science
& technology

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

NATIONAL HYDROGEN AND FUEL CELL TECHNOLOGIES RESEARCH, DEVELOPMENT AND INNOVATION STRATEGY

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EXECUTIVE SUMMARY

The use of hydrogen as an energy carrier, combined with fuel cell technologies to produce electricity, is attracting considerable interest from governments, international bodies and commercial companies worldwide. This is part of a global move towards developing sustainable energy systems and reducing greenhouse gas emissions.

In South Africa, hydrogen is extensively used in the chemical and fuel-refining sectors, but is produced mainly from non-renewable sources such as coal and natural gas. Hydrogen and fuel cell technologies (HFCT) are therefore currently used in very few industrial activities in South Africa. The use of hydrogen is likely to expand significantly in future, driven by new cost-effective mobile and stationary applications and battery replacement. The Department of Science and Technology has identified HFCT as one of its frontier science and technology initiatives, which is to **foster proactive innovation and create knowledge and human resource capacity**. In addition, an important component of most types of fuel cell is a platinum-group-metal-based electrocatalyst. The use of platinum group metals (PGMs) in electrocatalysts will increase the demand for PGMs, and it is estimated that South Africa possesses 80% of the world's PGM reserves.

This Strategy document sets out South Africa's response to the globally emerging HFC sector. It acknowledges that the government needs to take the lead by funding an appropriate knowledge base and stimulating the innovation process. This creation of knowledge is essential in order to understand these new technologies, evaluate their local use and implications, develop suitable policies and stimulate commercial activities. It is envisaged that this will facilitate the development of high-level human resources and the creation of a manufacturing base in the medium to long term. In the short to medium term, through collaboration with international research organisations, South Africa can fast-track its research efforts and become a player in the evolving global market. The management of intellectual property will be a key factor in the success of these research efforts.

Demonstration is an important part of the process of translating results from the laboratory into eventual applications, and applies mostly to early markets. The Strategy recognises that flagship demonstration projects have the potential to attract commercial partners to co-fund research programmes and speed up commercialisation. It also recognises the need for a marketing drive targeting international funding organisations, international collaborative efforts, strategic organisations and gatherings. There are several strong national and international projects and programmes on HFCT, and South Africa should participate in these in a coordinated manner in order to accelerate its research, development and innovation (RDI) activities.

The Strategy will provide support for human capital development at tertiary education institutions by means of research chairs, hub-and-spokes knowledge centres and postgraduate bursaries aligned with priority focus areas. To facilitate the transfer of technology output from RDI at higher education institutions to the HFC sector, preference will be given to joint projects with private sector interest and funding.

The vision of the Strategy is to use local resources and existing knowledge to create knowledge and human resource capacity, enabling the development of high-value commercial activities in hydrogen and fuel cell technologies.

The objectives of the Strategy are as follows:

- Creating wealth through high value-added manufacturing and developing the PGM catalysis value chain to position South Africa to supply 25% of catalyst demand for the global HFCT industry by 2020.
- Building on existing knowledge of high-temperature gas-cooled nuclear reactors and coal gasification and liquefication technology (the Fischer-Tropsch process) in order to develop local cost-competitive hydrogen generation solutions.
- Promoting equity and inclusion in the economic benefits of South Africa's resources.

The objectives will be advanced by pursuing the following strategic goals:

- Establishing a base for hydrogen production, storage technologies and processes.
- Establishing a base for developing catalysts based on PGM resources.
- Building on existing global knowledge and HFCT to develop niche applications to address regional developmental challenges.

The Hydrogen and Fuel Cell Technologies Frontier Programme driven by this Strategy will generate intellectual property from which commercial products and processes may be derived. In the long run, the implementation of the Strategy will result in specific benefits such as the diversification of energy supply to a more environmentally benign energy mix, and the development of highly technical enterprises along the PGM beneficiation value chain. An interim policy dispensation, incorporating relevant codes and standards and spread over a number of government departments, will be required to manage the safety aspects, among other things, of new developments in HFCT.

The Programme will be hosted by a suitable government instrument in the National System of Innovation with expertise in the management of collaborative research and intellectual property. The host will supply the administrative infrastructure (financial, personnel and logistics management, as well as office space). It is recommended that a dedicated staff complement be appointed or seconded to manage the Programme, consisting of an executive manager and a number of project managers, information specialists and administrators.

The proposed mechanisms for implementing and managing this Strategy, as well as for supporting a healthy RDI environment and human resources development, will require a sizeable capital investment from government. Ensuring an adequate RDI and education infrastructure and proper management will require funding of approximately R400 million over three years. 80% of the funding will be channelled towards technology and expertise development, while the remaining 20% will be used to stimulate private sector funding.

ABBREVIATIONS

AFC	Alkaline fuel cell
CPT	Core Planning Team
DMFC	Direct methanol fuel cell
DST	Department of Science and Technology
FC	Fuel cell
HFC	Hydrogen and fuel cell
HFCT	Hydrogen and fuel cell technologies
H_2	Hydrogen
IA	International advisors
MCFC	Molten carbonate fuel cell
PAFC	Phosphoric acid fuel cell
PBMR	Pebble bed modular (nuclear) reactor
PGM	Platinum group metals
R&D	Research and development
RDI	Research, development and innovation
SOFC	Solid oxide fuel cell SWG
	Strategy Working Group
UPS	Uninterrupted power supply

1. INTRODUCTION

1.1 Hydrogen and fuel cell technologies

The use of fuel cells to convert hydrogen into electricity is attracting considerable interest from governments, international bodies and commercial companies all over the world, and hydrogen and fuel cell technologies (HFCT), like biotechnology, information technology, and nanotechnology, are developing rapidly.

The Department of Science and Technology has identified HFCT as one of its frontier science and technology initiatives, which is to **foster proactive innovation and create knowledge and human resource capacity**. This knowledge creation is essential for participation in the emerging HFCT sector.

The hydrogen economy

Because of the problems related to the present global energy supply system, the world will enter a transition phase in future that will involve cleaner and more sustainable energy sources. Regardless of the primary sources of energy, there will be a need for another clean and versatile energy carrier besides electricity.

