DRAFT

COFISA Biotechnology Foresight:
1st Gauteng Workshop Report

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1 Introduction

1.1 Background

Biotechnology is one of the "grand challenge" areas that has been identified in the ten-year innovation plan published by the Department of Science and Technology (DST), and supported by Cabinet. As such, significant public-sector investments will be made in biotechnology. Its cross-cutting nature means that in the next 20 years there is significant scope for new opportunities to emerge in the intersections between biotechnology and a wide range of other disciplines and sectors. There is every reason to believe that stakeholders in Gauteng will be well-positioned to play a leading role in exploiting some of these opportunities, provided that they are identified early enough. Foresight is the method of choice by which early insights may be had into such opportunities.

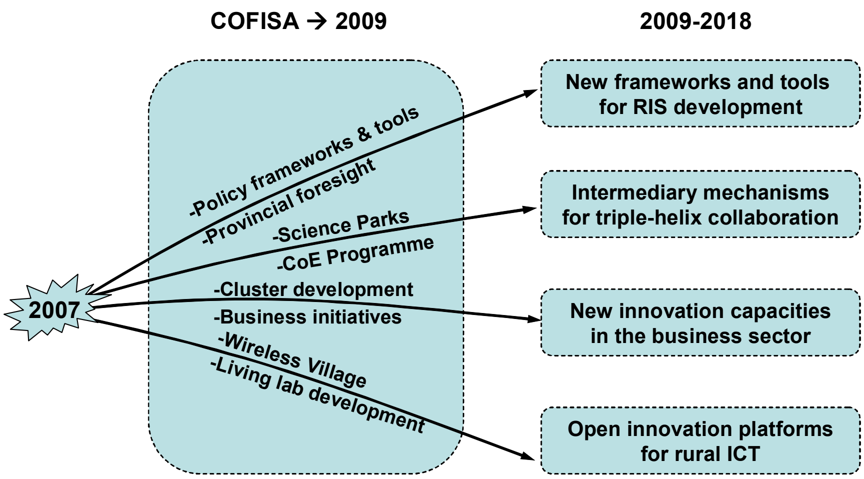
From November '07 to March '08, the Cooperation Framework on Innovation Systems between Finland and South Africa (COFISA) held a successful Foresight exercise that focused on the future of Gauteng as a whole, with a particular emphasis on the role of innovation in that future. Following on from this, and in support of DST's biotechnology "grand challenge", COFISA decided to hold a biotechnology Foresight exercise for Gauteng during late 2008 and early 2009. The objectives of this exercise are:

- To anticipate emerging areas of opportunity related to biotechnology, with a particular focus on Gauteng;
- To support existing and encourage new biotechnology SMMEs in Gauteng.

The exercise began with a two-day (residential) workshop that took place on Wednesday 29th and Thursday 30th October 2008, at the St George Hotel, Pretoria. The details of the workshop are covered in this report.

1.2 Overview of COFISA

During the introductory session, Mrs. Nirvashnee Seetal, the COFISA South African National Coordinator provided an overview of the aims and objectives of the COFISA programme. COFISA is a programme that has been developed jointly by the Governments of SA, through the Department of Science and Technology, and Finland, through the Embassy of Finland in Pretoria. Its objective is to contribute to the enhanced effectiveness of the national system of innovation contributing to economic growth and poverty alleviation. COFISA's three pilot provinces are Gauteng, Eastern Cape and Western Cape. The figure below illustrates four key areas of innovation system development, grouping together key COFISA activities into four strategically important lines of action focusing on building structures and competences at the Provincial level. These form the basic building blocks of the COFISA contribution to SANSI development and link the Project to the national 10-year plan.



New frameworks and tools for regional innovation system development:

The concept of a regional innovation system or policies related to its development is relatively new in South Africa. Yet, it is widely accepted that complementing a national innovation policy with a strong regional development focus has been successful in many countries in developing regional capacities to benefit from national or supra-national flows of resources.

National innovation policy must find concrete manifestations at the regional or local level. Furthermore, innovation processes occur between a large number of actors, such as companies, R&D organisations and the public sector. Regional innovation policy should exist to provide platforms for cooperation between these different actors.

Intermediary mechanisms for triple-helix collaboration:

The triple helix model postulates that collaboration among private, academic and public institutions is key for the promotion of innovation in a knowledge-based economy. Innovation intermediaries are entities providing infrastructure and services to undertakings involved in innovative activities. These almost universally include Science Parks and in specific cases programmes such as the Centres of Expertise (CoE) programme in Finland. Collaboration between the triple-helix players has to be actively promoted and resourced.

New innovation capacities in the business sector:

A specific characteristic of the innovation environment in South Africa is the relatively modest involvement of the private sector in innovative activities. This is especially true of the SMME sector, whereas large companies are often well-resourced to carry out R&D and to innovate. The role of innovation in strategic business plans needs to be highlighted and the SMME sector needs to be drawn into collaborative settings with other innovation players.

Open innovation platforms for rural ICT:

ICT-based rural development and rural innovation are currently carried out within individually funded project settings, resulting in challenges in terms of the sustainability of the models, practices, products or services. New platforms for open, user-centric innovation, testing and piloting of solutions and sharing of resources are needed.

Flagship Projects

- **Provincial and Sectoral Foresight** –Foresighting focuses on “what can be” and then directs efforts towards systematically developing the desired futures. COFISA has conducted a broad provincial foresight initiative in the Western Cape, Eastern Cape and Gauteng. In addition to the Biotechnology foresight exercise in the three Provinces, COFISA will also be supporting foresight activities for the ICT and boatbuilding sectors of the Western Cape;
- **Centre of Expertise Programme** –the pilot Centre of Expertise Programme in Gauteng, adapted from successful Finnish experience, focuses on encouraging triple-helix collaboration in innovation-based projects. The aim is to assist in bridging the innovation chasm though the translation of research into useful products, services or businesses in a more direct and effective way;
- **Science Parks** – COFISA has been instrumental in increasing awareness and understanding of the role of Science Parks as key innovation-enabling mechanisms across South Africa, and in addition to conducting studies related to their co-ordination and development;
- **Dwesa Living Lab and a Network of Living Labs** – The Living Lab platform will focus on promoting open, user-driven innovation in rural ICT services and applications; and
- **Knowledge and Innovation for Rural Development Platform (KIRD)** – KIRD is an initiative which intends to build on European, and particularly Finnish, experience and expertise in turning the Eastern Cape from being the core of South Africa’s rural (and urban) poverty, to becoming an exemplary region of socio-economic stability and growth based on environmentally sustainable urban-rural balance. The idea for the KIRD arose out of the Foresight exercise conducted during the first year of the implementation of COFISA, wherein the need for

sustainable interventions for stimulating innovation in rural areas in the Eastern Cape was identified.

Why is Foresight Important to COFISA?

- There are insufficient foresight capabilities at national and provincial level;
- Foresight is a good tool in helping to create commitment, enhance collaboration and build common ground;
- To help creative proactive policies and strategies that respond in time, learn in time and are able to adapt and evolve; and
- The long time horizon used in the foresight process neutralizes contentious issues thus facilitating cooperation between diverse actors as well as consensus building.

Through the foresight processes, COFISA thus aims to achieve the following:

- Grow the understanding and awareness of foresight;
- Facilitate the establishment of networks;
- Transfer knowledge and skills;
- Facilitate the initiation of relevant projects related to the foresight exercises that may be collaboratively implemented or driven by specific role-players e.g. an SMME's; and
- Feed into strategic processes at the government level.

1.3 Overview of the COFISA Biotechnology Process

Preparation for the Workshop

The quality of the outputs of any Foresight process depends to a large extent on the mix and appropriateness of the expertise and experience of the delegates and reference groups that participate. This is particularly the case for such a widely cross-cutting area as biotechnology. Significant effort, therefore, was put into identifying within Gauteng a broad range of people with either generalist or specialist expertise in biotechnology, as well as practitioners in biotechnology related private sector activities, and public sector stakeholders. The details of the twenty five participants who attended the workshop are provided in Annexure 1.

To optimise the productivity of the carefully selected delegates during the 2 day workshop, they were asked to study two documents which were circulated to them prior to the workshop:

- *Biotechnology Trends Analysis:* Prepared for COFISA by Dr Sibongile Gumbi, this draft report provides an overview of Biotechnology Trends at several levels: Developed economies and multinationals; Emerging economies; and South Africa. (See Annexure 3).

- *Three Proto-Scenarios for Gauteng - 2030:* Prepared for COFISA by Non-Zero-Sum Development, these proto-scenarios were synthesised from the contents of the first set of Futures Wheels created during the previous COFISA Gauteng Foresight process. (See Annexure 4).

Workshop Processes

The workshop began with brief self-introductions of all the delegates, an Overview of COFISA (see above), and a description of the processes to be followed over the two days (see Annexure 2 for full programme). Following this introduction, two main items were pursued:

- **Gauteng Biotechnology Trends:** Following a slide presentation by Dr Sibongile Pefile based on her previously circulated "Biotechnology Trends Analysis" document (presentation available at www.cofisa.org.za), the delegates were asked for the rest of the first morning to add any relevant knowledge they had, particularly related to current or emerging biotechnology activities anywhere in Gauteng. To achieve this, they were asked to choose one of 3 groups based on the following sub-components of biotechnology:
    - Food & Agriculture;
    - Animal & Human Health; and
    - Industrial Biotechnology, Environment and Natural Resources.

- **Gauteng Biotechnology Scenarios:** Following a slide presentation by Dr Bob Day based on the previously circulated "Three Scenarios for Gauteng - 2030" document (presentation available at www.cofisa.org.za), the delegates were asked for the remaining 1.5 days of the workshop to participate in foresight activities which began to convert these proto-scenarios into full Gauteng Biotechnology Scenarios. To achieve this, they were asked to choose one of 3 groups, each based on one of the proto-scenarios. Each group was then employed to produce two levels of biotechnology futures wheels for their particular proto-scenario. Finally, based on the most important issues that they had highlighted in their futures wheels, the groups then wrote fairly detailed biotechnology proto-scenario fragments.

Post-Workshop Activities

Following the first workshop the following activities will be undertaken by the COFISA Foresight Team, supported by the workshop delegates and the broader reference group:

- The modifications to the biotechnology trends review will be summarised into a brief document which will be distributed electronically amongst the workshop participants and the wider reference group, and feedback solicited. A final COFISA Biotechnology Trends Analysis document will be produced for general distribution.

- The set of biotechnology proto-scenario fragments will be crafted into the related original proto-scenario to produce preliminary drafts of each of three Gauteng Biotechnology Scenarios. Material from these draft scenarios will be distributed electronically amongst the workshop participants and the wider reference group, and feedback solicited. The feedback will be incorporated into each draft scenario to produce Version 1 of the set of Gauteng Biotechnology Scenarios. These will form the primary input to the second workshop, when Biotechnology Road Maps, and Action Plans to Stimulate Biotechnology SMMEs will be developed.

The Foresight exercise will be concluded following a second two-day residential workshop to be held in February - March 2009.

2 Biotechnology Trends Analysis

As described above in section 1.3, the delegates were asked to add any relevant knowledge they had, particularly related to current or emerging biotechnology activities anywhere in Gauteng, to the draft Biotechnology Trends Analysis report produced by Dr Sibongile Gumbi. The ***UNEDITED*** inputs from the three working groups are provided below under the biotechnology sub-component headings used to define the groups:

- Food & Agriculture;
- Animal & Human Health; and
- Industrial Biotechnology, Environment and Natural Resources.

2.1 General issues

During discussions, a number of issues, that are important for the success of intended biotechnology initiatives in Gauteng, were raised. A brief description of each topic is provided next:

- For biotechnology to succeed, it is necessary to develop adequate skills and capacity through training. The focus should be on training of researchers from undergraduate to post-doctoral level. Employment opportunities and conditions for graduates need to be examined.
- There is a need to raise public awareness and understanding of biotechnology so that the public will be able to appreciate and value the applications of biotechnology.
- There is a need to expand R&D to encompass the wide-range of biotechnology areas.
- It is important to develop networks of company's engaged in biotechnology.
- A robust and effective regulatory framework is required, especially in fields of biotechnology where there are many ethical and regulatory issues concerned.
- Financial resources and support is required for GM demonstration trials as well as for general research
- It is important that there is market pull, inbound transfer of technologies (in-licensing), scale of economies and consideration of local (African) versus global markets
- What is the objective of biotech? *Personal* versus *national* priorities should be balanced.

