technology, not used on a large scale anywhere
- A lack of practical knowledge and experience internationally.

Recommendations

- Carry out a scoping study to establish the state of knowledge, the research that is taking place and perceptions of the specific use of hydrogen and the time frame for practical application, including the development of fuel cell systems.
- Target research to the identified focus areas, including production methods and technology, which will give low-cost production from the multitude of local fossil feedstocks.
- Carry out pilot projects as a joint venture with (an)other country(ies).
- Where required, buy the intellectual property rights and implement.

6.8.7 Large-scale, efficient electricity storage systems including superconductivity (but excluding pumped water storage)

Large-scale efficient electricity storage systems would become extremely important to South Africa. One of the contributing factors is the profound increase in morning and evening electricity peaks. Superconductivity, flywheels and other technologies could play a significant role in alleviating the problem. South Africa has had limited involvement in superconductivity or molten-salt research, with the former technology being applied on a small scale for power quality applications. South Africa generally has little involvement in large-scale energy storage research. Currently, there is a limited range of technologies evident but this could change in the future. South Africa's metallurgy and materials knowledge and resources could be used productively in such an endeavour.

Recommendations

- Investigate, evaluate and recommend priorities for fundamental research.
- Undertake research programme at a local institution or institutions.
- Link research to complementary applications, such as bulk solar generation.

6.8.8 High efficiency electricity transmission, superconductance and high-voltage direct current systems
South Africa has an extensive transmission network to which to apply new technology improvements and maintain low-cost advantages. Issues that need to be resolved are the following:

- No involvement in superconductivity research and limited recent developments in HVDC research
- Needs materials research — weak linkages between electricity industry and materials engineering research
- Low involvement in high-power electronics
- Need to differentiate between technical efficiency and cost efficiency.

**Recommendations**

- Identify key applications on which to concentrate.
- Import technology or joint venture for regional application.

6.9 **Recommendations for technologies requiring further investigation**

It is recommended that the three technologies listed be further explored to determine their potential role in the South African energy system — if any.

6.10 **Key success factors to support the recommendations**

6.10.1 **Human resource development (HRD) initiatives**

Three areas of human resource needs have been identified under energy. They are as follows:

- Biological energy specialists;
- Engineers; and
- Software systems and process control engineers.

**Medium-term HRD (5–15 years)**

- South Africa produces a high quality of engineers and technologists and the profession is very well regulated through the Engineering Council of South Africa (ECSA). High standards of education excellence for professional engineers, technologists and technikons are ensured through ECSA’s accreditation scheme for HEIs at universities and technikons respectively. However, the number of engineers and technologists produced per capita compares unfavourably with that of developing countries, mainly as a result of insufficient numbers of school leavers with mathematics and the natural sciences as subjects. Furthermore, the
ratio of engineers to technologists and technicians, ideally 1:3, is not achieved in South Africa, where the ratio is of the order of 1:1. Technicians and technologists to support engineers are in short supply and consequently many engineers at present are misapplied, doing work that could have been done by a technician or technologist. Effective articulation at the HEI level is at present not well developed and should be addressed to make provision for career path planning. In general, engineering is regarded as a 'difficult' study area by many school leavers.

- Education in this sector is focused more on the supply side than on the demand side, yet knowledge and skills development is required in the latter. The low level of awareness of energy and appliance options by users requires intervention.
- Engineering designs at present are technically of a high standard, but in many cases not environmentally friendly. Engineering education should be more multidisciplinary, making provision for the human and interpersonal skills element, and taking cognisance of social, economic, environmental, and managerial skills development in undergraduates.
- A need exist for the optimisation of engineer and technologist education and research, and inter–institutional cooperation on both a regional and national basis should take place.
- Customisation of engineering designs to address local conditions, problems and community needs more effectively is required. These issues should be emphasised in engineering courses at HEIs.
- The electrification of households in rural areas is not adequate and research into engineering technology must be speeded up for cost–effective rural electrification and to provide the necessary control systems (for e.g. single–wire supply systems in rural areas).
- Effective solar, wind, and other energy systems development should be encouraged, and studies in renewable energy sources require attention at HEI level.

**Long–term HRD (>15 years)**

- Institutional capacity in the area of biological energy technology is limited at present, with only one institution involved in research in this area. A national strategy to investigate this and other forms of energy must be implemented.
- A need exists for training agricultural sciences, biochemical, chemical engineering and botany students in an interdisciplinary approach towards researching problems in, for example, biomass.
- A noticeable improvement in the quality of life of our own people and those of other African countries could result from a concerted South African effort and experience in the area of biotechnology for energy applications, specifically with a long–term view (in excess of 20 years).

**6.10.2 Business development initiatives**
South Africa's energy intensity is one of the highest in the world. The energy sector is an important component of people's lives. A measure of a country's level of development is the amount of annual energy used per capita. South Africa can only become prosperous if it can adopt an export-oriented economy, moving away from primary and large-scale industries in a transition towards small-scale and high-value-adding industrial and commercial activities.

The following business development areas were identified:

• **The development of smart materials for passive air-conditioning of buildings**

  Experience has shown that passive methods of air-conditioning, e.g. insulation materials, proper design methods, etc. have the shortest payback period on the investment made. Passive methods already reduce energy needs in buildings and the use of smart materials may obviate the need for air-conditioning in buildings. A better quality of life and health will result if smart materials could lead to fireless and smokeless houses in winter. These materials could be made in South Africa, creating business opportunities.

• **Pebble Bed Modular Reactor (PBMR)**

  At the remote end of the transmission network or at local networks in remote rural areas, incremental power generation will lead to higher overall efficiency of electrical supply. The PBMR has a huge export and foreign income potential for South Africa.