Hydrogen satisfies the requirements for such a carrier, and in the long term, electricity and hydrogen could satisfy all final energy needs. Fuel cells are one of the technologies that utilise hydrogen in producing electricity. Because of its versatility, efficiency and modularity, the fuel cell will not only play a significant role in the future use of energy, but it will also most likely be a driver for wider use of hydrogen and for the development and commercialisation of technologies for hydrogen production, storage and distribution. This will create a path toward the extensive use of hydrogen in the energy sector, with the somewhat erroneous title of the "hydrogen economy", a term coined in the 1980s. Such an energy system will be independent of energy sources because both hydrogen and electricity can be produced from all of the available primary energy sources. Even if new energy sources are discovered and added to the energy supply mix, the energy system will not have to change.

- Dr Frano Barbir, International Centre for Hydrogen Energy Technologies, June 2006

1.2 International HFCT RDI and policy context

The growing international interest in HFCT is based on increasing concern about energy security, a cleaner environment and, in the long term, sustainable energy development. Economic competitiveness and job creation in new technologies are also important targets. The transport sector is the primary focus in most countries in terms of new fuel supply and traction systems. Most patent applications in the areas of hydrogen production and generation, hydrogen storage technologies and fuel cell catalyst technologies in the recent past have come from the automotive industry. As shown in the figure below, Toyota, Nissan, Honda and Matsushita are major players in all three focus areas, while companies such as Mitsubishi, Sanyo and Asahi specialise in only one of the three areas.

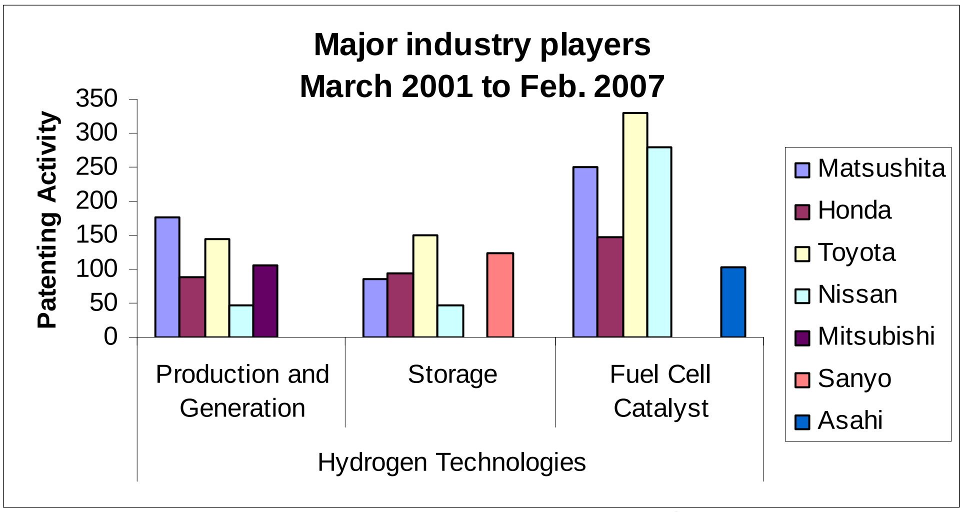


Figure 1: Automotive industry patent applications in hydrogen production and generation, hydrogen storage technologies and fuel cell catalyst technologies

HFCT are described as 'new wave' or 'advanced' technologies in most energy technology literature. In the last 15 years, these technologies have received increased funding for RDI and policy development activities[1]. Global government funding in 2003 was estimated to be in the region of US$3 billion per annum[2]. The private sector, mainly the automotive industry, invests in excess of US$2 billion per annum.

The use of hydrogen is therefore likely to expand significantly in future, driven by existing and new applications. With applications in transport, stationary and portable power generation, fuel cells are expected to grow into a multibillion dollar industry. Significant technological challenges must still be overcome to make these technologies viable, offering opportunities for innovation.

1.3 South African HFCT RDI and policy context

Government recognises that the mastery of modern technologies, including HFCT, and their integration into social and economic activities, are paramount for the sustainable development of the South African economy. Technology diffusion to all sectors of society is a major challenge for South Africa. The transition from primary resource dependence to high-technology/knowledge-intensive growth is key to South Africa's sustainable development.

The government is taking the lead by funding RDI and the development of a knowledge base in HFCT. It is envisaged that this will attract investment from the private sector and facilitate the development of highly technical manufacturing concerns. HFCT is an emerging technology, and at present no industrial concerns in South Africa are investing in these technologies.

This Strategy will be implemented in the context of the DST's innovation strategies, the Department of Minerals and Energy's policies and strategies on sustainable energy systems, and the Department of Trade and Industry's industrial development strategies. It links directly into the following existing government strategies:

- National Biotechnology Strategy, 2001
- National Advanced Manufacturing Technology Strategy, 2004
- Energy Efficiency Strategy, 2005

[1] A number of governments have published hydrogen vision documents and/or roadmaps on the development and implementation of HFCT.

[2] SA Hydrogen and Fuel Cell Technologies Baseline Study, 2004.

- National Renewable Energy Strategy, 2005
- Minerals Development Bill, 2005
- National Nanotechnology Strategy, 2006
- National Energy Research and Development Strategy, 2006
- Integrated Energy Plan, 2006

This Strategy is aligned with the specific objectives of various Department of Minerals and Energy policies addressing the diversification of energy sources. The international factors mentioned (in par. 1.2 above) also apply to South and Southern Africa. In addition, reliable distributed electricity supply systems are required to address current shortcomings and meet needs cost-effectively.

The value of South Africa's investment in HFCT RDI, measured by patent outputs, is low by international standards. This is manifested by the small number of patents filed by South Africans as compared to countries leading in the field, as indicated in the diagrams below.