Strengths:

- Forestry biotech research
- Indigenous cereals – breeding and processing

Opportunities:

- IKS – global pharmaceuticals
- Biobanks

- Training, mentoring: to fill skills vacuum. HEI graduates are not market-ready – requires formalized experiential learning
- Establishment of twin/sister cities – science parks; needs to be taken to a micro level

Problems:

- IP
- Disruptive technologies (e.g. rapid diagnostics – animals, humans, plants)
- Biotech companies:
    - Don't know each other
    - Don't share knowledge
    - Don't interact with Universities

2.2 Provincial trends

2.2.1 Food, Agriculture and Animal (Livestock) Biotechnology

Current projects in plant biotechnology:

In vitro culture and genetic modification

- Ornamental biotech (Sylvean Biotech)
- *In vitro* culture systems for indigenous crops –development of new and improved protocols
- Engineering disease resistance in crops (UP,WITS, ARC, CSIR) e.g. maize
- Engineering drought tolerance in crops - soya bean, maize, cassava, forestry (ARC)
- Engineering crops for nutritional enhancement (CSIR,WITS, UP, ARC)
- Engineering crops for insect resistance - cystatins
- Beneficiation of indigenous cereals and vegetables crops (UP)
- Field trial of GM crops - *Bt* potato – bred in variety Spunta for small scale farmers based in KZN (ARC)
- Developing protocols for crops with high essential oil content

Diagnostics and Marker aided selection

- Developing arrays in Solanaceous crops – e.g. Tomato Genome Project (UP)
- Identification of markers in forestry- for quality (Lignin and cellulose content) and markers for disease resistance (FABI, UP)
- Maize disease diagnostics (UP)

Value added

- Bio- prospecting indigenous flora for novel foods (CSIR, ARC)
- Bio-prospecting indigenous flora for novel bioactive compounds e.g. *Hoodia* (CSIR, UP)

- Improved bioprocessing of indigenous crops and cereals for human and animal consumption
- Plant metabolamics – nutritional profiling in potatoes and maize using genomics and proteomics
- Sorghum Biofilms for post harvest quality control (CSIR)
- Cassava as an industrial crop – improved starch content for application in paper production and reduction of cyanide containing compounds
- Vaccines & various bio-pharming applications
- Algal biotechnology – for production of valuable products
- Enzymes for Agave (sisal) processing
- Commercial production of biological inoculants - e.g. mycorrhizae for seedlings
- Novel enzymes for industrial application

Resources

- Plant bank (ARC)
- Gene bank exists at (ARC)

Current projects in animal biotechnology:

Breeding

- Markers for breeding & looking for novel traits in Nguni cattle (ARC)
- Aqua culture – fish farming, beneficiation of waste to produce fish feed
- Markers for fish breeding stock (tilapia, salmon)
- Genetic fingerprinting of horse populations to determine pedigree linkages

Emerging areas:

- Nutrigenomics – understanding human genomics and how it relates to disease (UP and CSIR)
- Proposal for Plant DNA ban for indigenous plants and crops
- Genomics of both crops and pathogens
- Functional foods – e.g. for HIV patients, combining food, nutritional and health focus areas
- Plants as chemical factories
- Forestry biotech research

2.2.2 Health: Animal & Human biotechnology

Human Health

Pharmaceuticals:

- biologicals (recombinant therapeutics - second generation)
- bioprospecting
- drug discovery (HIV, TB, malaria)

Diagnostics:

- Antibodies
- Genomics, proteomics, metabolomics
- Preventative and intervention genotyping
- Importance of rapid tests
- Biomarkers eg. Cancer
- High content diagnostics

Vaccines:

- Recombinant vaccines
- Biovac

Other:

- Regenerative medicine including stem cells – storage and service
- Nanotechnology – drug delivery
- Prevention based on genomic profile – personalized medicine
- Probiotics (first generation – neutraceuticals)
- CSIR aptamers – diagnostic and therapeutic

Animal Health

- Vaccines (first (DNA) and second generation)
- Species identification (third generation)
- Paternities
- Diagnostics (Onderstepoort) – genotyping of pathogens (TB, brucellosis)

2.2.3 Industrial biotechnology and the environment and natural resources

- Focused a lot on indigenous knowledge which is not always essential to bio-prospecting (BP). In most cases BP can be devoid of indigenous knowledge. Sometimes can be a minus if IK is involved. This should be discussed further in the document as well as the legislation.
    - New BP regulations have been promulgated and all BP activities must be in terms of these regulations. There are thus now regulatory obstacles and researchers etc. must plan enough time to factor in the administrative regulatory hoops.
    - Bio-prospecting not only about plants - also microbes, animals
    - Coral reefs, fynbos and extremeophiles in the deep mines – from a Gauteng perspective we can maybe go on sampling expeditions (fynbos and coral reefs and other marine) and do the R&D here especially if the infrastructure is here.
- Mining sector - an opportunity to be exploited.

- Refer to the Biotechnology Strategy of Gauteng – gives perspectives of biodiversity in the Province as well as other relevant issues.
- Water as an example for Gauteng – unique anthropogenic features of Gauteng as a result of the mining in the wetlands – big issue in Gauteng is the water quantity and quality. What are the possibilities of enhancing the microbial breakdown of mining by-products using the wetlands. Biotechnology orientated mining work.
- From an industrial perspective – bio-leaching using micro-organisms (Mintek)
- PBMR – leaching related to radioactive products
- Artificial wetlands for domestic sewage and other waste (CSIR)
- Human settlements are threatening our resources. Rapid increases in residential developments are seeing a destruction of wetlands rather than including them in the design of human settlements. If you take stock of wetlands – trying to encourage the protection of larger wetland sites and rehabilitating those that are of value especially in areas where they can provide ecological services such as waste management.
- Smart/advanced manufacturing technologies:
    - Microfluidics – micro-reactor based manufacturing for multi-ton products per year – smaller environmental footprint (use less water and energy)
    - There are more that are not highlighted in the document
- Industrial biotech
    - Microbes
    - Plants and Algae – bio-farming, cell or bio-factories
        - Very relevant to Gauteng because of very limited land. High value plant bio-pharmaceuticals give much higher value per hectare.
        - Algae – easy to manipulate on a genetic level. High yield per hectare and grows on marginal land.
- Water reuse and recycling – enhanced through biotechnology.
    - Bacterial filters for water purification (mines)
- Dried microbes for bio-remediation (septic tanks etc)
    - “Archia” Biosystems? (Archia a form of organism that falls within its own kingdom – not eukaryotic or prokaryotic)
- Industrial – synthetic biology: driven a lot by the advances in microfluidics
    - Take biological components and put them together in ways not found in nature.
- Trade secrecy - minimises opportunities for clustering and collaboration in the sector. Therefore things like common environmental benefits are lost e.g. mining firms not sharing research on new technologies to remediate water.
- There’s a gap between the knowledge generated and making it economically viable.

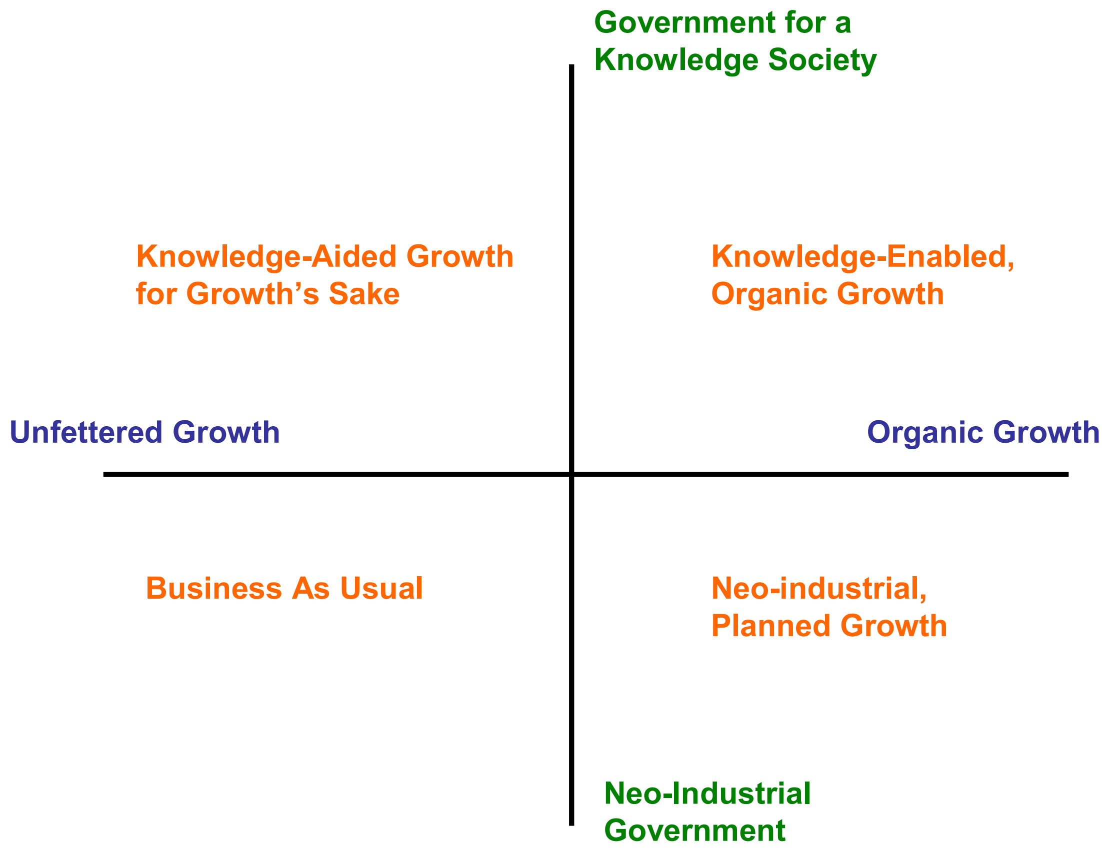
- We have a pipeline packed with opportunities. The roadmap generated out of this initiative should address how we address the issues of economic viability, internationalisation, etc.
- Total systems approach (role for biotechnology here) e.g. with sustainable energy sources.
- Integrated approaches and inter-disciplinary collaboration needed.
- DME Strategy for Biofuels
    - Certain species jump in favour and out of favour with certain government departments regularly
- Algae as a source of energy
- Agricultural expansion in Gauteng is being reined in because it is water intensive. Want to focus on high value crops. High value, low space and resource requirements.
- Biopharmaceuticals from plants – extraction of therapeutics from plants can revive whole aspects of the agricultural economy.
- Animal feed-stocks that are able to reduce the amount of methane the animal produces – included in the Draft Climate Change Strategy.
- GM work on Sorghum – permits to do greenhouse work by the CSIR took two years to obtain. Approvals tend to be affected by individual perspectives on GMOs.
- Research focuses change according to funding available. This is an emerging problem. R&D is chasing money. Lack of funding in South Africa leads to our technology being licensed offshore.
- The death of simple biotechnology – we need to do what is practical, focus on what we have. We need to look at what we can actually do. The level of training at the HEIs can allow us to comfortably do 2nd generation work and use that as a springboard to move toward 3rd generation work. We must make the most of our knowledge in 1st and 2nd generation biotech. But to succeed with the 10 year plan we must most certainly up-skill in 3rd generation biotech.
- We should also focus on research that will address our problems before we look outside the country. But at the same time if we can do the work here in SA at a better quality we will be able to make an impact on the global economy. If we see biotech as a problem-solver we shouldn't only focus on solving SA's problems.
    - Biotech companies funded by public funds tend to be less ambitious and have more of a local focus due to the funders' expectations.

3 Biotechnology Scenarios

As described in section 1.3 above, the delegates were asked to participate in foresight activities aimed at converting the proto-scenarios distributed earlier into full Gauteng Biotechnology Scenarios. The three proto-scenarios were built from the futures wheels produced during the earlier COFISA Gauteng Foresight process. The contents of these futures wheels were combined and synthesised, revealing two major areas of contrast, i.e.:

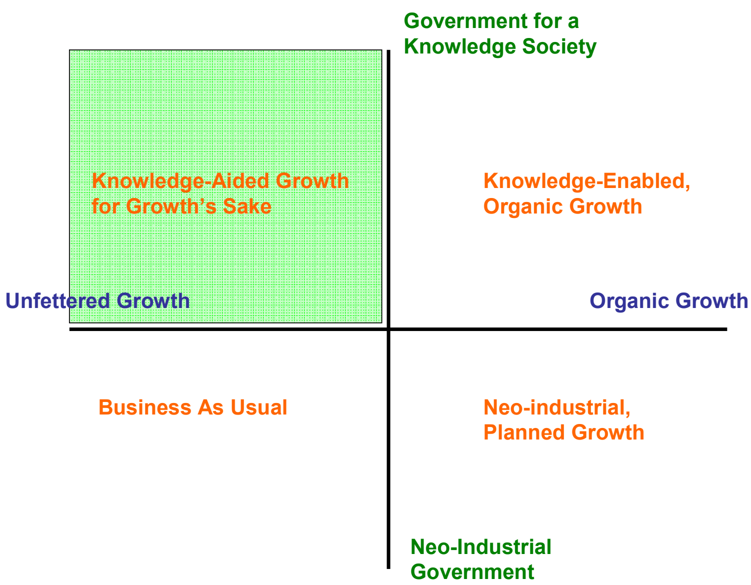
1. The promotion of unfettered growth versus the quest for more widely distributed, organic growth;
2. The impact of government aiming for a knowledge society versus the better understood neo-industrial government approach.