• **The manufacture of renewable energy equipment like solar stoves, solar stills, biogas equipment, etc. In rural areas where they are needed**

  The rural communities are mostly poor and will have to rely on renewable energy technologies that are affordable. Job creation will be enhanced through the manufacture of equipment that the local community needs.

  By the year 2012, about three million rural households will still not have electricity. Those who have electricity, use electricity mostly for lighting, radios and TV. Therefore, a significant future market exists for affordable, renewable energy equipment.

• **Spatial development initiatives (SDI) for utilising natural gas opportunities**

  Gas pipelines along SDI corridors will stimulate business opportunities owing to relative cheap gas, which will result in energy for heating purposes costing cheaper
than electricity. The manufacturing industry will benefit most, but households along the corridor could also benefit.

- **High-value products from coal and gas**

  With South Africa producing the cheapest coal in the world and gas being a by-product of coal, high-value products from coal and gas could be competitively produced for the global export market.

### 6.10.3 Beneficiation initiatives

The group had expert input from the mineral and the biochemical sector.

The general conclusion was that there are a number of areas within the mining industry where substantial GNP could be generated through the use of the low-cost energy available for beneficiation. There would not be a significant level of jobs from this process but the wealth creation within South Africa could then be directed to downstream industries, which would have a higher level of job creation.

In many cases the technology skills for development are already available in South Africa and the entrepreneurs just need tax policy incentives to justify the developments. If South Africa can productively beneficiate imported materials into aluminium then it should not miss out on other mineral beneficiation opportunities. South African expertise developed the concept now used by the Zimbabweans to overtake South Africa and produce more gold jewellery. This opportunity and other, similar ones are still available to South Africa.

The biochemical discussions are not recorded here as they did not generally utilise energy in significant proportions.

### 6.10.4 Policy recommendations

This project can be regarded as the implementation of Clause 8.5.4 of the White Paper on Energy Policy in terms of the development of a medium- to long-term energy R&T strategy. In addition, during the project it became abundantly clear that national energy policy and R&T strategies are linked, at times closely. In order to realise the priority technology challenges over the long-term horizon of 15 to 20 years, it is necessary that the Department of Minerals and Energy—

- accepts the responsibility of ensuring the implementation of these results over time;
- creates the necessary systems, structures and bodies for this purpose;
• amends or develops new energy policies to support foresight activities where appropriate;
• coordinates the development of appropriate policies by the responsible bodies in the financial, trade, environmental and human resource domains;
• obtains and/or channels the necessary resources to implement the Foresight recommendations;
• coordinates the activities of the role players in the public and private sectors so as to address these recommendations;
• in a coordinated effort with DACST, introduces a monitoring, communication and planning system to ensure that the project keeps on track, that results are communicated and that replanning takes place as determined by results achieved, lessons learnt and changes in the national and international environment.

6.10.5 Resource implications

The mission (section 1.2.2) of the ESWG did not include determining the resources required to implement these recommendations. Neither was this possible when the evolvement over the medium to long term of each technology challenge is considered. It is nevertheless the case that —

• no dedicated national funding for energy R&T exists;
• existing national funds are extremely limited;
• the allocation of energy funding by public sector (energy) bodies (DME, CSIR, Mintek, AEC, DACST, Eskom and CEF) are not coordinated or focused on national priorities.

It is recommended that —

• medium- to long-term national funding be appropriately balanced over the main R&T challenges;
• a foresight energy fund be created and funding mechanisms developed to ensure that these R&T challenges are met;
• the need for resources to meet the technology challenges be assessed from time to time and appropriate adjustments be made to resources, systems, objectives and implementation plans.

6.10.6 General recommendations

In addition to the specific recommendations detailed above, the following recommendations are made in the interests of an improved implementation of Foresight as well as the sustainability of the process:
• The maintenance of the Working Group in the form of annual meetings to review both the extent of implementation and the need for reprioritisation of R&T opportunities.

• The preparation of user–friendly and easily understandable presentation material, to be available on CD–ROM, for purposes of awareness development throughout the energy sector. This material would be used by Working Group members to sensitise their major stakeholder groups to the priorities developed as well as the opportunities presented by Foresight.
Chapter 7: Conclusion

7.1 Lessons learnt

The first South African Foresight project has been a tremendous learning experience for the participants. The participants have generally benefited from exposure to new processes and new ideas. It should be stressed that Foresight is not merely a once-off intervention, but rather a continuous process that needs full integration with the National System of Innovation. For future Foresight interventions, the following points should be factored in as lessons learnt:

a) Continuity of leadership and clear planning are essential.
b) A committed and continuous core for the Sector Working Group is required.
c) An appropriate support structure and direction by the sponsors are essential.
d) Documents must be distributed timeously for workshops and meetings.
e) More support is required at the end of the project so that impetus is not lost.
f) Owing to its complexity, some work was not easy to incorporate and present to stakeholders at large. In addition, the SWOT and scenarios were not easily conveyed to group that completed the questionnaire.
g) The importance of broad-based stakeholder consultation is unquestionable. However, practical problems did occur. Specific expertise was lacked in certain areas and access to specialists needs attention.
h) The process took too long and it was difficult to retain information. The process should be reduced to six months. This could be achieved with careful planning of the survey.
i) A trend of generating new ideas was established, which then fell off table. The results of the survey tended to average out any innovation. The analysis tended to exclude high-risk innovative thinking, especially where outside general understanding was limited. A Working Group override was therefore required to recapture innovative ideas.
j) Integration of technical and social issues is essential for effective implementation of many technologies, especially those interfacing directly with consumers.
k) The strong environmental component in the energy sector indicates that environment should be a cross-cutter and not a separate sector in future foresight activities.