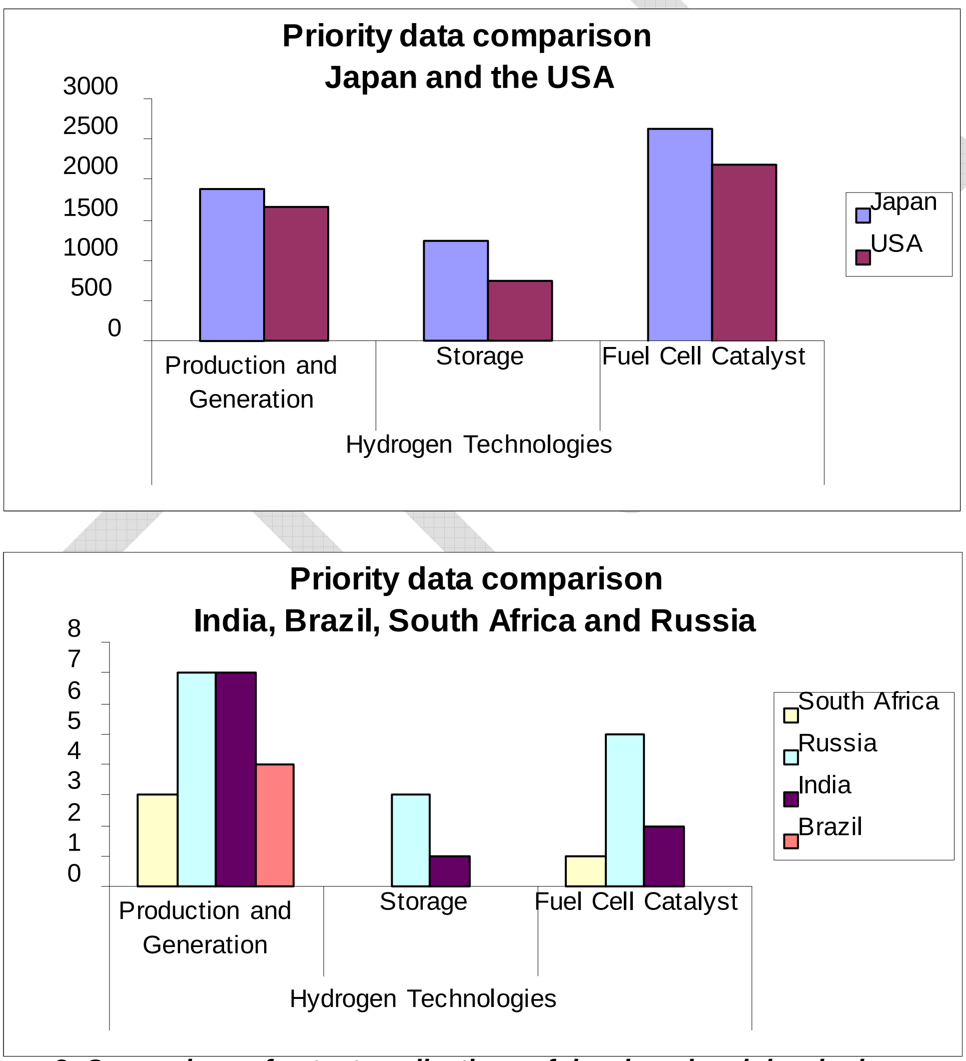


Figure 2: Comparison of patent applications of developed and developing countries

There is considerable interest from the research community in increasing the availability of resources for RDI in HFCT so as to position South Africa to benefit optimally in the development of the global HFC industry.

The South African economy is highly energy intensive, and is reliant on low quality coal for 71% of its primary energy needs and imported crude oil for another 18%[3]. Crude oil reserves are virtually non-existent in South Africa and gas reserves are low. Coal, through advanced coal gasification and liquefication technology (the Fischer-Tropsch process), is also used to meet a large portion of South Africa's liquid fuel requirements. South Africa needs to enhance its ability to beneficiate its PGM reserves for optimal, sustainable and equitable benefit to the country. In addition to its PGM resources, South Africa has the following competitive advantages, which it could leverage to commence a focused RDI effort in HFCT immediately:

- Large coal reserves
- Solar energy - an abundant and underutilised resource;
- Leadership in fourth-generation nuclear reactors;
- The DST/National Research Foundation Centre of Excellence in Catalysis;
- Expertise and global leadership in coal liquefication technology;
- HFCT RDI activities at some universities and science councils;
- World-class photovoltaic RDI group;
- The National Nanotechnology Strategy;
- Advanced fluorine processing technology and expertise, and
- A policy environment conducive to the promotion of natural resources beneficiation and manufacturing initiatives.

2. STRATEGIC PLAN

2.1 Strategy development process

The DST has led the drive to increase the HFCT knowledge base in South Africa. In 2004, the DST commissioned the SA Hydrogen and Fuel Cell Technology Baseline Study to investigate local and international developments related to HFCT.

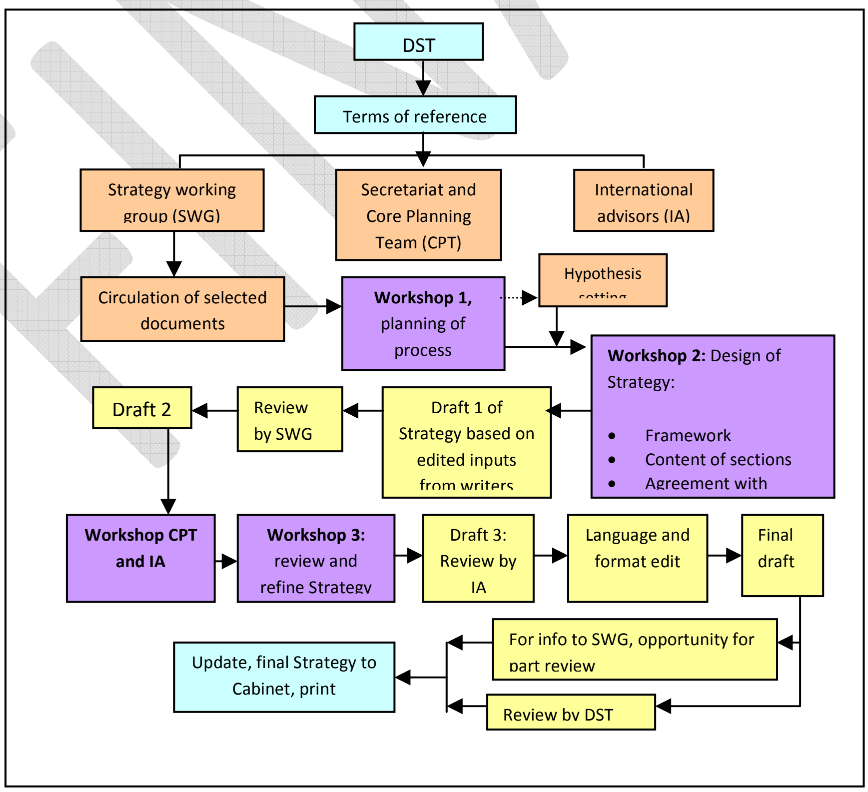


Figure 3: Strategy development process

[3]Development Bank of Southern Africa, Infrastructure Barometer, 2006, p 45.