These axes were then used to create the following quadrant diagram, and each quadrant provided the basis for one of the three Gauteng proto-scenarios.



To convert these proto-scenarios into full Gauteng Biotechnology Scenarios, each delegate was asked to choose which of the three proto-scenarios provided them with the opportunity to best represent their expertise and ideas. Three working groups were then formed, each based on one of the proto-scenarios. Each group was then employed to produce two levels of biotechnology futures wheels for their particular proto-scenario. Finally, based on the most important issues that they had highlighted in their futures wheels, the groups then wrote fairly detailed biotechnology scenario fragments. The ***UNEDITED*** inputs produced as a result of these three activities by each working group are provided below.

3.1 Group 1: Knowledge-Aided Growth for Growth's Sake Proto-Scenario



3.1.1 Group 1: First Level Futures Wheel

To produce the following futures wheel, the delegates were asked to "dump" (with little group judgement being applied at this creative stage) those biotechnology related ideas that had come to mind as they imagined themselves living and working within this 2030 scenario. At the end of the session, the group was asked to discuss and agree upon the most important 2 – 4 issues within their futures wheel. It was emphasised that the delegates should feel strongly about (even be excited by) these issues, since they would be working on them for the remainder of the workshop.

Biotechnology strategy will marginalize private SMME ever more

- High value crop? But cant export efficiently
- No agric, agv water (water shortage, drought tolerance)
- Fuel crisis – diff. reach market

- Money – university – scientist with no prospect
- R&D driven by international donor
- R&D dies (CSIR)

Knowledge-Aided Growth for Growth's Sake

Water crisis

Problem = opportunity

No biotechnology research in SA in 2030

- Patent almost 0
- Knowledge economy decline
- Incompetence
- Fanatical BEE

- Emigration
- White and Black IQ
- Not competitive (whatever it is still funded)

No bio-prospecting in the next 10 years

Opportunities

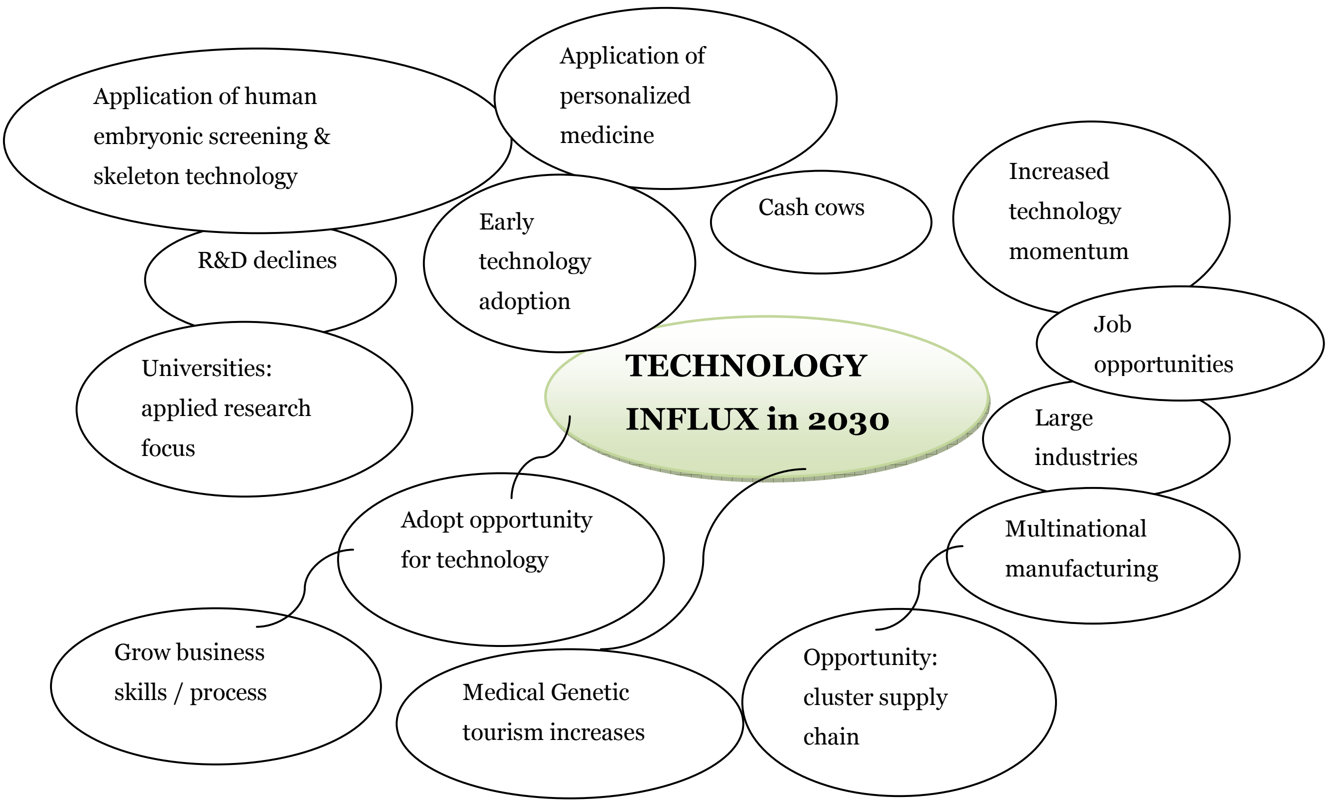
- As R&D dies
- Universities continue
- Malaria diagnosis/pharmaceuticals + preventative (disease not 1st world)
- Bioremediation
- Type II diabetes and other chronic disease = solutions
- Personalized medicines for chronic disease
- Pockets
- Adapt and improve technologies for local conditions

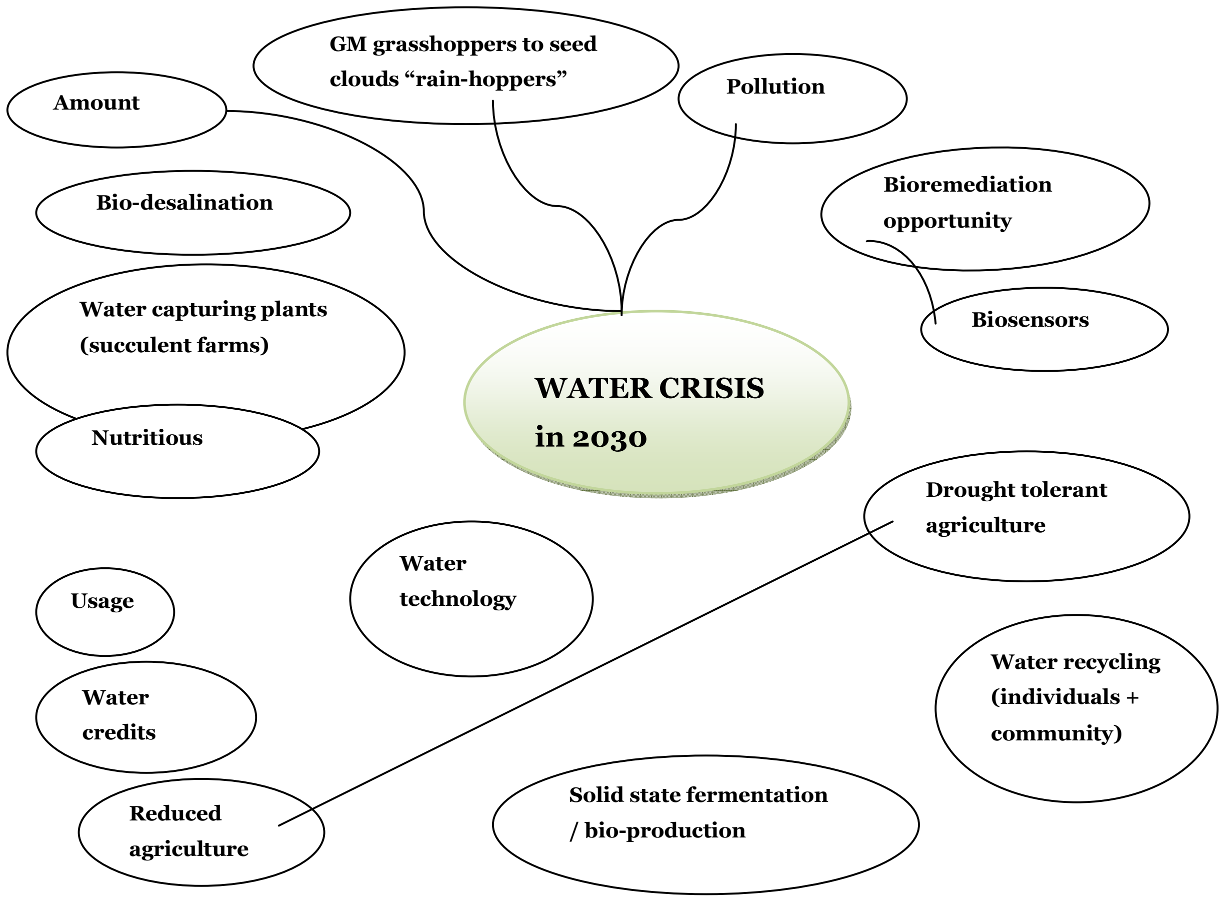
3.1.2 Group 1: Second Level Futures Wheels

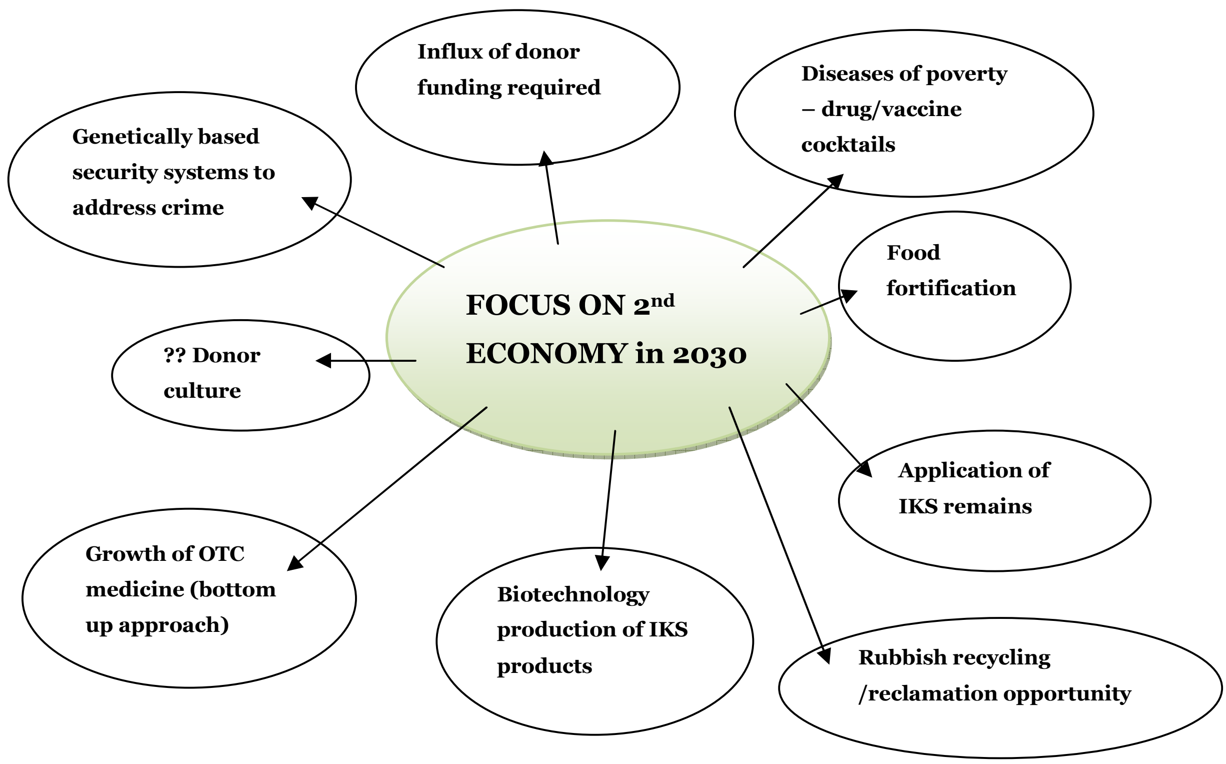
The delegates were now asked to create more detailed futures wheels for each of the issues they had prioritised at the end of the previous session. Again, they were asked to focus on biotechnology related ideas within the context of their 2030 scenario.