7.2 Conclusions
7.2.1 A mixture of medium- and long-term technological opportunities were identified across the full energy spectrum albeit with a lower focus on liquid fuels and transport. These opportunities represent a balance between supply, demand and end use for both conventional and renewable energy applications.

7.2.2 Technology development cannot be evaluated in isolation of policy. In particular, development and applications are closely linked as addressed in the strategies detailed in this report.

7.2.3 Whilst the National Research and Technology Foresight exercise has been a valuable initiative, real added value will only be realised in the future implementation of the recommendations in this report.

7.2.4 Lack of resources has been identified as a major constraint, thereby mandating a focus on the highest priority areas and excluding others. This emphasises the need for national technological capacity building if optimal value is to be realised from Foresight.

7.2.5 Work in these areas is being undertaken by many role players. However, there appears to be a lack of coordination. A mechanism needs to be put in place to effect the coordination of foresight-aligned activities in South Africa.

7.2.6 If South Africa is able to address most of the Research and Technology challenges identified in this process through the implementation of the strategies detailed in this report, then it will enable marked improvement in wealth creation and quality of life, whilst positioning South Africa strongly in the global energy sector.

7.2.7 Recommendations should be robust to accommodate all four scenarios — they need to address projects that can be undertaken on a regional basis. Although the scenarios are equally plausible, the strategies support particular policies integrating South Africa with the rest of world rather than inviting isolation.
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Appendix A:
NRTF Sectors

Agriculture and Agroprocessing
• Food production, agroprocessing
• Forestry and fishing
• Food security
• The food and beverage industry

Biodiversity
• Conservation
• Sustainable use of biodiversity

Business and financial services
• Capital flow
• Venture capital availability
• Applications of information and communication technologies

Energy
• Alternative sources
• Generation
• Distribution

Health
• Health as an industry
• Pharmaceuticals and treatment regimens

Information and communication technologies
• Communication technologies
• Information systems

Environment
• Pollution control and waste management
• Natural resource management

Manufacturing and materials
• Specific industries/sectoral perspective
• Primary production
• Market niches
• Materials processing
Mining and metallurgy
- Extraction and purification technologies
- Beneficiation

Crime prevention, criminal justice and defence
- Defence and security
- Refocus capacity to civil application
- Criminality (social behaviour component)

Tourism
- Infrastructure
- Tourist culture and marketing

Youth
- Auditing current attitudes
- Building S&T culture and capacity
- Reward system
- Entrepreneurship

Cross-cutters
- Education / HRD / skills development
- Business development
- Beneficiation
# Appendix B:
## Working Group Members

<table>
<thead>
<tr>
<th>Name</th>
<th>Position/Institution</th>
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<tbody>
<tr>
<td>Dr T Auf der Heyde</td>
<td>Wits Technikon</td>
</tr>
<tr>
<td>Mr C Bain</td>
<td>LPG Safety Ass SA</td>
</tr>
<tr>
<td>Mr J.A. Basson</td>
<td>Consultant</td>
</tr>
<tr>
<td>Mr F.J. Botha</td>
<td>Sasol (PTY) Ltd</td>
</tr>
<tr>
<td>Mr P Brits</td>
<td>ARC</td>
</tr>
<tr>
<td>Mr N Croucher</td>
<td>National Electricity Regulator</td>
</tr>
<tr>
<td>Mrs M Davison</td>
<td>Energy Strategy Consultant</td>
</tr>
<tr>
<td>Mrs J Du Toit</td>
<td>University of Stellenbosch: IFR</td>
</tr>
<tr>
<td>Prof. A Eberhard</td>
<td>Energy and Development Research Centre, UCT</td>
</tr>
<tr>
<td>Prof. CT Gaunt</td>
<td>GBB AFRICA</td>
</tr>
<tr>
<td>Prof. D Holm</td>
<td>UP: Div of Env. Design and Man</td>
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<tr>
<td>Ms L Hutchinson</td>
<td>Paraffin Safety Association</td>
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<tr>
<td>Ms L James</td>
<td>NUM</td>
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<tr>
<td>Mr A Kenny</td>
<td>Energy Research Institute, UCT</td>
</tr>
<tr>
<td>Dr SJ Lennon</td>
<td>Eskom</td>
</tr>
<tr>
<td>Ms NA Lisa</td>
<td>DME</td>
</tr>
<tr>
<td>Mr P Loots</td>
<td>Sasol (Pty) Ltd</td>
</tr>
<tr>
<td>Ms K Mabuane</td>
<td>Minerals and Energy Policy Centre</td>
</tr>
<tr>
<td>Mr M Makgalemele</td>
<td>NUM</td>
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<tr>
<td>Mr D Nkosl</td>
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<tr>
<td>Ms Y Pillay</td>
<td>SANEA Youth</td>
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<tr>
<td>Mr E Rorke</td>
<td>Billiton</td>
</tr>
<tr>
<td>Mr J Sthole</td>
<td>Soweto City Council</td>
</tr>
<tr>
<td>Dr W Stumpf</td>
<td>Atomic Energy Corporation</td>
</tr>
<tr>
<td>Dr T Surridge</td>
<td>DME</td>
</tr>
<tr>
<td>Prof. EA Uken</td>
<td>Cape Technikon: R&amp;D</td>
</tr>
<tr>
<td>Mr PJ Van Niekerk</td>
<td>Greater JHB Metro Electricity</td>
</tr>
<tr>
<td>Mr DW Wright</td>
<td>Beigen Petroleum</td>
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<tr>
<td>Dr G Wright</td>
<td>CSR Corporate</td>
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Appendix C:
Working Group Work Programme