In 2005, the DST hosted a high-level policy workshop[4] at which a number of international experts evaluated South Africa's comparative and competitive advantage in HFC. The findings were presented to Cabinet, which approved the DST's plan to invest in the creation of a knowledge base for a future economy in which HFCT would play a significant role.

The SWG was assembled to develop a strategic framework to advance the creation of this knowledge base. The team was composed of representatives of government departments, private companies, science councils and higher education institutions, as well as international experts. The resultant strategic framework was developed through a process represented in the diagram below. More detailed information is given in Appendices A to C.

2.2 Vision of the Strategy

The vision of the Strategy is to use local resources and existing knowledge to create knowledge and human resource capacity, enabling the development of high-value commercial activities in hydrogen and fuel cell technologies.

2.3 Strategic objectives

The objectives of the Strategy are informed by the need for knowledge generation, the availability of resources, both physical and natural, the need for economic development, and participation in the global knowledge economy. The primary objectives of the Strategy are as follows:

2.3.1 Wealth creation through high value-added manufacturing

Economic development is a priority for South Africa and a shift to high-value, knowledge-intensive products is a national objective. It is intended that investment in RDI will lead to the commercialisation of the resulting technology, leading to increased employment, exports and national wealth. As the world's largest PGM reserves are found in South Africa, developing the PGM catalysis value chain will position the country to supply 25% of the global HFCT industry's demand for catalysts. At the heart of most hydrogen production processes and fuel cells is a range of catalysts. Extensive RDI and knowledge generation is required, and catalysis has been identified as one area in HFCT that requires a substantial amount of fundamental scientific research. RDI will focus not only on technical matters but also on costs, life cycles and applications.

2.3.2 Developing hydrogen infrastructure solutions

Building on the existing knowledge of high-temperature gas-cooled nuclear reactors and coal gasification and liquefication technology (the Fischer-Tropsch process), local, cost- competitive methods for hydrogen generation will have to be developed. The large-scale production of hydrogen is key to a successful transition to HFCT, and remains one of the biggest challenges facing the nascent industry. Focused RDI efforts will improve production and storage methods, and reduce costs and environmental impact.

2.3.3 Equity and inclusion

This Strategy is in part about creating a path for the economy as a whole to benefit from South Africa's natural resources. The economic rent from the country's large PGM resources has been limited by the lack of an appropriate manufacturing base. For economic benefits to reach the poor and marginalised part of the population, more employment opportunities would have to be created. The long-term secondary benefits would include the effective and reliable supply of energy to deep rural areas, leading to a better quality of life. In the short term, HFCT

[4] DST, SA Hydrogen Fuel Cell Indaba Executive Report, May 2005.

have the potential of providing cost-effective and reliable electricity or energy services for a number of niche applications in Southern Africa. In many cases these are applied in deep rural areas or are of a decentralised nature. Often, the need is for both electricity and thermal energy. At current international prices, clean energy technologies are still inaccessible to most poor people.

The above objectives will be realised by investment in instruments and programmes that will yield suitable and specialised human resources. Skilled people are required at all levels for the innovative development of and support for technological activities. This Strategy pays considerable attention to growing human capital, including attracting young researchers to the field and cultivating a vibrant mentoring environment. A targeted human capital development programme will ultimately influence the nature, direction and commercialisation of HFCT RDI in South Africa. In addition, the outputs of RDI need to be made available for entrepreneurial activities and small, medium and micro enterprise development as part of the national empowerment policy.

The objectives will be advanced by pursuing the following strategic goals:

- Establishing a base for hydrogen production, storage technologies and processes;
- Establishing a base for developing PGM-based catalysts, and
- Building on existing global knowledge and developing know-how to apply and build on existing HFCT for niche applications to address regional developmental challenges.

2.4 Key initiatives

The following key initiatives will support the vision of the Strategy:

2.4.1 Policy and regulatory influence

A number of government departments are responsible for policy relating to future HFCT activities, including the DST (science and technology policy), the Department of Minerals and Energy (energy planning and regulation), the Department of Public Enterprises (state enterprises), the Department of Environmental Affairs and Tourism (physical environment), the National Treasury (fiscal reform), the Department of Trade and Industry (industrial policy), the Department of Transport (transport policy) and the Department of Labour (industrial safety). The Intergovernmental Committee on Hydrogen (drawn from the above departments and the Department of Education) will ensure coordination and cooperation among the departments. This committee will meet at least once very six months.

Techno-economic analysis capacity will be built to support continuous policy analysis. Conducting a complete cost analysis is an important component of the Hydrogen and Fuel Cell Technologies Frontier Programme.

The implications of the following policy initiatives in the energy domain are not clear at this stage:

- Environmental and pollution standards and environmental fiscal reform.
- Taxes, levies and financial incentives.
- The pricing of energy, especially full cost pricing.
- The Kyoto Protocol's Clean Development Mechanism.
- Competition policy or regulation of monopoly activities.
- Safety and fire safety regulations, as detailed below.

2.4.2 Codes and standards

Current safety legislation on piped gases under pressure (including the Occupational Health and Safety Act, the National Building Regulations and Building Standards Act, the Construction Regulations, and local fire safety regulations) does not specifically address the issue of hydrogen, and is inconsistently applied. An interim policy dispensation, incorporating relevant codes and standards and spread over a number of government departments, will be required to manage the safety aspects, among other things, of new developments in HFCT. Once these codes and standards have been developed, appropriate methods for their consistent application by local governments, including a suitable education programme, need to be explored.