Group 1 produced the following three second level futures wheels:

- Technology Influx
- Water Crisis
- Focus on Second Economy




WATER CRISIS in 2030
Amount
GM grasshoppers to seed clouds "rain-hoppers"
Pollution
Bio-desalination
Bioremediation opportunity
Biosensors
Water capturing plants (succulent farms)
Nutritious
Drought tolerant agriculture
Usage
Water technology
Water recycling (individuals + community)
Water credits
Reduced agriculture
Solid state fermentation / bio-production


FOCUS ON 2nd ECONOMY in 2030
Influx of donor funding required
Diseases of poverty – drug/vaccine cocktails
Genetically based security systems to address crime
Food fortification
?? Donor culture
Application of IKS remains
Growth of OTC medicine (bottom up approach)
Biotechnology production of IKS products
Rubbish recycling /reclamation opportunity

3.1.3 Group 1: Biotechnology Scenario Fragments

Technology influx in 2030

It's great having all this new technology available, but where does it all come from?

The focus is on licensing in new technology and manufacturing of biotech products, customised for the South African market. These factors create economic growth and new job opportunities. Universities focus on applied research and consulting to large industry. This leads to training being more applied. Gauteng is an entry-point for technology and tech-products to Africa.

Multinational manufacturers: Some of the big companies involved in biological manufacturing are prominent now in Gauteng. High end consumer demand has grown as a result of the new technologies available. This has led to a growth in jobs for qualified biotechnologists within the multinational company operations.

Clusters to support biotech companies: With the entry of the multinationals, a biotech cluster emerged to support the technology manufacturing on their doorstep. This led to a re-emergence of funders for the industry after years of struggling to find applications of science based research. This should improve relations between government and industry that have recently deteriorated markedly.

Medical genetic tourism: Medical genetic tourism has become a significant industry in South Africa. Some biotechnology entrepreneurs have licensed in the newest embryonic screening and selection technology – some of which is illegal in most of the developed world – and are offering these designer and diagnostic services to those willing to pay. Although some old-school bioethicists object to this state of affairs, the relevant entrepreneurs are politically well-connected, resulting in the regulatory gap being maintained. Additionally, companies are offering genetically personalized preventative (including anti-aging) and therapeutic services linked to package holidays.

University environment: The universities have reacted to the changes by becoming more relevant and applied in their R&D focus so that they can service the needs of the multinationals and other technology importing companies.

Adapting technologies for Gauteng and exporting to Africa: Gauteng is an early adopter of technologies which leads to the opportunity to modify and improve the technologies for local conditions. Gauteng provides an ideal environment to pilot technology development and adaptation, with its combination of rich and poor. As a technology conduit, we can modify the technology for application in the rest of Africa.

Licensed technologies as catalysts for new developments: The money earned from the rapid growth of biotech through in-licensed technologies generates the resources and a truly enabling environment to catalyze the open innovation process. R&D is starting to take off in Gauteng with the multinationals as final clients of products. Personalized franchise medicine clinics with tailored technology applications are springing up in all the more affluent areas.

Water Crisis

We all have to save water - there just isn't enough for all the people in Gauteng. We have to address the fact that the crisis is on a much bigger scale than ever seen in Gauteng before, and it's only going to get worse.

How did we get ourselves into this situation? When we were youngsters there were a few dry years, but there was always water to go around. But the population's exploded, and with the economic growth everyone's been using more water. Supply has been dwindling, also due to climate change. With the financial crisis we can't afford to just buy in water.

What are we going to do?

- *Bio-desalination:* We'll use halophilic microorganisms to concentrate the salt, as well as plants that concentrate salt. This can be done at the coast before pumping the water up to the Highveld. There will be a lot of bioprocess engineering involved to get this to work effectively.
- *We'll develop water capturing plants:* Succulent farms will be established around Gauteng (may be outside Gauteng itself) to capture water, and to provide nutritious edible succulents. This will require genetic modification of the chosen succulent varieties to enhance their nutritive value. Every square metre of available ground in people's gardens will be planted with succulents where possible.

- *Other drought tolerant agriculture:* Apart from the succulents, we'll be using a range of crops that have been genetically modified for drought tolerance. Regulations are already in place to prevent farmers planting water-hungry crops and irrigation is not allowed. But in general the area for agriculture in Gauteng is reduced, and agriculture is much more intensive than it used to be.
- *Water credits:* Like carbon credits, water credits are becoming an important part of our lives. We're all trying to be water neutral as well as carbon neutral. Water credits can be traded for other services, and a whole water credit economy is evolving.
- *Waterless technologies:* Water credits can be earned by developing and/or implementing waterless technologies such as waterless showers, waterless cleaning methods, waterless laundry etc. Microorganisms that "eat" dirt will be used, with a minimum of water. Enzymes that operate in organic solvents will be important.
- *Water recycling:* At both individual and community level, water will be captured and recycled. Highly efficient biological recycling mechanisms will be in place to purify the water. Microbes attached on to solid substrates will be used to filter the water effectively. Biofilm technology will be highly developed. Microorganisms will be developed whose faster growth is triggered by the electrical potential in the water.
- *Manufacturing:* Most of our manufacturing is moving towards minimal water usage. Technologies such as solid state fungal fermentation for manufacturing of a range of products are becoming commonplace.
- *Stimulation of higher rainfall:* An amazing new technology is being tested using GM grasshoppers. They have been genetically modified to produce protein particles that stimulate rain formation. The rainhoppers will be fluorescent so they can be identified and differentiated from normal grasshoppers. They will also be sterile to avoid environmental concerns regarding cross-breeding with the natural population.
- *Pollution control:* We have to address water quality issues at all levels (industrial and household). These have to be closed systems. At household level small scale bioreactors for water purification will be promoted. Biofilters and biomembrane technologies will be essential, as well as wetland remediation. On site artificial wetlands for remediation of heavy metals etc in mine waste is one example. Groups of companies are moving towards pooling resources and centralizing waste reclamation.

- *Pollution monitoring:* Hand in hand with pollution control, sophisticated biosensor technologies for pollution monitoring are being implemented at all levels of society. This includes rapid dipstick tests as well as flow-through monitoring systems at industrial level.

The Second Economy

The strain on Gauteng's infrastructure has become more and more evident over the previous years, but now, in the context of the fallout of the failed knowledge society strategy, the GPG could not exercise the necessary leadership. In these dark times for the second economy, the gap between rich and poor has widened, and poverty has worsened throughout Gauteng. A large sector of Gauteng's population is struggling to survive. But despite all these seemingly insurmountable problems, all is not lost. Whenever there is a crisis, there is also an opportunity for clever entrepreneurs and scientists that can solve the problem.

What are these opportunities?

- *Influx of donor funding:* The polarity between rich and poor has triggered humanitarian concerns and donor organizations are being canvassed more by governments and private organizations. Wealthy South Africans are starting to come to the party and aligning the NGOs in spite of the "donor fatigue" syndrome.
- *Application of Indigenous Knowledge Systems remain:* Because of poverty, general disillusionment with government and the crumbling medical infrastructure, more and more of Gauteng's populace is turning to traditional leaders and medicine. Because of the shortage of indigenous plants in the wild, an increasing number of products based on indigenous knowledge are being produced using biotech methods.
- *Growth in Over-The-Counter medicine:* The poor and disenfranchised sectors of society are unable to afford formal health care, and thus the market for OTC medicine has grown.
- *Genetically based security systems to address crime:* Crime is an ongoing problem in Gauteng given the high levels of poverty. The development of rapid genomic profiling and diagnostic kits, as well as transgenic biosensor bacteria with far more sensitive smell than police dogs, has led to a complete paradigm shift in crime investigation internationally.
- *Food fortification:* Given the challenges of ensuring adequate nutrition in the second economy, biotechnology has been harnessed both to produce food additives (vitamins, minerals, amino acids etc) as well as to develop genetically modified crops with enhanced nutritive value. GM technology has advanced to the point where release of genetically

modified indigenous crops such as sorghum and millet can safely be undertaken.

- *Diseases of poverty:* The ever-expanding health crises in South Africa, particularly related to diseases of poverty including HIV/AIDS, TB and malaria has given energy to efforts to develop drugs and vaccines, largely fuelled by donor funding since poor people are not able to afford expensive, localized medicine.
- *Garbage reclamation:* Microbial technologies and enzymes are being employed to recycle waste materials that have been collected and separated to facilitate the use of tailored recycling technologies. Organic waste is being used to generate gas for heating and cooking purposes. At the individual household level, systems are being introduced for recycling and energy production purposes.

Alternative (Minority) Scenario:

In 2030, Gauteng economy was in ruins. The strain on Gauteng's infrastructure has become more and more evident over the previous years, but now, in the context of the fallout of the failed knowledge society strategy, the GPG could not exercise the necessary leadership. Signs of breaking point were noticeable in many areas, including sanitation, energy and road transport, but it was the water shortage that held centre stage. Water rationing regulations led to serious civil strife, and mining companies were fighting massive legal battles against the government.

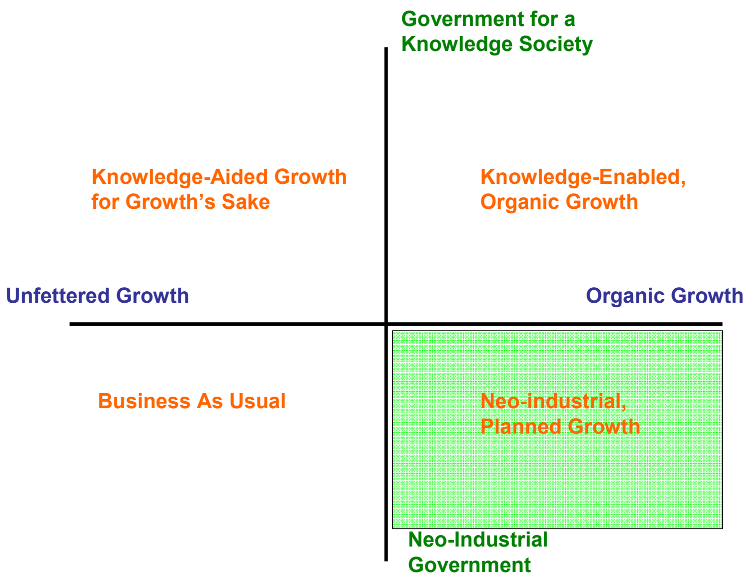
In these dark times, the gap between rich and poor had widened, and poverty had worsened throughout Gauteng. Most of Gauteng's population was struggling to survive within the second economy. But despite all these seemingly insurmountable problems, all was not lost. Whenever there is a crisis, there is also an opportunity for clever entrepreneurs and scientists that can solve the problem. What were these opportunities? (These solutions are unrealistic, so the only way in which these can be achieved are…)

- *Influx of donor funding:* After years of seeing their donations disappearing into the abyss of corrupt officials, international donors have, reluctantly, stopped donating any money to South Africa. The Gauteng government therefore decided that international donors must be forced to give money. An assassination unit was set up, and potential donors were given a simple ultimatum: donate or die.
- *Application of Indigenous Knowledge Systems remain:* Because of the general disillusionment with government and the crumbling medical infrastructure, more and more

of Gauteng's populace turned to traditional leaders and medicine. This, however, led to higher death rates from HIV and TB, which were blamed on the government and international conspiracies, which caused an ever-expanding vicious circle of civil strife

- *Biotech production of IKS products:* Despite the world-wide failure of IKS (excepting a rare few successes) Gauteng government forced the few remaining biotech researchers to develop products based on IKS. Most notorious were the new “PreCog” police units, using traditional healers' presumed extra-sensory abilities to find criminals and solve crime.
- *Growth in Over-the-Counter medicine:* In order to avoid doctor's consultation fees, the market for OTC medicine grew. Unfortunately, since self-medication is not entirely accurate, this led to further health crises.
- *Genetically based security systems to address crime:* The development of rapid genomic profiling and diagnostic kits, as well as transgenic biosensor bacteria with far more sensitive smell than police dogs, led to complete paradigm shift in crime investigation internationally. Unfortunately, South Africa saw little advantage and crime continued unabated. The under-funded and corrupt South African police service was unable (or unwilling) to implement the new profiling kits, and the hapless citizens that lived in the 2nd economy were left as defenceless against crime as ever.
- *Diseases of poverty:* The ever-expanding health crises in South Africa gave researchers and entrepreneurs alike the idea of developing localized drugs and vaccines for the South African population. Unfortunately, as these eager people soon discovered, poor people are not able to afford expensive, localized medicine. In addition, the international donor foundations, particularly those set up by the late Bill Gates and Warren Buffet, were already spending trillions of Rand on vaccination schemes in the rest of Africa and the Middle East, so very little money was given to South Africa, which was slightly richer than the rest of Africa.