Meeting Dates and Activities:

• **First Meeting, Energy Sector Working Group of the National Research and Technology Foresight Project, 9 and 10 February 1998**
  - Orientation
  - Sector working group terms of reference
  - Sector foci finalisation
  - Introduction of local study
  - Introduction of international study
  - Finalise working group work programme

• **Second Meeting, 26 March 1998**
  - Feedback on local and international studies
  - ID gaps for further research
  - SWOT (1st iteration)
  - STEEP (1st iteration)
  - Introduction of survey discussion

• **Third Meeting, 21 April 1998**
  - Feedback on gaps and new information
  - Presentation of macro-scenarios and discussion
  - Identification of trends, drivers and issues
  - SWOT and STEEP (2nd iteration)
  - Developing the survey I

• **Fourth Meeting, 25 and 26 May 1998**
  - Developing the survey II
  - Finalising survey logistics
  - Sector-specific scenarios I
  - Discussion on strategic agenda
  - ID interviewees including 'remarkable people'
  - Sector-specific scenarios II
  - Identifying key uncertainties
- Identifying further information that needs to be researched

• **Fifth Meeting, 26 June 1998**

  - Sector-specific scenarios III
  - Report-back on interviews
  - Feedback on research done
  - Reviewing survey progress and gaps

• **Sixth Meeting, 14 August 1998**

  - Sector-specific scenarios IV
  - Systemic exercise
  - Generating scenarios

• **Seventh Meeting, 24 February 1999**

  - Feedback on survey
  - Feedback on scenarios
  - SWOT (3rd iteration)
  - Developing the key technology topics
  - Strategies for disseminating sector findings and progress to stakeholders

• **Eighth Meeting, 4 and 5 August 1999**

  - Feedback from stakeholders
  - Cross-cutters: presentations and discussions
  - Present draft sector report
  - Discuss strategies for implementation
  - Finalise foresight sector report
### Appendix D:  
Macroscenarios for South Africa's R&T system

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<th>Innovation Hub</th>
<th>Global Home</th>
<th>Frozen Revolution</th>
<th>Our Way Is The Way</th>
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<td>no consistent alignment</td>
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<td>SA not a significant player either regionally or globally</td>
<td>SA loses general global role (reduced), withdraws from global agenda and follows self-determination and interaction with alliance partners</td>
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<td>Government Character</td>
<td>directed development via innovation</td>
<td>diminished role of government, private sector dominant</td>
<td>interventionist on a reactive basis</td>
<td>interventionist oriented government on a proactive basis</td>
</tr>
<tr>
<td>Vision</td>
<td>long-term vision – focused on regional values and needs – gives competitive edge</td>
<td>to be a global player</td>
<td>short-term &quot;vision&quot;, reacting to symptoms, not causes</td>
<td>long-term vision – focused directly on SA development</td>
</tr>
<tr>
<td>National Identity</td>
<td>strengthening of regional identity</td>
<td>tendency towards global identity</td>
<td>no national identity</td>
<td>national identity</td>
</tr>
<tr>
<td>Social</td>
<td>Vision</td>
<td>development of regional social contract</td>
<td>No centralised social contract</td>
<td>to develop social contracts</td>
</tr>
<tr>
<td>Plan</td>
<td>regional directed plan for incremental development</td>
<td>individual responsible for social needs</td>
<td>several social development plans and policy, but no delivery</td>
<td>focused national social development plan</td>
</tr>
<tr>
<td>Human Development Index (HDI)</td>
<td>Gradual increase in HDI</td>
<td>HDI increase marginally</td>
<td>HDI declines</td>
<td>HDI initially down and then increases</td>
</tr>
<tr>
<td>Services</td>
<td>Private, higher-quality public services slowly improve, but lower quality than private social services, with universal access</td>
<td>private, high-quality social services only for those who can pay. Public service quality gradually decreases</td>
<td>private and public social services quality declining</td>
<td>public services quality initially declines sharply, but then improves – public/private services slowly converge</td>
</tr>
<tr>
<td>Knowledge Systems</td>
<td>innovative application of regional indigenous knowledge systems</td>
<td>global knowledge system dominate and decreased consideration of indigenous knowledge</td>
<td>Western Knowledge system dominates, but all knowledge systems are unsupported</td>
<td>indigenous knowledge based culture with traditional systems and values</td>
</tr>
<tr>
<td>Learning</td>
<td>innovation directed education and training</td>
<td>global market related learning and training for some</td>
<td>undirected, low relevance learning and training</td>
<td>life-long learning toward knowledge based society</td>
</tr>
<tr>
<td>Environmental Issues</td>
<td>environmental issues addressed as a result of its intrinsic and economic value</td>
<td>only addressed via compliance to international standards</td>
<td>no consideration of environmental sustainability</td>
<td>selective focus on some national environmental issues</td>
</tr>
<tr>
<td>Law and Order</td>
<td>generally crime decreases due to more growth</td>
<td>global crime decreases local crime increases</td>
<td>crime increases</td>
<td>reduction in crime</td>
</tr>
<tr>
<td><strong>ECONOMIC</strong></td>
<td><strong>INNOVATION HUB</strong></td>
<td><strong>GLOBAL HOME</strong></td>
<td><strong>FROZEN REVOLUTION</strong></td>
<td><strong>OUR WAY IS THE WAY</strong></td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------</td>
<td>-----------------</td>
<td>----------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Policy</td>
<td>proactive economic policy</td>
<td>economic policy facilitatory</td>
<td>reactive economic policy</td>
<td>proactive economic policy</td>
</tr>
<tr>
<td>Primary Focus</td>
<td>Southern African region focused</td>
<td>globally focused</td>
<td>no specific focus</td>
<td>primarily a national focus secondary focused on developing world e.g. south-south</td>
</tr>
<tr>
<td>Market Character</td>
<td>strategic and directed by government</td>
<td>open market</td>
<td>non-strategic and directed by private sector</td>
<td>strategic and directed by government</td>
</tr>
<tr>
<td>Investment</td>
<td>initially limited international investment, but increase gradually</td>
<td>high international investment</td>
<td>international investment in fluid assets</td>
<td>very limited international investment and active disinvestment by developed countries</td>
</tr>
<tr>
<td>Economic Agenda</td>
<td>SA national interest dominating Southern African region</td>
<td>determined by international agreements</td>
<td>vested interests dominating</td>
<td>SA national interest to create equity across developing countries</td>
</tr>
<tr>
<td>Model</td>
<td>strong drive towards value – addition of resources</td>
<td>focused on niches</td>
<td>remain primary resource driven</td>
<td>focus on services and SMMEs</td>
</tr>
<tr>
<td>GINI co-efficient</td>
<td>rich-poor gap remains, but number of poor decreases</td>
<td>rich-poor gap increases, but number of poor decreases</td>
<td>rich-poor gap increases, number of rich decreases</td>
<td>rich-poor gap decreases, number of rich decreases</td>
</tr>
<tr>
<td>Impact</td>
<td>initially down to 0%, but improve to 8%</td>
<td>initial GDP 6%, slowly shrinks to less</td>
<td>initial GDP &lt; 2%, shrinks to –4%</td>
<td>initial GDP 2%, then down to –3%, but slowly growing to 5%</td>
</tr>
<tr>
<td><strong>S&amp;T</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy</td>
<td>active promotion of innovation and technology management</td>
<td>S&amp;T to be globally competitive</td>
<td>low emphasis on S&amp;T, but emphasis on populist projects</td>
<td>S&amp;T aimed at self-sufficiency</td>
</tr>
<tr>
<td>Focus</td>
<td>increased regional focused innovation</td>
<td>SA innovation focused on global niches only</td>
<td>little local innovation</td>
<td>growth in local usable innovation</td>
</tr>
<tr>
<td>Impact</td>
<td>S&amp;T significant contributor to socio-economic growth</td>
<td>S&amp;T allows exploitation of niches</td>
<td>low impact on socio-economic development</td>
<td>SA specific technology basis contributes to socio-economic development</td>
</tr>
<tr>
<td>Science and Technology Acquisition</td>
<td>appropriate technology developed locally foreign technology adapted by licence</td>
<td>global access by licence and technology developed to exploit niches</td>
<td>S&amp;T sourced from elsewhere in complete kits</td>
<td>access to global S&amp;T capacity and information by all means possible technology base is SA specific, this may be incompatible with international trends</td>
</tr>
</tbody>
</table>
Appendix E: Additional SWOT issues identified in the scenario process of Chapter 4