2.4.3 The continuous development of an active network of local and international stakeholders

Since South Africa is starting its HFCT research activities 10 to 15 years later than many other countries, it must take into account the knowledge that already exists in the global community, and the numerous international partnerships tackling the challenges facing the future Hydrogen Economy. South Africa's participation in these joint efforts will ensure that the country stays abreast of developments in the field.

3. IMPLEMENTATION

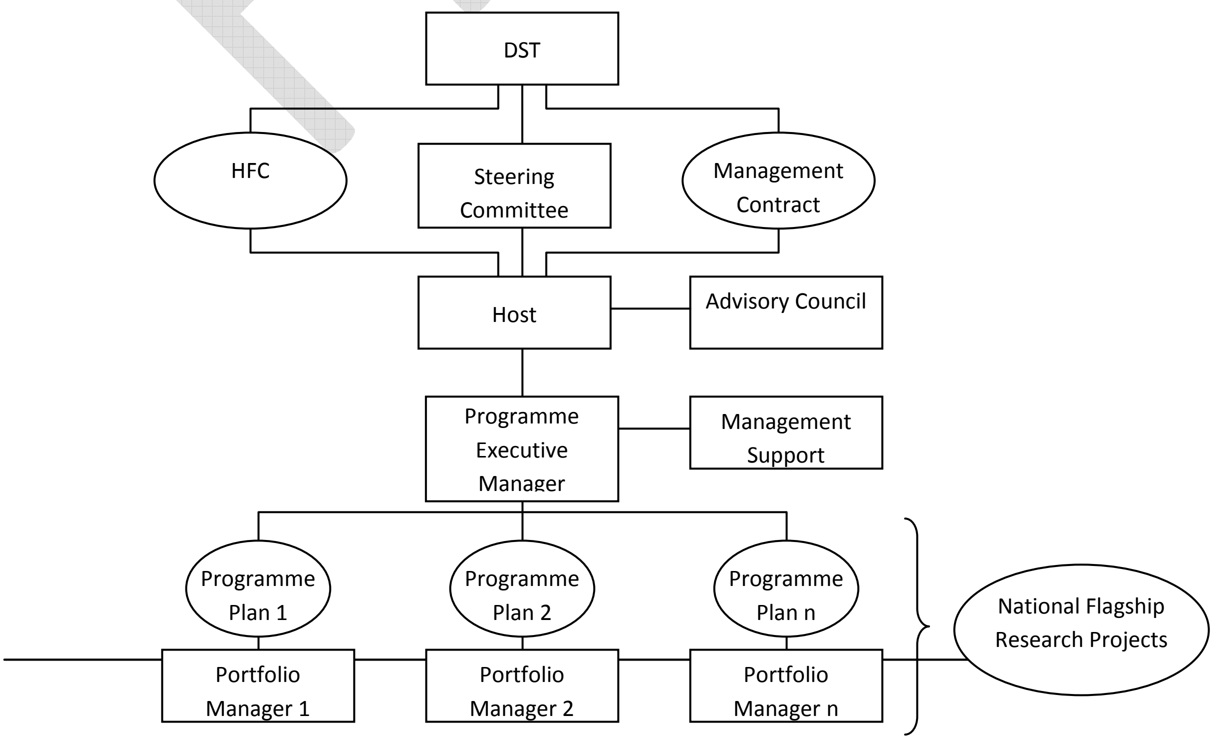
3.1 Implementation plan

This Strategy will guide the development of an appropriate knowledge and technological base to prepare the National System of Innovation to participate in the emerging global HFC industry. The DST will meet this mandate by supporting appropriate RDI activities, human capital development and demonstration projects; facilitating cooperation with programmes that have advanced internationally; conducting outreach and marketing activities; and continually analysing international developments in HFC technologies. A detailed implementation plan will be articulated.

3.2 Management structure

The implementation office will be hosted by a suitable government instrument in the National System of Innovation. The host will supply the administrative infrastructure (financial, personnel and logistics management, as well as office space). It is recommended that a dedicated staff complement be appointed or seconded to manage the implementation office as per the schematic diagram below:

Figure 2: Main elements of management structure



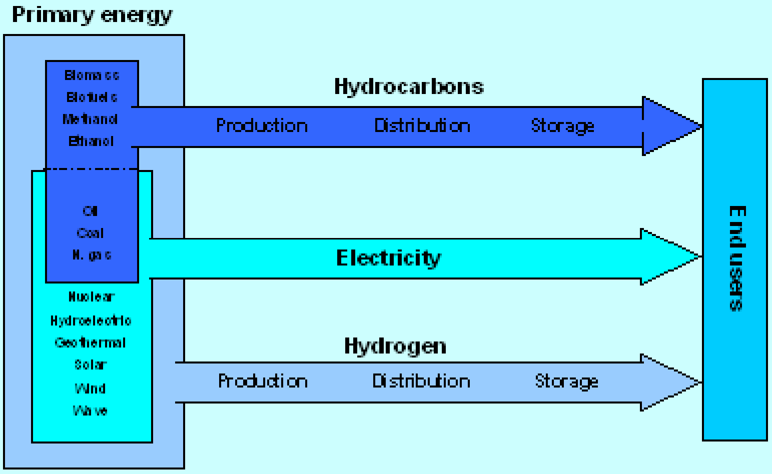
4. PROJECTED IMPACT

It is important for South Africa to position itself as a significant player in the development of HFCT, which is part of the global agenda to integrate energy systems. To do this, it will have to invest in RDI and human resource development, among other things.

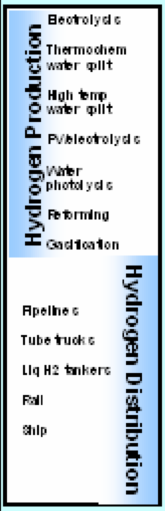
It is clear that hydrogen will play an important role in a multi-fuel future, especially as it can be stored, as part of the global move towards sustainable energy sources, in the medium term in decreasing the use of petroleum through the diversification of energy supply, hence reducing emissions and decreasing energy imports. This change process is illustrated in Figure 3 below.