3.2 Group 2: Neo-Industrial Planned Growth Proto-Scenario



3.2.1 Group 2: First Level Futures Wheel

To produce the following futures wheel, the delegates were asked to "dump" (with little group judgement being applied at this creative stage) those biotechnology related ideas that had come to mind as they imagined themselves living and working within this 2030 scenario. At the end of the session, the group was asked to discuss and agree upon the most important 2 – 4 issues within their futures wheel. It was emphasised that the delegates should feel strongly about (even be excited by) these issues, since they would be working on them for the remainder of the workshop.

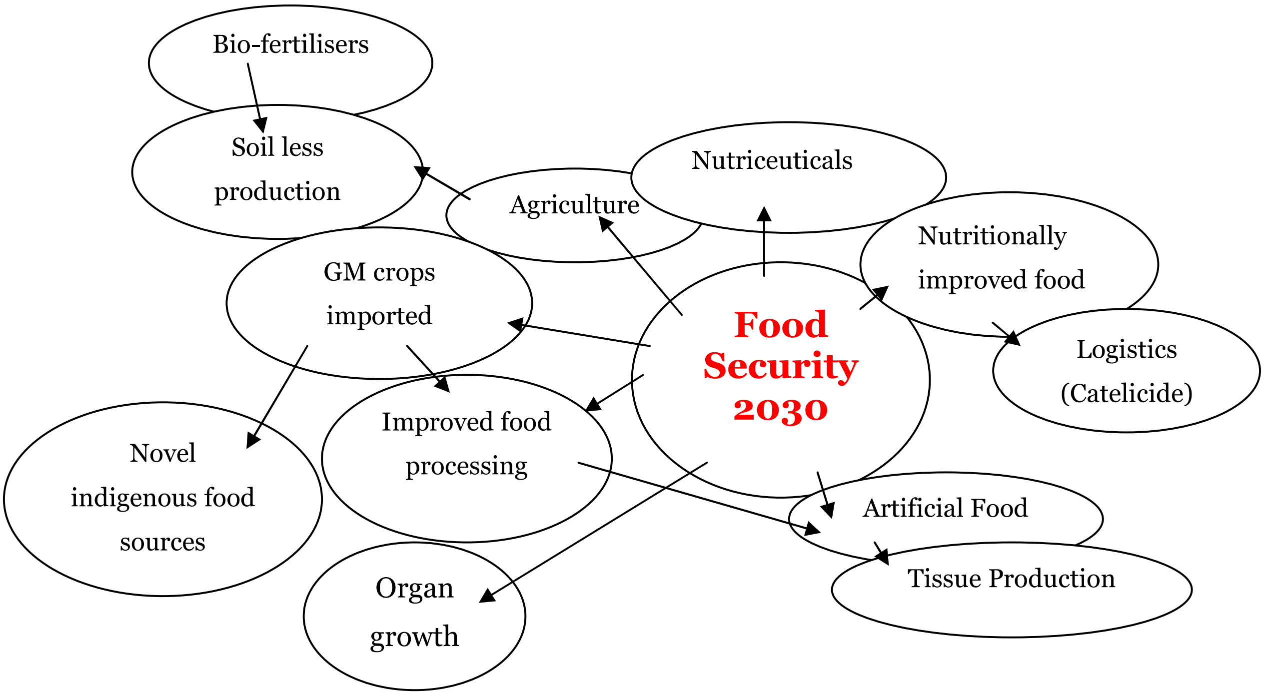
3.2.2 Group 2: Second Level Futures Wheels

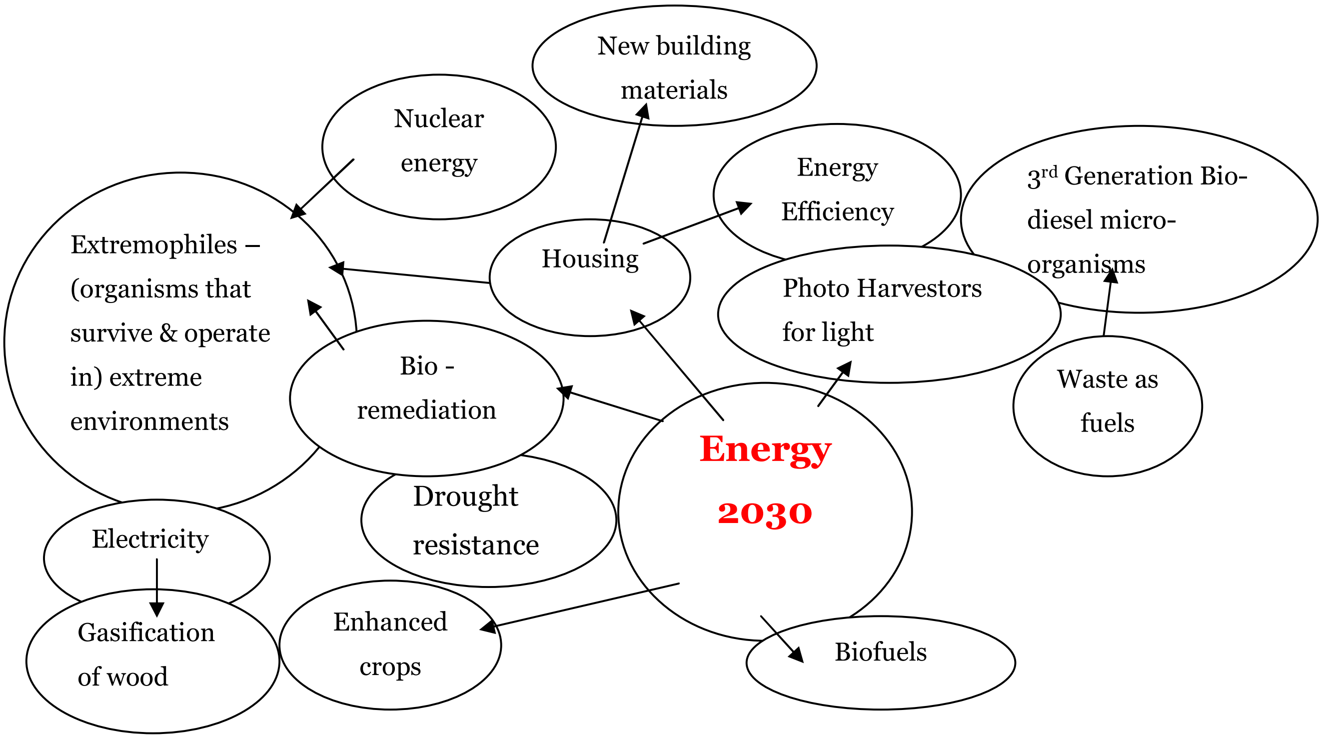
The delegates were now asked to create more detailed futures wheels for each of the issues they had prioritised at the end of the previous session. Again, they were asked to focus on biotechnology related ideas within the context of their 2030 scenario.

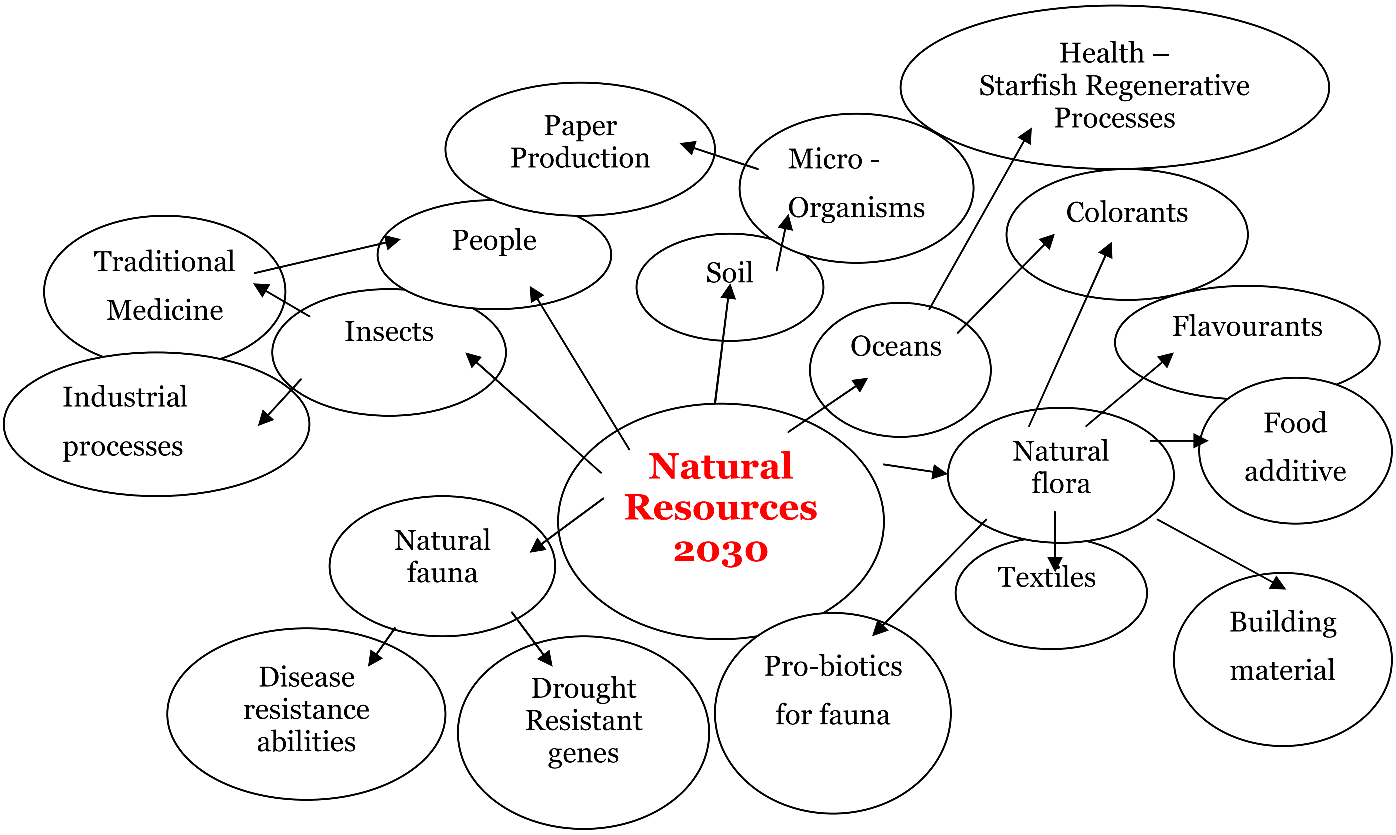
Group 2 produced the following three second level futures wheels:

- Biotech applications for Food Security

- Biotech applications for Renewable and Sustainable Energy
- Biotech applications for Natural Resources




New building materials
Nuclear energy
Energy Efficiency
3rd Generation Bio-diesel micro-organisms
Extremophiles – (organisms that survive & operate in) extreme environments
Housing
Photo Harvestors for light
Bio - remediation
Waste as fuels
Energy 2030
Drought resistance
Electricity
Gasification of wood
Enhanced crops
Biofuels


Health – Starfish Regenerative Processes
Paper Production
Micro - Organisms
Traditional Medicine
People
Soil
Colorants
Insects
Oceans
Flavourants
Industrial processes
Food additive
Natural Resources 2030
Natural flora
Natural fauna
Textiles
Building material
Pro-biotics for fauna
Disease resistance abilities
Drought Resistant genes

3.2.3 Group 2: Biotechnology Scenario Fragments

Biotech applications for Food Security

Due to space constraints in Gauteng, GPG investigated alternate food production strategies. Soil-less production systems were investigated, using plant organ culture and growth of GMO crops engineered with shortened growth cycles. By 2030 all traditional food crops had been genetically modified. In 2029 the results of a five year survey of nutritional values of indigenous plants was published, and several new food sources were identified. This led to the generation of SMMEs to downstream process and value add for the local market. However, due to problems with local legislation and acceptance of these products, these novel foods were exported to the rest of the Continent and the East.

Biotech applications for renewable and sustainable energy

In 2030 there has been a seamless transition to nuclear power in Gauteng. Fossil fuels are not used for generating power and nuclear power is now the main source of energy. Furthermore, concerns regarding nuclear waste was overcome by the use of extremeophiles. This breakthrough was discovered in 2013 due to a vast investment by the "Green Fund" supported by the Department of Energy and chanelled through SMME's which focused on the exploitation of natural resources, whereby a significant amount of knowledge about extremeophiles was gathered. This was utilized to process nuclear waste for the production of biofertilizers.