1 Innovation Hub (describes how South Africa's comparatively developed infrastructure creates opportunities for strategic regional development).

Strengths
1. South Africa is prepared to go it alone and develop appropriate technology for regional needs.
2. Technical diversity exists in the region.
3. Social diversity leads to a richer spectrum of ideas and challenges group thinking.
4. Enhanced SADC collaboration will increase its strength as a regional entity.
5. Current momentum through innovation to address needs
6. Large, close and well understood market.
7. Improvisation and adaptation of technology development

Weaknesses
1. Inward looking
2. Lack of focus on environmental issues
3. Still focused on national security hence proliferation of unnecessary power stations in the region
4. Indigenous funding cannot match the power of global funding in guiding regional development
5. Weakness of process and not technology or policy leads to implementation progress sacrificed

Opportunities
1. Pebble bed nuclear reactor
2. Regional gas grid
3. Distance education
4. Electrification technology
5. Subsidised housing developments.
6. Water grid
7. Development of appropriate technologies
Threats
1. Focus on regional development, isolated from globe
2. Availability of water supplies
3. Lack/availability of international funding
4. Impact of AIDS on technical staff

2. Global Home (is about government embracing global liberalisation and facilitating private sector empowerment to respond to global market forces, in line with global trends and opportunities).

Strengths
1. Abundant coal, strong resource base and a variety of energy options
2. Strong well developed research, education, energy, rail, road, grid infrastructure
3. The electrification programme is delivering
4. Economy of scale, large companies with low cost appropriate technology
5. Multiskilling abilities ('boer maak 'n plan')
6. Climatic conditions: High solar radiation compared to many countries
7. Summer six months out of phase with most developed countries

Weaknesses
1. Lack of a future orientation, leads to short term policies
2. Geographic location: transportation
3. Lack of specialised expertise
4. High transport costs, related to imports and exports
5. Different climatic conditions

Opportunities
1. Local product of photo voltaic solar home systems
2. Speed up of natural gas infrastructure development.
3. Off peak car battery charging technology
4. Local production of wind pumps and electric generators
5. Pebble bed nuclear reactors
6. International funding and export opportunities
7. Encourage the development and use of indigenous technology
8. Export ultra low cost high efficient housing technology
9. Regulate that subsidies are only available when they support specific policies
10. Export of catalytic converters
11. Participation in joint R&T programmes (e.g. IEA)
12. Production and export of energy efficient appliances
13. Low cost energy for information technology
14. Availability of energy for breakthrough transport and end-use technology
15. Clean domestic biomass appliances
Marketing of energy efficient products in international markets

Multi powered hybrid vehicles

Improved S&T education and research

African grid power inter alia sold to Europe

Job creation by means of labour intensive technology such as energy efficiency and renewable energy

Export of low water consumption technology

Coal as a chemical feedstock and value added product

Benification of own raw materials

Bulk electricity production from solar–thermal and wind energy

Threats

1. High labour costs, restrictive labour market, low productivity
2. More unemployment
3. Prescription by other governments and international agencies
4. Low R&D investment level, especially related to the rural poor
5. Shortage of adequately trained human resources related to problems in the educational system
6. Application of inappropriate technology, techno–economic colonialism
7. Low innovation

Frozen Revolution (highlights the effect of the non–implementation of government policy towards socio–economic upliftment that leaves the masses dissatisfied and key players fragmented and individually focused.