Hydrogen is also extensively used in the chemical and fuel-refining sectors in South Africa. Currently, hydrogen is produced from non-renewable sources such as coal and natural gas. The cost-effective production of hydrogen from renewable sources would extend the life of South Africa's coal reserves and reduce carbon emissions.

Other envisaged spin-off benefits that these focused RDI activities will provide in addition to South Africa's entry into a hydrogen-rich energy sector include the development of people with highly portable skills in engineering, science and technology (chemical, electrical, mechanical, systems, electrochemical, materials and catalysis).



A hydrogen-rich energy sector would require the establishment of an energy hub that uses hydrogen as the carrier between primary energy sources and end users. This hydrogen hub would be parallel to the electricity hub (grid) and, in the transition period, also the hydrocarbon hub (which uses mostly fossil fuels). Hydrogen can be produced from almost all known primary energy sources and, at least at the point of use, would be clean and free of emissions.



Initially, the principal primary energy for the production of hydrogen would have to come from fossil fuels, so the hydrogen would be only as clean as the primary energy conversion process. However, as fuel cells are highly efficient, energy would be conserved, lowering overall fossil fuel consumption and greenhouse gas emissions. Hydrogen's potential to utilise primary fuels in a cleaner and more efficient way in the energy-intensive transport sector is a major driver for the development of the technology, and is critical to providing energy security.

In the future, with fossil fuels expensive and scarce, and their use restricted because of environmental concerns, hydrogen will make it possible to integrate multiple energy sources into a single "fuel". Hydrogen's intrinsic energy storage capacity and efficient conversion into electricity in fuel cells could be of significant advantage in dealing with in large-scale energy storage challenges.

There are numerous potential RDI opportunities in materials, catalysis, components, systems and applications across the primary energy generation, hydrogen production and distribution, and hydrogen storage and utilisation value chain. Significant advances in costs, performance, durability and reliability need to be made before HFCT can compete with existing hydrocarbon and electrical technologies.

A significant output of a South African HFCT RDI programme would be the identification, development and ultimately commercialisation of several niche technologies and applications. The best combination of primary energy sources for hydrogen production in South Africa would also have to be identified.

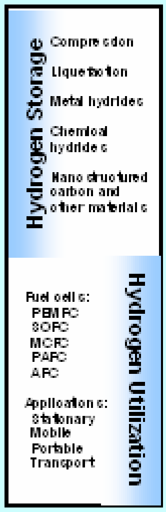


Figure 3: Hydrogen-rich energy sector

Potential application of fuel cells in rural areas

A village grows crops that are converted into biodiesel at the village's small-scale refinery to fuel farm equipment. The biodiesel is converted into hydrogen, using a larger reformer to feed the village clinic's combined heat-and-power fuel cell. This fuel cell generates not only *electricity for use at the clinic and the adjoining school, but also hot water for the clinic. Some of the hydrogen generated from biodiesel is stored in small, portable, metal hydride canisters, and is used to supply hydrogen to a fuel cell that powers a computer, a printer, a phone transmitter and an Internet uplink at a small business centre.*

At night, the village's central fuel cell produces electricity to power street lights, enabling the villagers to remain economically active after dark, and also facilitating safe social interaction. Outside the village, a small dam is monitored remotely by the local municipality, and a small fuel cell powered by hydrogen bought from the village in a portable metal hydride canister powers the underground telemetry equipment. Neighbouring villages are growing rapidly and do not have sufficient hydrogen to satisfy demand. Hydrogen is therefore traded between villages, further stimulating economic activity in the region.

A scenario for HFC in 2040

It is 07:00 and I am driving to work in my all-electric five-seater Vukile Sport, which weighs only 300 kg and has the safety, space and performance of cars at the turn of the century. It is totally silent (with a background sound level of less than 50 db) and I can relax to soothing music. The Vukile is powered with a proton exchange membrane fuel cell with an output of 20 kW that seamlessly powers an electric drive system. I fill up with liquid hydrogen at the local filling station, a process that takes less than five minutes. Hydrogen is available all over the country at twice the price of petrol at the start of the century (for the same energy content, and expressed in constant rand terms). Pollution in all South Africa's urban areas has decreased six-fold.

The electricity grid supplies 90% of the country and is linked to a mix of solar energy, clean coal and nuclear power stations, with greenhouse gas emissions at 50% of the 2000 level. Energy demand is the same as in 2000 because of huge increases in the efficiency of energy use. This makes sense, as the cost of electricity in real terms is double what it was in 2000. Electricity supply in many remote rural areas and on electricity-intensive farms utilises multicycle high temperature fuel cells, with the surplus heat used for process applications.

As crude oil is no longer available, the small amount of liquid fuel is obtained from coal by means of a low carbon dioxide process. There are hydrogen pipelines in selected urban areas, and in other cases hydrogen is transported by road tanker as a liquid to points of use or of refilling, using state-of-the-art materials and technologies.

The HFC sector has been growing at a rapid rate in the past 30 years, and currently employs more than 10 000 people. Over 50 companies are active in this sector, collectively generating foreign earnings in excess of R5 billion per annum.

5. PROPOSED FUNDING

The proposed mechanisms in this Strategy for implementation and management, as well as for supporting a healthy RDI environment and human capacity development, will require operational and capital investment.

Funding will take place in terms of the Research and Funding Plan, which defines the portfolio of RDI initiatives to be funded. The portfolio will reflect an appropriate mix of basic and applied research, different research bodies, including the private sector, and short and long- term projects.

Projects can be co-funded by stakeholders such as commercial partners, both local and foreign, and international programmes and governments. It is estimated that, for the Programme to have the desired impact, a budget of R400 million will be required over three years. Part of this funding will be used to put in place a basic hydrogen fuelling infrastructure to attract the manufacturers of HFCT fuel cell vehicles to demonstrate their products in South Africa during the 2010 Soccer World Cup.