While this was being done, the Department of Environmental Affairs was looking at the production of electricity through the process of gasification. For this process genetically modified underutilized indigenous trees were produced by collaboration between the University of Pretoria and Advanced Forestry Systems, a KIBS which was a spin off from forestry academic experts at the University. Although these technological advances were significant, the lack of trust, communication and collaboration between the departments did undermine the rollout of these technologies to underserved communities. There was also duplication of resources and wastage of funds.

Several SMMEs were also looking at various ways of enhancing biofuel and biodiesel production utilising different biotechnological processes. One group worked with an impoverished community that was using a local plant species with high sugar content for ethanol production. This crop was genetically modified in 2015 for drought resistance, increased sugar content, biomass and accelerated growth.

To combat the problem of increased domestic waste generated by the influx of people and growing population in 2012, GPG put out tenders for novel ways for dealing with this problem. A BEE SMME "Waste for Africa", in collaboration with an overseas company marketed and implemented an "off the shelf" technology solution to convert domestic waste into fuel utilizing genetically modified micro-organisms. In 2014, due to a lack of understanding of the applicability of this particular "bug" to Gauteng's climatic conditions, this technology failed. In addition GPG was faced with eradication of this foreign micro-organism in the local biosphere. By this time GPG stopped supporting this project and the SMME looked within Africa for other organisms.

In a parallel development Habitat International supported local SMMEs for the sourcing and improved development of locally produced housing materials. They looked at local species for tensile strength in "biofab" materials and combined this trait to produce photoharvesters to capture photons during the day and have these "devices" release light during the night. In 2019, Eco International completed an audit of Gauteng's carbon footprint and it was found that GPG had a huge carbon credit mainly through the foresight of implementing these ecofriendly biotechnology related policies. Due to the good carbon credit status of Gauteng, it led to a renewed influx of people into Gauteng which led to concerns about food security.

Biotech applications for Natural Resources

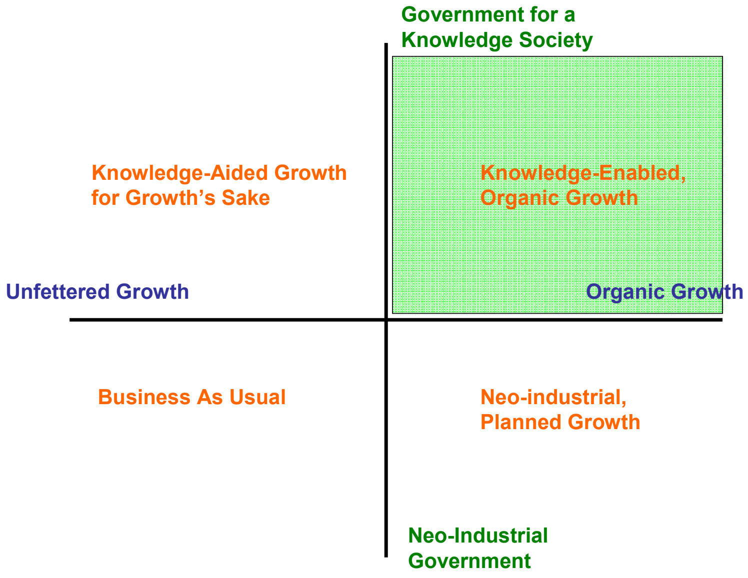
In 2013, a supplemental activity supported by the "Green Fund" focused on development of Natural Resources in Gauteng which stimulated novel discoveries within local communities. Some of these were the discovery of a local fungus and its large scale production through bioprocessing to produce enzymes for application in the pulp and paper industry, making the use of chemicals used in processing obsolete. A spin off of this was the discovery of novel aphrodisiacs from fungi growing in old mine shafts. This stimulated economic partnerships with the Chinese government. A further consequence of the financial crises in 2015, was the exodus of large companies from Gauteng, which led to a gap in the market. The resulting gap created opportunites for SMMEs and the development of a growing nutriceutical industry based on the knowledge gleaned from bioprospecting in indigenous floral and fungal species.

As a measure to monitor cross border control of game, molecular markers from Gemsbok, Kudu and Burchell's Zebra were collected in a gene bank. Due to the fact that these populations were sourced from endemic malaria areas, these gene banks were analysed to identify the genetic component for malaria resistance. Common alleles were found to occur across species and this opened up the possibility for DNA therapy.

A large project was undertaken by the Dept of Trade and Industry and Dept of Environmental Affairs to bioprospect natural flora with respect to new textile sources, food additives (colorants & flavourants), bioenzymes, essential oils and building materials. To support the development of SMMEs in the informal sector, several projects for developing expertise and know-how in processing natural products were launched.

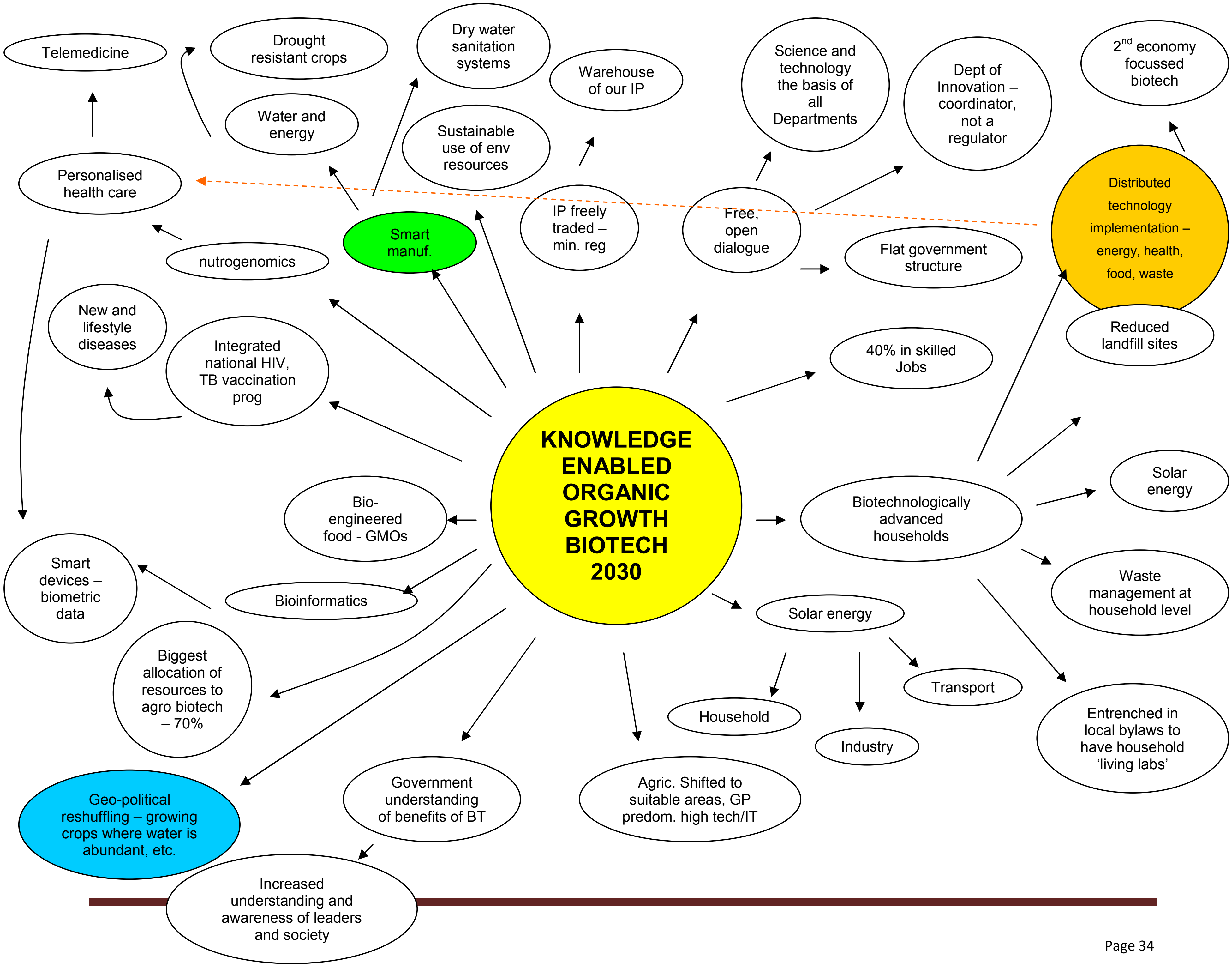
This resulted in the emergence of a few successful companies focused on core technologies in food additives, essential oils and textiles. This provided growing prospects for the emerging SMME sector which managed to deflect the impending economic crisis.

3.3 Group 3: Knowledge-Enabled Organic Growth Proto-Scenario



3.3.1 Group 3: First Level Futures Wheel

To produce the following futures wheel, the delegates were asked to "dump" (with little group judgement being applied at this creative stage) those biotechnology related ideas that had come to mind as they imagined themselves living and working within this 2030 scenario. At the end of the session, the group was asked to discuss and agree upon the most important 2 – 4 issues within their futures wheel. It was emphasised that the delegates should feel strongly about (even be excited by) these issues, since they would be working on them for the remainder of the workshop.

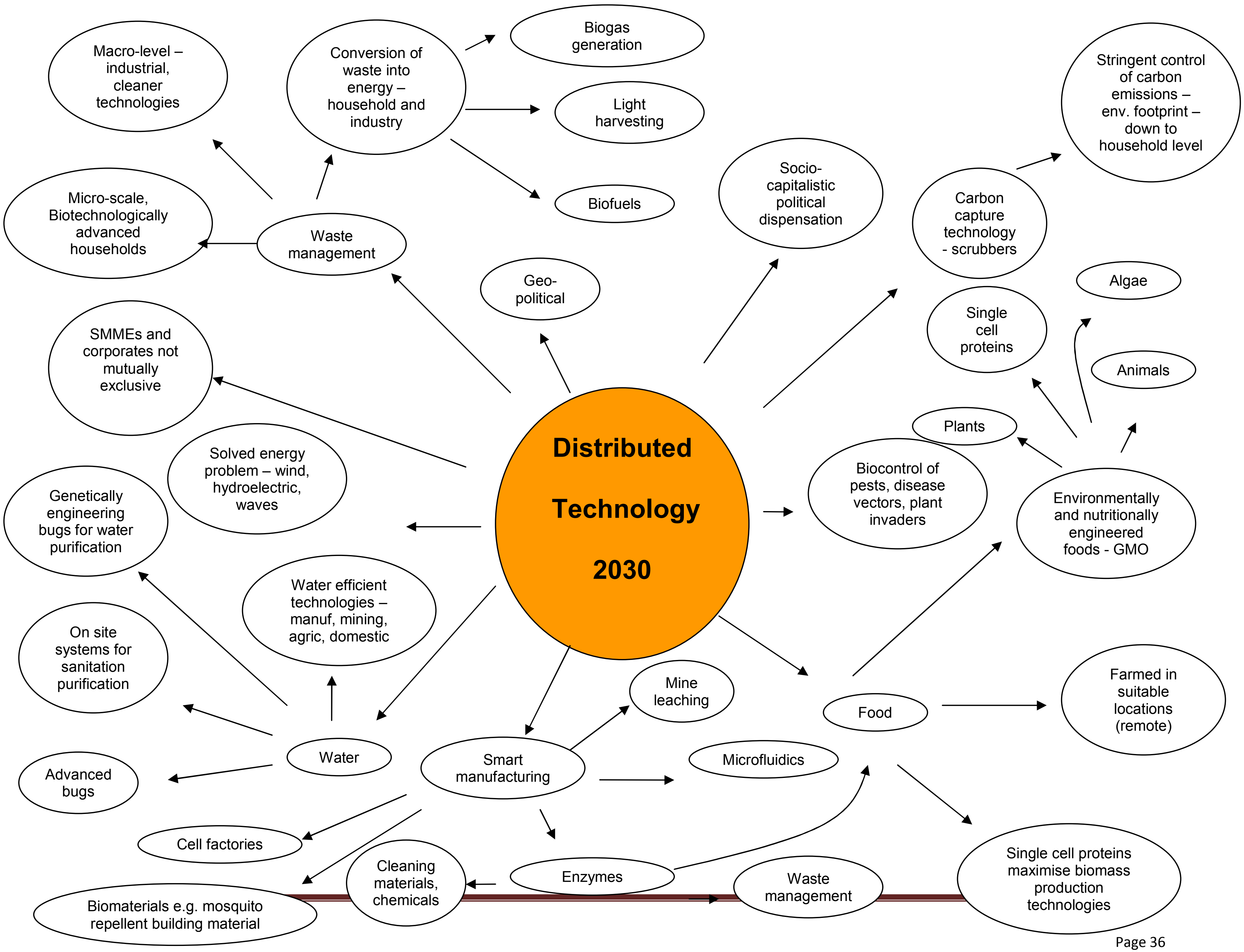

KNOWLEDGE ENABLED ORGANIC GROWTH BIOTECH 2030
Telemedicine
Drought resistant crops
Dry water sanitation systems
Warehouse of our IP
Science and technology the basis of all Departments
Dept of Innovation – coordinator, not a regulator
2nd economy focussed biotech
Water and energy
Sustainable use of env resources
Personalised health care
Smart manuf.
IP freely traded – min. reg
Free, open dialogue
Flat government structure
Distributed technology implementation – energy, health, food, waste
nutrogenomics
New and lifestyle diseases
Integrated national HIV, TB vaccination prog
Reduced landfill sites
40% in skilled Jobs
Solar energy
Bio-engineered food - GMOs
Biotechnologically advanced households
Smart devices – biometric data
Bioinformatics
Waste management at household level
Solar energy
Biggest allocation of resources to agro biotech – 70%
Transport
Household
Industry
Entrenched in local bylaws to have household 'living labs'
Geo-political reshuffling – growing crops where water is abundant, etc.
Government understanding of benefits of BT
Agric. Shifted to suitable areas, GP predom. high tech/IT
Increased understanding and awareness of leaders and society