Strengths

1. Old technocrats are still available as a resource that can improve the availability of technical skills
2. Experience build up for reverse engineering, recycling, short term maintenance
3. Experience in survival at all levels
4. Manufacturing capability to maintain existing installations
5. Inventiveness supporting 'Can do' approach

Weaknesses

1. Failure leads to blame redirection, deflection of responsibility
2. Buck–passing problem focus vs. solutions and progress.

Opportunities

1. Donor/aid funded research
2. International research as part of agreements and treaties
3. Short term maintenance and retrofit approaches.
Appendix F:
Themes from SWOT to develop the survey questions:

1. Strengths and opportunities

1.1 A strong resource base and a variety of energy options available to which value is being added.
   1.1.1 One million remote households in South Africa obtain their electricity from PV.
   1.1.2 All new houses in South Africa are built with solar (thermal) water heating systems.
   1.1.3 The practical use of wind on South Africa's coastal belt or offshore to generate electricity.
   1.1.4 Eighty per cent of South Africa's coal is used locally rather than being exported (currently only 55% of coal is used locally).
   1.1.5 Widespread value is being added to South Africa's coal rather than it being burnt as fuels (greater margins on chemicals produced from coal).
   1.1.6 The practical use of solar energy farms in desert areas for small industries.
   1.1.7 Development of small, stand-alone, inherently safe nuclear plants for remote villages and industries.

1.2 A strong resource base and a variety of energy options available that is utilised to improve quality of life.
   1.2.1 Widespread use of clean coal by households in South Africa for cooking in areas where coal is the preferred option.
   1.2.2 Development of clean technology for coal to reduce South Africa's CO2 emissions to 1990 levels.
   1.2.3 A 40% reduction in respiratory diseases in households that use clean-coal technology as energy source.
   1.2.4 Small-scale coal mines provide 10% of South Africa's coal.
   1.2.5 Safe gas and paraffin will be utilised by 30% of South Africa's domestic users for heating and cooking.
   1.2.6 South Africa's average efficiency in the combustion of coal to generate electricity is increased to 50% from our current 34%.
   1.2.7 Practical use of inherently safe nuclear as part of South Africa's energy mix.

1.3 South Africa has a strong, well-developed research, educational, energy, rail, road and grid infrastructure that is used to add value to its abundant natural resources.
1.3.1 South Africa exports a significant amount of coal mining technology and expertise to earn valuable foreign exchange.

1.3.2 South Africa loses its coal mining technology and expertise because of globalisation and its smaller contribution to GDP.

1.3.3 Widespread use of appropriate research results developed in South Africa in the energy sector.

1.3.4 Widespread exporting to the SADC region of South Africa energy sector expertise (also health and safety, etc.).

1.4 A strong, well-developed research, education, energy, rail, road and grid infrastructure that is used to improve quality of life.

1.4.1 Widespread use of emissions trading leads to a 20% reduction in the real cost of energy.

1.5 A strong, well-developed research, education, energy, rail, road and grid infrastructure that helps with the regional and international integration of markets, R&D, etc.

1.5.1 South Africa's strong electricity grid forms the basis for low-cost electricity delivery to the region.

1.5.2 30% of South Africa's electricity is supplied from the region.

1.5.3 Development of a centre of excellence in dry-cooling technology in South Africa.

1.5.4 Development of a centre of excellence in pre-payment metering technology in South Africa.

1.5.5 Development of a centre of excellence in low-cost reticulation technology in South Africa.

1.5.6 Development of a centre of excellence in gassification technology in South Africa.

1.5.7 Development of a centre of excellence in lightning protection technology in South Africa.

1.5.8 Development of a centre of excellence in high-altitude, high-voltage transmission technology in South Africa.

1.6 South Africa has an electrification programme that is delivering to improve quality of life.

1.6.1 Ninety per cent of South African households have access to electricity.

1.6.2 Availability of electricity to 90% of SMMEs.

1.6.3 All end users have a choice between coal, gas, liquid fuels, electricity or biomass.

1.7 South Africa has an electrification programme that is improving our energy efficiency (conversion, carrier, housing, transport, appliances, demand-side management, integrated energy planning, manufacturing).
1.7.1 Household energy costs reduced by 20% thanks to energy efficiency improvements in appliances.
1.7.2 The proportion of household expense on energy in low-income households will reduce by 20% by subsidies on efficient appliances and other funding mechanisms.
1.7.3 Widespread mandatory energy efficiency labeling on all domestic energy appliances exists in South Africa.
1.7.4 Mandatory energy efficiency labelling leads to 20% reduction in energy costs.
1.7.5 Widespread application of more efficient transmission and distribution carrier technology reduces electricity costs by 15%.
1.7.6 Widespread application of DSM prevents the building of a 3 600 MW Power Station.