6. SUCCESS INDICATORS

The success of the Strategy in the medium to long term will be encapsulated by the following success indicators:

- The commercial application of research, resulting in the creation of sustainable businesses and employment.
- The extent of technology development and skills development taking place outside the higher education sector.
- The development of well-paid jobs for the skilled as opposed to poorly paid jobs for the unskilled.
- The development of a pool of qualified researchers and technicians.
- International recognition for research, e.g. citations and publications in peer-reviewed journals.
- The quality and quantity of intellectual property held by South African institutions.
- The international recognition of commercialisation through foreign direct investment, joint ventures and exports.
- Measurable impact on the quality of life of affected communities through improved standards of living, a cleaner environment, better access to suitable energy services and employment.

7. CONCLUSIONS

This document sets out an ambitious and comprehensive Strategy for HFCT RDI in South Africa. It will initially lead to the development of high-level human resources that are linked to specific research outputs. In parallel, it will bring to South Africa high-profile and visible demonstration activities to stimulate commercialisation of HFCT and facilitate the creation of new businesses. One of the eventual outputs will be the value enhancement/addition of South African PGMs. The Strategy has specific requirements for interaction between the public and private sectors and the role of academia.

In the long run, it is envisaged that the Hydrogen and Fuel Cell Technologies Frontier Programme will lead to niche applications in the energy sector. However, its core objective is an increased HFC knowledge and technology base in South Africa. This will make it possible to apply these technologies in the local energy sector, starting with informed performance and cost information for energy analysis and planning purposes.

Detailed analysis of the contextual environment for a Strategy of this nature in South Africa has been done, followed by recommendations concerning RDI focus areas and an initial implementation plan.

The strategy implementation office will develop a three-year comprehensive implementation plan for approval by the DST. The Strategy Working Group acknowledges that for successful implementation, sizeable funding will be required from both the public and private sectors of the South African economy.

APPENDIX A: STRATEGY DEVELOPMENT PROCESS

The background to the development of this Strategy appears in par. 1.1 of the Strategy. The DST drafted the terms of reference (see Appendix B) for the Strategy Working Group (SWG) in early 2006. The SWG, Core Planning Team (CPT), Secretariat, and international advisors (IA) were subsequently appointed (see Appendix C). The Strategy was developed by the SWG and the IA during a series of workshops, as indicated in the table below:

Date	Place	Purpose	Participants
30 March 2006	La Chateau Guesthouse and Conference Centre, Terenure, Kempton Park	Planning of activities	SWG
24-26 April 2006	Birchwood Executive Hotel and Conference Centre, Boksburg	Develop framework for Strategy	SWG
23-24 May 2006	The Commodore Hotel, V&A Waterfront, Cape Town	Discuss and refine draft strategy document	IA
25 May 2006	The Commodore Hotel, V&A Waterfront, Cape Town	Discuss and refine draft strategy document	IA and SWG

A strategy framework was developed as an output of the second workshop, and selected individuals were given the brief of writing the text for specific sections using the framework as a guide. These sections were reviewed and edited for consistency. The resulting draft strategy was circulated for comment to the SWG and IA, and was then analysed, discussed and revised at the final two workshops.

The revised draft was presented to the DST's management, whose comments were analysed and incorporated in the final draft submitted. The development process is illustrated in Figure 3 on p. 4.

APPENDIX B: BRIEF TO STRATEGY WORKING GROUP

The following is an extract from the March 2006 Strategy Working Group Terms of Reference, giving the Strategy Working Group's original brief from DST.

Objective

To prepare a strategic framework for publicly funded R&D in Hydrogen and Fuel Cell (H&FC) Technologies to position South Africa to play a role in the emerging energy economy in which hydrogen plays a significant role during the next 10 to 20 years. The framework needs to address both top-down and bottom-up elements.

Scope of work

In line with international developments, the SWG will draft strategic recommendations for South Africa's R&D effort in H&FC Technologies, which focus, amongst other things, on:

- Establishing a framework to guide government's investment in R&D in Hydrogen and Fuel Cell Technologies;
- Presenting recommendations on mechanisms and structures required for implementation of the Strategy;
- Identifying research focus areas that offer high growth potential, critical strategic intent and that are essential enablers for accelerating entry into the Hydrogen and Fuel Cell Technologies;
- Addressing Human Capital Development challenges and needs;
- Exploring possible links with international platforms;
- Exploring synergies with international partners, with a focus on international Hydrogen and Fuel Cell Technologies R&D funding mechanisms;
- Creating the funding infrastructure to facilitate the execution of the Strategy, through the alignment of funding across the public and private sector;
- Establishing the necessary supportive frameworks and infrastructure to facilitate collaboration for R&D across government, industry and academia;
- Addressing the policy and regulatory environment impacting on Hydrogen and Fuel Cell Technologies, with a focus on influencing a regulatory environment that supports, facilitates and enables the goals of the Hydrogen and Fuel Cell Technologies R&D Strategy; and
- Identifying and addressing intellectual property issues.

APPENDIX C: PARTICIPANTS IN THE STRATEGY DEVELOPMENT PROCESS

Core Planning Team

Name	Affiliation
Mr Johann Basson (Coordinator)	Independent consultant
Dr Sakib Khan	Intelligent Energy
Dr Boni Mehlomakulu, Ms Pinda Sitetyana	DST
Dr Molefi Motuku, Dr Gary Pattrick, Mr Garth Williams (Secretariat)	Mintek

Strategy Working Group

Name	Affiliation
Mr Greg Austin	Agama Energy
Dr Douglas Banks	RAPS Consulting
Mr James Blignaut	Beatus
Mr William Black	Impala Platinum
Dr Anthon Botha (facilitator of second workshop)	InnovationLab
Mr Mike de Pontes	Central Energy Fund
Mr Gerhard Gericke	Eskom
Mr Seelan Gounden	Air Products
Ms Renée Greyvenstein	Pebble Bed Modular Reactor
Prof. Jack Fletcher	University of Cape Town
Prof. Nelson Ijumba	University of KwaZulu-Natal
Prof. Vladimir Linkov	University of the Western Cape
Mr John Marsh	Anglo American Research Laboratories
Mr Albert Jamieson, Ms Francesca Lessing	Lonmin Platinum
Dr Mkhulu Mathe	Council for Scientific and Industrial Research
Dr David Molapo, Dr Francis Peterson	Anglo Platinum
Ms Isayvani Naicker	Earth Rehabilitation Services
Prof. Phuti Ngoepe	University of Limpopo
Mr Graham Pye	Afrox
Mr Brian Tait, Mr Harko Mulder	Sasol
Mr Willem van Zyl	Independent consultant