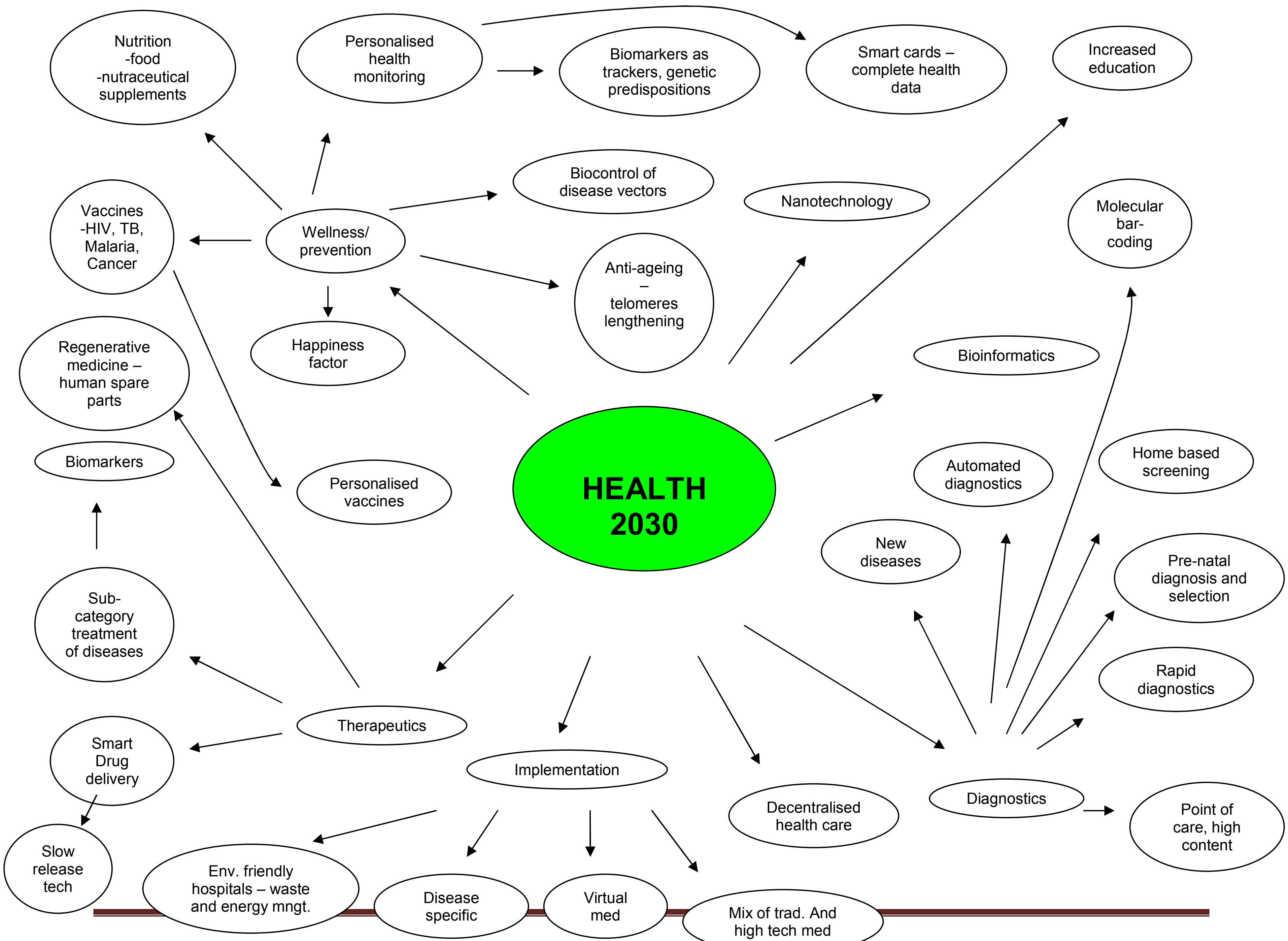
3.3.2 Group 3: Second Level Futures Wheels

The delegates were now asked to create more detailed futures wheels for each of the issues they had prioritised at the end of the previous session. Again, they were asked to focus on biotechnology related ideas within the context of their 2030 scenario.

Group 3 produced the following two second level futures wheels:

- Distributed technology
- Health


Distributed Technology 2030
Macro-level – industrial, cleaner technologies
Conversion of waste into energy – household and industry
Biogas generation
Light harvesting
Biofuels
Stringent control of carbon emissions – env. footprint – down to household level
Socio-capitalistic political dispensation
Carbon capture technology - scrubbers
Micro-scale, Biotechnologically advanced households
Waste management
Geo-political
Algae
Single cell proteins
Animals
SMMEs and corporates not mutually exclusive
Plants
Solved energy problem – wind, hydroelectric, waves
Biocontrol of pests, disease vectors, plant invaders
Environmentally and nutritionally engineered foods - GMO
Genetically engineering bugs for water purification
Water efficient technologies – manuf, mining, agric, domestic
On site systems for sanitation purification
Mine leaching
Farmed in suitable locations (remote)
Food
Water
Smart manufacturing
Microfluidics
Advanced bugs
Cell factories
Cleaning materials, chemicals
Enzymes
Waste management
Single cell proteins maximise biomass production technologies
Biomaterials e.g. mosquito repellent building material


Nutrition
-food
-nutraceutical
supplements
Personalised
health
monitoring
Biomarkers as
trackers, genetic
predispositions
Smart cards –
complete health
data
Increased
education
Biocontrol of
disease vectors
Nanotechnology
Molecular
bar-
coding
Vaccines
-HIV, TB,
Malaria,
Cancer
Wellness/
prevention
Anti-ageing
–
telomeres
lengthening
Happiness
factor
Bioinformatics
Regenerative
medicine –
human spare
parts
Biomarkers
Personalised
vaccines
HEALTH
2030
Automated
diagnostics
Home based
screening
New
diseases
Pre-natal
diagnosis and
selection
Sub-
category
treatment
of diseases
Rapid
diagnostics
Therapeutics
Smart
Drug
delivery
Implementation
Decentralised
health care
Diagnostics
Point of
care, high
content
Slow
release
tech
Env. friendly
hospitals – waste
and energy mngt.
Disease
specific
Virtual
med
Mix of trad. And
high tech med

3.3.3 Group 3: Biotechnology Scenario Fragments

Scenario General Cross-cutters:

Geo-politics

Increased levels of Educational

Bioinformatics

Decentralisation

Environmental sustainability

Robotics and automation

Convergence of traditional and high tech medicines

Distributive technology implementation

Key drivers/enablers:

- Producing a critical mass of qualified and competent people between 2009 and 2019. This will be achieved as the OBE system of formal education gathers momentum, informal training and the recognition of prior learning (RPL) is achieved (experiential learning -non-formal, relevant education), overseas training and exchange programmes for citizens and human capital importation.
- Sufficient investment and financing to allow R&D. Current (2009-19) national investment is approximately 7% of GDP.
- Technological Capability: During the period 2009-19 there was a massive investment in commercial and research infrastructure to support the required 2030 growth targets.
- Access to infrastructure: Clusters were developed to enable the sharing of infrastructure and other resources, which also minimized start-up and operational costs.
- Regulatory Framework and Deregulation: SMME supportive regulatory framework (400% growth of SMMEs). Model facilitates a greater inclusion of the second economy. These include tax incentives, minimal regulatory requirements.
- Market availability and accessibility: These relate to financial viability and sustainability of SMMEs and would be better effected when the geo-political and administrative boundaries are “broken down” / “porous”.

Biotechnology and advanced manufacturing (migration to smart manufacture):

- Convergence of disciplines eg bio-microfluidics – development of mobile manufacturing systems. Factory can be taken to where the raw materials are – rural areas (collaboration)

- Smart manufacturing (smart technology)
- Employment of people where they live (outreach). Focussed on socio-capitalistic system that supports a distributive model where the benefits are spread to the local community and its environment. Encouraging a culture of entrepreneurship as part of outreach - taking commercial opportunities to where the people are.
- Positive spin-off for minimization of urban densification – population more evenly spread out and not concentrated into the nodes of pre-2009.
- Exploiting and building niche markets (commercial expansion)
- Establishment of centres of excellence in advanced manufacturing (enzyme-based manufacturing, diagnostics and cell reactors, GMOs, etc).
- Household "living labs" – integrated management of resources (biodigesters, own food production)
- Legislation and by-laws, incentive schemes for household and industry expansion of smart manufacturing.
- Types of plants that predominate the commercial landscape in Gauteng include: Pharma-plants - unique designer enzymes, bio therapeutics and biomaterials, nano-biotechnology
- Enhanced opportunities are created through, for example, biotech in the mining sector resulting in discoveries in the health field eg detoxification of chemicals in the blood-stream. Smart-bugs designed for the mining sector then used in the healthcare system.

Food:

- Smaller space requirements for higher production (mass) and value type foods
- Regulatory structure and frameworks (Dept of Sustainable Development – individual govt spheres do not exist – flat structure) do not impede the implementation of GMO type foods
- SCP – alternative foods R&D as a niche market

Health

Introduction

The scenario described herein reflects our vision of the human health domain in Gauteng in 2030. It is based on the following *key assumptions*:

- there is free and efficient communication between all governmental departments
- the education system has succeeded in making the general population responsive to the general benefits of biotechnology

- the regulatory environment is conducive to the emergence of cutting edge high tech biotech companies
- the funding environment can support all of the above.

We have divided our scenario into the following 4 components:

- Wellness and Prevention
- Diagnostics
- Therapeutics
- Implementation

Wellness and Prevention:

- *Personalized Health Monitoring:* There will be a trend towards decentralization and increased individual responsibility for one's own health.
  - *Genetic profiling:* Our genetically diverse population forces us into a situation where we have to be cognisant of ethnic differences in the susceptibility to various diseased. These include for example cardiovascular diseases (hypertension, cardiomyopathy), diabetes, cancer and neurological diseases.
  - *Biomarkers:* Biomarkers will be used in routine clinical care for the selection of the most appropriate and effective therapeutic agent for the treatments of the disease in question.
    - Therapeutic responses will be monitored in their initial phases by alterations in levels of biomarkers prior to overt modifications in the disease itself.
    - Biomarkers will also be used for prognostic and diagnostic purposes.
    - Biomarkers may be in the forms of protein or genetic markers.
- *Vaccines:* Vaccines will be in the form of DNA, RNA or protein and will be used both prophylactically and therapeutically.
  - *Infectious diseases:* The entire population would have received effective vaccines against all major infectious disease. The vaccines would have been administered to all neonates during an established routine childhood vaccination program.
  - *Cancer:* For cancers where the etiologic agent is known to be infectious (eg. HPV in cervical cancer), neonates will be routinely vaccinates as part of a national program. Therapeutic vaccines will be administered to patients in whom the presence of specific molecular targets has been identified.

    - *Diseases of lifestyle:* Vaccines targeted at cellular components of, for example atherosclerosis, will be used in susceptible individuals.
    - *Other:* Vaccines for various indications such as smoking will be available.
- *Nutrition:* Most of the commercially available foods will have been produced by plants, animals, algae or single cellular organisms which have been genetically modified to optimize nutritional value.
    - *Neutraceuticals:* It will be routine practice to establish the nutritional status of an individual. The biotech component will be in the design and manufacture of tools for determining nutritional status. On the basis of these results, scientifically formulated and validated neutraceuticals will be prescribed to correct any deficiencies.
    - *Supplementation:* Food will be supplemented eg. with proteins that are derived through biotech systems (eg. single cell factories). This will be on a personalized basis.
    - *Delivery systems:* Protective coatings will ensure that foods reach their desired destination for optimal absorption following passage though parts of the GIT that otherwise would have altered their molecular composition to a less favourable status.
- *Nutrigenomics:* Based on genetic profiles which predict physiological consequences of the interaction between genetic susceptibility to disease and the environment i.e. food, it will be possible to make specific recommendations with regard to dietary intake.
- *Anti-aging technology:* Research into ageing processes will have identified several well-validated molecular targets that will form the basis of anti-ageing interventions.
- *Mental wellness:* Much attention will be devoted to the mental health status of individuals through the development of quantitative parameters and the use of highly specific medications.