1.8 South Africa has an electrification programme that is utilising renewable energy technologies.
1.8.1 Widespread use of imported hydropower to meet the morning and evening electricity demand peaks.
1.8.2 Widespread use of hybrid systems to meet the morning and evening electricity demand peaks.
1.8.3 The practical use of hybrid vehicles due to environmental considerations and economic incentives.

1.9 South Africa has an electrification programme that is maximising the benefit of distributed generation.
1.9.1 Widespread use of distributed generation (regionalisation) that leads to an increase in reliability and quality of supply of electricity.
1.9.2 Widespread use of distributed generation leads to transmission system becoming stranded assets.

1.10 South Africa has an electrification programme that helps with the regional and international integration of markets, R&D, etc.
1.10.1 Ten per cent of South Africa’s electricity is generated from natural gas.
1.10.2 Independent Power Producers generate 10% of South Africa’s electricity.
1.10.3 Taxation and privatisation of electricity market leads to 80% access to electricity in the region.
1.10.4 Restructuring of the Electricity Supply Industry (ESI) leads to a 20% increase in efficiency of delivery.
1.10.5 Widespread adoption of a competitive ESI structure in the region.
1.10.6 DSM becomes unnecessary thanks to a competitive ESI structure.
1.10.7 Widespread electrical equipment manufacturing in SADC stimulated by regional electrification.
1.11 South Africa has an electrification programme that is maximising the benefit of its natural gas infrastructure.

1.12 South Africa has large economy of scale companies with low-cost, appropriate, home-grown technologies that are adding value to the abundant natural resources.

1.13 South Africa has large economy of scale companies with low-cost, appropriate, home-grown technologies that are improving our energy efficiency (conversion, carrier, housing, transport, appliances, demand-side management, integrated energy planning, manufacturing).

1.14 South Africa has a core skills base that is being used to add value to its abundant natural resources.

1.15 South Africa has a core skills base that is being used to improve quality of life.

1.16 South Africa has a core skills base that is utilising renewable energy technologies.

2. **Strengths and threats**

2.1 South Africa has an electrification programme that is reducing poverty, low economic growth and development, and improving non-payment and non-delivery.

2.1.1 Widespread use of remote metering technology.

2.2 South Africa has an electrification programme that is reducing the environmental burden of the energy system.

2.2.1 Practical uses of electrical power storage equipment using secondary batteries for load leveling.

2.2.2 Widespread uses of hydrostorage for load leveling.

2.3 South Africa has an electrification programme that is meeting the challenge of mass urbanisation.

2.4 South Africa has a core skills base that has a technology focus and can rapidly develop technology.

2.4.1 The development of a fossil fuel technologies skills base that can consult internationally (centre of excellence in fossil fuel technologies, extraction, preparation and conversion).

2.4.2 Development and demonstration of PBMR in South Africa.
2.4.3 Widespread application of heat pumps that have been developed and built in South Africa.

2.5 South Africa has a core skills base that is being utilised to reduce the costly delivery of energy systems.
2.5.1 The development of sustainable biomass systems for remote households in South Africa.
2.5.2 The widespread implementation of industrial waste energy systems in South Africa.
2.5.3 The development of an integrated energy plan for South Africa.
2.5.4 The development of an integrated energy plan for SADC.

3. Weaknesses and opportunities

3.1 South Africa has changed its supply side mentality and has developed a national gas infrastructure.
3.1.1 There is a complete gas ring around South Africa supplying the main centres.
3.1.2 Five per cent (500 MW) of the bulk heating requirements on this ring are supplied by piped gas.
3.1.3 One peak power station of 500 MW is running off gas.
3.1.4 The piped gas is in the control of only two suppliers.

3.2 South Africa, in embracing the wide use of solar technology for the energisation of rural homes has become a world leader.
3.2.1 Two million homes are powered by solar photo voltaic panels for lighting and entertainment/communications.
3.2.2 Non economical grid connection areas were disconnected some years ago when the electricity utility had to become economically viable.
3.2.3 The TV broadcast area has been increased to cover 95% of these solar powered homes areas and 70% of these homes do have TVs, but only 40% have TV licences. Twenty per cent of viewing time has been of an educational bases for the last 10 years.
3.2.4 Based on its large internal solar panel requirements, South Africa set up manufacturing facilities some years ago and now exports 50% of its production. South Africa also exports the infrastructure used in this programme to over 30 countries.
3.2.5 As a result of the above, rural home air pollution has been reduced by 80% and the related health problems have been reduced by 80% over the 20–year time period.
3.2.6 All schools were finally electrified using this technology some 10 years ago.

3.3 Nuclear Energy was embraced by South Africa as a major energy supplier for medium-sized communities. Most of these units are connected to the grid.
3.3.1 Inherently safe nuclear units have cut the line losses to medium-sized communities by 50%.
3.3.2 Inherently safe nuclear units have enabled the utilities output level of pollutants to be reduced in total terms by 30%.
3.3.3 Inherently safe nuclear units have greatly improved the opportunity for South Africa to continue converting its coal reserves into high-return chemicals well into the next century.
3.3.4 The standardisation of the nuclear units has enabled South Africa to become a world exporter of these units and the technology. The problem of waste is minimised, especially when compared to the coal discards and ash problems.

3.4 Ten per cent of South Africa electrical needs are supplied by major hydroelectric systems in Southern African countries.
3.4.1 Ten per cent of South Africa's electrical needs are supplied by major hydroelectric systems in Southern African countries and has been restricted so as to ensure that South Africa cannot be too seriously disrupted from outside the country.
3.4.2 Ten per cent of South Africa's electrical needs are supplied by major hydroelectric systems in Southern African countries and were purchased by long-term agreements at advantageous prices.
3.4.3 Long-term agreements on power imports have in return facilitated substantial export of manufactured goods.