International advisors

Name	Affiliation
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APPENDIX D: POTENTIAL RDI AREAS

A hydrogen-rich energy sector will require much RDI. Technologies that lower costs, reduce emissions, enhance performance, and extend the durability and reliability of fuel cell systems are required, as are fuelling systems and infrastructure. The production of commercially viable and publicly acceptable products for the multiple end uses of HFCT will require a significant RDI effort. There are thus many RDI opportunities throughout the value chain of the future system, including fuel cells fuelled directly by fuels other than hydrogen.

Publicly funded RDI in South Africa cannot address every possible area of activity, and will therefore focus on important and strategically advantageous areas, several of which are listed in the diagram below. These are also the broad RDI areas being vigorously pursued worldwide.

Hydrogen storage

Catalysis

Electrocatalysis
- fuel cells
- methanol oxidation
- electrolysis

Fuel processing
- reforming
- water-gas-shift
- preferential oxidation

H_2 storage
- rapid adsorption /desorption

Photocatalysis
- direct photo water splitting

Ru, Rh, Ir, Au, Re, Pd
- electrocatalyst promoters
- general catalysts

Materials

Membranes
- H_2 purification
- Fuel cell electrolytes

Electrodes
- direct methanol
- electrolysis

High temperature alloys/ceramics

Nanomaterials

Hydrogen production

Nuclear (PBMR)
- thermochemical cycles
- electrolytic processes

Coal
- clean technology
- small-scale gasification and liquefication

Solar
- photovoltaic-driven electrolyser
- direct photo water splitting
- solar furnace water splitting

Reforming
- biofuels, biomass
- fossil fuels

Electrolysis

Hydrogen distribution

Pipelines

Tube trucks

Hydrogen storage

Compression

Liquefaction

Storage media
- hydrides
- nanostructured carbon
- other nanomaterials

Large-scale low-pressure compression

Fuel cell platforms

Proton exchange membrane
- high temperature polymer electrolyte FC
- DMFC
- SOFC
- MCFC
- PAFC
- AFC

Systems and subcomponents

Stationary
- Mobile
- Portable
- Vehicle
- Components
  - power electronics
  - bipolar plates
- Micro FCs

Manufacturing

- Assembly machines
- Membrane electrode assembly coating machines
- Process engineering

Fuel cell applications

- Rural
- Niche vehicles
  - mines
  - leisure
- UPS
  - hospitals
  - telecoms
  - banks
- Industrial battery replacement

Hydrogen applications

- Heating
- Cooling
- Fossil fuel processing

Other fuels

- Natural gas
- Methanol
- Biofuels
  - Syngas

Direct FC

- Methanol
- Ethanol
- Syngas
- SOFC
- MCFC

Analysis and modelling

- Life-cycle analysis
- Environmental impacts
- Source-to-use energy efficiency
- Energy scenario modelling
- Techno-economics
- Market evaluation

Codes and standards

Harmonisation of local and international codes and standards

APPENDIX E: CURRENT STATUS OF HFCT

HFC technologies are still being refined. In many applications, applied research and technology development remains a vitally important part of the industry.

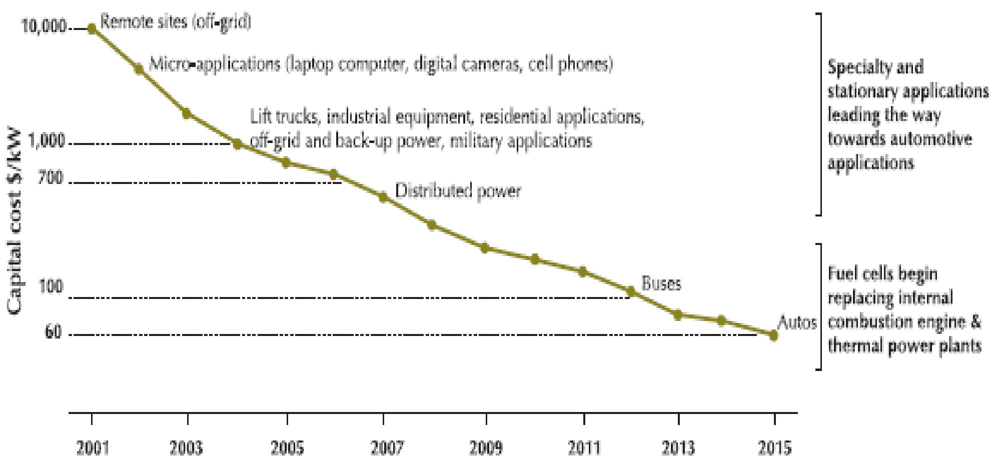
As the technology develops there will be winners and losers in the commercialisation process. It is too early to tell which technologies will ultimately dominate in certain applications, but the direction of some major application areas, such as proton exchange membrane fuel cell technology in fuel cell cars, and solid oxide fuel cell technology in stationary applications, seems clear.

The commercialisation of fuel cell applications depends on the reduction of unit costs (see diagram below). Products will be commercialised at price points that make sense. Stationary and portable applications currently lead the way as fuel cells replace batteries in portable, stationary, light industrial and transportation applications.

In part, this reflects a technology push on products that have the potential to provide significant environmental benefits. Such products include military and remote power applications, auxiliary power units, and automotive applications, e.g. fuel cell buses.

This initial focus will help demonstrate product performance, reliability and durability, reduce production costs, establish codes and standards, build a skilled labour force, develop a hydrogen infrastructure, and create public awareness and acceptance.

Diagram of cost-based fuel cell market forecast[1]



[5] From *Canadian Fuel Cell Commercialisation Roadmap*, March 2003, quoting *Methanex*, September 2002.