3.5 LPGas sales to industrial business along the ring pipe line have been reduced substantially. However, the solar rural home programme has enabled the spare capacity (including that which had been exported) to be productively utilised in this market area.
3.5.1 The change in business from industrial bulk to domestic cylinders has impacted on the profitability of the LPGas suppliers.
3.5.2 This increase in rural LPGas business has facilitated an increase in the development of the rural local delivery services and small businesses.
3.5.3 The move to LPGas from wood-type fuels has reduced the pollution and the deforestation which had been taking place.

4. Threats and weaknesses

4.1 Labour and government policies scare off the required capital investment required for the country's growth.
4.2 The rural population is not included in the fast-track development of South Africa.
4.3 South Africa does not embrace the new nuclear opportunity.
4.4 Uneconomical grid connections continue and heavily impact's badly on the pricing of South African electricity to industry and commerce.
4.5 The non-payment of services continues to drain the financial resources of South Africa.

5. Additional themes that would be useful

5.1 Market (from German and UK exercise)
5.1.1 Widespread choice of energy source for transport exists.
5.1.2 Widespread use of energy-efficient houses that consume less than half as much power as does the current average house.
5.1.3 Widespread use of technologies that make it possible to treat and re-use wastes and to obtain energies such as methane at low cost using biotechnology.
5.1.4 Widespread use of hydrogen cars.
5.1.5 Widespread use of highly efficient energy production using biomass as raw material.
5.1.6 Widespread commercial recovery and utilisation of coal-bed methane.
5.1.7 Widespread recovery of energy from waste materials in South Africa.
5.1.8 Widespread use of technology that allows users to switch automatically between fuels and suppliers based on pre-set preferences for fuel price, type, availability and emission characteristics.
5.1.9 Widespread use of remote condition monitoring and control of distribution grids.
5.1.10 Underground cables cost-competitive with overhead transmission.
5.1.11 Underwater cables cost-competitive with overhead transmission.
5.1.12 Integration of current understanding and techniques into mainstream building design results in new buildings routinely requiring 50% less energy than does current design.
5.1.13 Widespread use of highly efficient (>20% improvement on current practice), low-emission engines for transport.
5.1.14 Widespread use of alternative fuels for vehicles (methanol, natural gas, hydrogen) in South Africa.
5.1.15 Cost-competitive, zero-emission vehicles capture 10% of South Africa's road vehicle market.

5.2 Technology (from German and UK exercise)
5.2.1 Practical use of electric vehicles powered by fuel cells and secondary batteries.
5.2.2 Practical use of electric vehicles powered by solar cells and secondary batteries.
5.2.3 Practical use of power networks utilising superconducting cables.
5.2.4 Practical use of large-area thin-film solar cells with a cell conversion factor of over 20%.
5.2.5 Practical use of large-scale combined-cycle power generation using high efficient gas turbines (inlet temperature over 1 500 °C).

5.2.6 Practical uses of an international energy supply system in which energy recovered from clean energy sources is transported after being converted into transportable forms, such as hydrogen.

5.2.7 Practical use of power generation by ocean thermal energy conversion.

5.2.8 Practical use of production methane and methanol from coal and biomass by means of hydrogen obtained from non-fossil sources.

5.2.9 Practical use of superconductive energy storage systems with a capacity (1 000 MW) as large as that of pumped hydrostorage.

5.2.10 Practical use of large-scale, underground coal gassification.

5.2.11 Practical use of power generation by coal gassification.

5.2.12 Practical use of direct coal liquefaction.

5.2.13 Practical use of energy plantations

5.2.14 First practical use of commercially competitive energy crops for electricity generation.

5.2.15 Advanced automation and robotics become a standard part of long-wall coal-mining equipment to improve the economics, safety and ability to operate in thin seams and hostile environments.

5.2.16 Practical reduction of 25% in the cost of removal of sulphur from run-of-mine coal.

5.2.17 Ex-works cost of photovoltaic modules is reduced to below $2 per peak Watt.

5.2.18 Practical use of intelligent, on-line inspection systems to detect all leakage and failure-producing defects in pipelines.

5.2.19 Development of cost-effective refinery processes that meet future requirements for clean transportation fuels.

5.2.20 Development of direct (non-syngas) conversion of methane to heavier hydrocarbons.
Appendix G:
Behaviour of SWOT in different scenarios

What is the importance or impact of the issue in a specific scenario?
(H=High, M=Medium, L=Low)

<table>
<thead>
<tr>
<th>Strengths</th>
<th>INNOVATION HUB</th>
<th>GLOBAL HOME</th>
<th>FROZEN REVOLUTION</th>
<th>OUR WAY IS THE WAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource base</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>H</td>
<td>H Physical</td>
<td>M</td>
<td>Human</td>
</tr>
<tr>
<td>Electrification programme</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>Appropriate technologies</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Skills base</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Weaknesses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy and vision</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>L</td>
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<tr>
<td>Supply-side mentality</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Economy and environmental impact</td>
<td>L</td>
<td>H</td>
<td>H Physical</td>
<td>L Energy</td>
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<tr>
<td>Local R&amp;D expertise</td>
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<td>H</td>
<td>M</td>
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<td>Knowledge and information systems</td>
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<td>H</td>
<td>H</td>
<td>H</td>
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<tr>
<td>Limited value-addition</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
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<tr>
<td>Govt. capacity</td>
<td>H</td>
<td>L</td>
<td>M</td>
<td>L</td>
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<tr>
<td>Restructuring of energy process</td>
<td>?</td>
<td>L</td>
<td>M</td>
<td>L</td>
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<tr>
<td>Entry biomass</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
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