Diagnostics

- *Home-based screening:* Microfluidic technologies incorporating biological materials will allow mass production of miniaturized disposable user friendly diagnostic devices.
- *Rapid diagnostics:*
    - *Point-of-care:* Diagnostic tests will be performed in the doctor's rooms or at the patient's bedside, and this will necessitate the development of mobile user-friendly diagnostic devices and easily accessible disposables.

    - *High content screens:* It will be possible to screen for several parameters in a single test.
- *Preimplanation screening and selection:* Based on the knowledge that a family may have of a genetic predisposition within the family to certain diseases we suggest that possible and accepted practice to perform preimplantation of diagnosis of embryos conceived *in vitro* which will enable the selection of embryos with low probabilities of the diseases in question. The screen will have evolved beyond monogenic disorders.
- *Bioimaging and molecular bar-coding:* Functional diagnostic tests will use labelled single molecules to map normal molecular pathways and aberrations thereof. Labelling will be in the form of fluorescent or radio-labelled tags.

Therapeutics

- *Disease subcategory treatment:*
    - Biomarkers will allow us to identify sub-categories of diseases, each of which will have a specific treatment regimen.
    - Small molecule drugs will be designed based on detailed molecular knowledge of disease mechanisms and will be rendered safe and efficacious through the use of pharmacogenomics.
    - Biologicals (eg. proteins and antibodies) will likewise be designed based on detailed molecular knowledge of disease mechanisms.
- *Drug delivery:*
    - *Slow release:*
        - Controlled release
        - Smart release
        - Nanotechnology
        - Targeted delivery
- *Regenerative medicine:*
    - Tissue and organ replacement
    - Human designer spare parts

Implementation

- *Hospitals:*
    - General super hospitals
    - Disease specific hospitals

    - Environmental management of hospitals:
        - Energy use
        - Waste management
- *Virtual Medicine:*
    - Telemedicine
    - Robotics
    - Smart cards

Annexure 1: Workshop Delegate Details

Project	:	BIOTECHNOLOGY FORESIGHTING PROJECT	Project No.	:	??
Subject	:	BIOTECHNOLOGY FORESIGHTING PROJECT	Date	:	??
Place	:	St George's Hotel, Rietvleidam, Pretoria	Time	:	09hr00

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Annexure 2: Workshop Programme

Gauteng Biotechnology Foresight Workshop

29-30 October 2008

<u>Wednesday, 29th October</u>

09h00-09h30: Registration and Coffee

09h30-10h45: Introductory Session (in plenary)
- Welcome
- Overview of COFISA
- Explanation of workshop processes
- Presentation and discussion of ***Biotechnology Trends Analysis***

10h45-11h00: Tea/Coffee Break

11h00-12h15: Trends Analysis Session (in working groups)
- Contextualise and consolidate the biotechnology trends analysis

12h15-13h00: Trends analysis report back (in plenary)

13h00-14h00: Lunch

14h00-14h45: Presentation of Gauteng Proto-Scenarios (in plenary)

14h45-16h00: 1st Scenario Session (in working groups based on macro-scenarios)
- Develop a futures wheel from a biotechnology perspective.

16h00-16h30: Futures Wheel report back (in plenary)

19h00-21h30: Networking Supper

Thursday, 30th October

09h00-10h30: 2nd Scenario Session (in working groups based on macro-scenarios)

- Develop second level biotechnology futures wheel(s)

10h30-10h45: Tea/Coffee Break

10h45-11h30: Futures Wheel report back (in plenary)

- Consolidate the main future biotechnology issues for Gauteng

11h30-13h00: 3rd Scenario Session (in working groups based on macro-scenarios)

- Produce biotechnology proto-scenario fragments.

13h00-14h00: Lunch

14h00-15h30: 3rd Scenario Session (in working groups based on macro-scenarios)

- Produce biotechnology proto-scenario fragments.

15h30-16h30: Wrap-up Session (in plenary)

- Report back on scenario writing
- Discussion of process
- Identification of additional participants for the 2nd Foresight workshop
- Identification of additional members of Gauteng Reference Group
- Thanks

Annexure 3: Draft Biotechnology Trends Analysis

SOUTH AFRICAN BIOTECHNOLOGY FORESIGHT INITIATIVE: TRENDS ANALYSIS

Prepared by:	**Sibongile Pefile**
Prepared for:	**COFISA**
Date:	**October 2008**
Version:	**Version 1.1**

Introduction

Over the last ten years there have been dramatic developments in basic research and in applications of biotechnology. This report provides a picture of the major trends in biotechnology that are taking place in South Africa and the rest of the world. The focus is on biotechnology developments in the areas of health, food security, agriculture, animal biotechnology, industry and the environment and natural resources. An overview of emerging disciplines including bioinformatics, genomics, marine and terrestrial microbial biotechnology, nano-biotechnology, stem cell research, and biodiversity is provided and the report ends with a brief summation of emerging biotechnology fields that are providing new applications and uses.

One of the more important benefits of biotechnology is its contribution towards addressing the needs of the poor, particularly in the area of human health (including HIV/AIDS, malaria and TB), food security and environmental sustainability. Many developing countries are harnessing biotechnology tools to improve local socioeconomic conditions. However more can be done to accelerate efforts and increase impact to provide a real benefit to marginalised members of society.

Definition: Because of its crosscutting nature, and ever growing influence, there are numerous definitions of biotechnology. The OECD uses the following definition. Biotechnology is "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or nonliving materials for the production of knowledge, goods and services".

Biotechnology involves a diverse collection of technologies that manipulate molecular, cellular and genetic components and processes with a view to developing products and services for commercial and other purposes. The hallmarks of biotechnology are cellular and genetic techniques that manipulate cellular and subcellular building blocks for applications in various scientific fields and industries such as medicine, animal health, agriculture, marine life and environmental management.

Biotechnology has developed through three major phases.[1] Each phase builds on the science and knowledge of the previous and for this reason it is difficult to determine the exact point in time at which subsequent generations became mainstream activities. As a result, one finds that first generation applications are used in second and third generation biotechnology.

[1] A National Biotechnology Strategy for South Africa, 2001.

The first generation largely involves the use of selected biological organisms to produce food and drink (such as cheese, beer, and yeast). The main cluster of techniques in this generation is fermentation, plant and animal breeding and the clonal propagation of plants.

The second generation is the use of pure cell or tissue culture to yield new products. This generation is associated with the production of metabolites such as antibiotics, enzymes and vitamins. Major developments in this generation include the exploitation of a growing body of scientific knowledge relating to the properties and characteristics of microorganisms such as fungi and bacteria. A characteristic of this generation is that mutagenesis and the selection of strains and cultivars are used to improve metabolite and crop yields.

Third generation, modern biotechnology, emerged in the last 30 years and is associated with recombinant DNA technology. It involves the "application of *in vitro* nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles.

Distinctive Attributes: Biotechnology is characterised by a number of distinctive attributes.

Firstly, it is a *crosscutting* technology. It is subject to wide application, across many sectors and biological boundaries. For example, a technique developed for and applied in human health can prove equally or even more useful in agriculture, and *vice versa*.

Secondly, the biotechnology industry is a *research-intensive* industry. While the chemicals and the pharmaceuticals industries do some biotechnology research, traditional biotechnology companies tend to be more research intensive and spend between 40% and 50% of revenue on R&D. Historically, it was the interests and enthusiasm of individual scientists and scientific institutions that led to the establishment of the biotechnology industry, sometimes in the absence of a market-pull. This close relationship between research institutions and the new biotechnology industry remains today. Economies interested in diversifying and moving towards a competitive edge in biotechnology need to take measures that will stimulate the emergence and growth of R&D-intensive biotechnology companies.

Thirdly, the development and application of biotechnology techniques requires the convergence of a variety of disciplines. It requires appropriate combinations of biochemistry, genetics, information technology, engineering and several other specialised areas. It is thus a *multidisciplinary* field.

A brief history of SA biotechnology

South Africa has a long history of biotechnology research and development largely dominated by first generation applications that have led to the successful establishment of the brewing, food and wine industries. Recent government policies and strategies are creating promising opportunities for third generation 'modern' biotechnology which includes research in gene therapy, molecular modelling, pharmacogenetics, and structural and functional genomics. Industrial applications that use biotechnology techniques and processes can be found in pharmaceuticals, agriculture, speciality chemicals, bioremediation and cleaner production methods. The earliest applications in pharmaceuticals targeted the production of proteins such as insulin, diagnostics and vaccines for viral and bacterial diseases. In agriculture the application of recombinant DNA technology has focused on the genetic improvement of crops.

In the past, biotechnology was poorly exploited in South Africa resulting in missed opportunities for benefiting socially and economically from this technological base. This is beginning to change as national and provincial initiatives in support of biotechnology activities gain momentum. An important area of investment is biotechnology for social application and uses.

The DST 10-Year National Innovation Plan sets out to accelerate South Africa's transition towards a knowledge economy. The Plan aims to establish five R&D investment areas that are expected to result in innovation and positive outcomes for the economy. Strengthening the bioeconomy is one of the five focus areas. The vision for 2018 in respect of biotechnology is captured in the excerpt below.[2]

By 2018 South Africa anticipates that it will:

Be one of the top three emerging economies in the global pharmaceutical industry, based on an expansive innovation system using the nation's indigenous knowledge and rich biodiversity

Have designed and created the appropriate technology platforms, and R&D and innovation infrastructure (including structural biology, functional genomics, etc.) that facilitate diagnostic and medical solutions

Have created and funded five theme-specific consortium–based centres of competence that focus on the five top national health priorities, linked to the growth of the local pharmaceutical industry

Increase foreign investment in South African health-related R&D (excluding clinical trials) through reinvigorated health research, with particular emphasis on pharmaceutical R&D

Have designed and created a platform in 3rd generation biotechnology for application to plant/animal improvement and biofarming

Invest in animal vaccine development and manufacturing facilities to strengthen animal health and production

Have created an active biosafety platform providing regulatory guidance and support for product development in 3rd generation plant and animal biotechnology

A key feature of this bioeconomy is that it should contribute towards addressing national priorities in terms of access to and the affordability of health care, the provision of food security, job creation and environmental protection.

Main areas of investment (emerging)

While the industrial (mainly food and beverage) and agroprocessing field continue to play a dominant role in biotechnology applications in South Africa, a new area of biotechnology investment

[2] DST 10 year National Innovation Plan, 2008.

is emerging in human health applications, particularly involving: gene therapy; genetic engineering; nanotechnology; pharmacogentics and drugs; vaccines; and diagnostics research to address the challenges of communicable diseases, namely malaria, tuberculosis and HIV. [3]

In the energy sector, biofuels are creating great interest and to an extent, so are biotechnology applications based on South Africa's local biodiversity. In the agricultural and food security arena, genetically modified crops and foods have increased in importance and application.

Global context

On the international front, the Human Genome Project has made a significant impact on the advancement of genomics globally, and as a consequence, has resulted in major impacts in respect of practices and production processes that are based on living organisms. Even though the human genome project was said to be complete in 2003, it will take much time to determine and map the 28 000 to 35 000 genes identified and to understand how they interact with one another. The project has generated an unprecedented amount of knowledge about human genetics and health. This is made evident by the proliferation of genomics research clusters globally. Although the US leads in biotechnology research, there are excellent scientific groups in the developing world, including Cuba and Brazil in Latin America, as well as China, Korea and India in Asia.

Biotechnology in the health sector is expected to continue delivering incremental changes at least for the next five years. This is based on the preliminary analysis of global clinical trials which indicate that an average of 15 new biopharmaceuticals will be introduced into the market annually up until 2015. While biopharmaceuticals have historically offered a significant therapeutic advantage over small molecule therapeutics, they will continue to account for a relatively small share (approximately 14%) of all new pharmaceuticals. Despite this, in years to come, biotechnological knowledge will be so pervasive, for example for the identification of drug targets, that all new therapies could be based in part on biotechnology.

In agriculture, the use of biotechnology techniques, including both genetically modified (GM) cultivation and marker assisted selection (MAS), is a major success story even though many governments have been reluctant to support these applications. The share of all crops planted that use biotechnology has been rising rapidly over the past 10 years and this trend will likely continue into the future. If it does, well before 2030, all major food crop varieties will have been developed using some form of biotechnology and these crops could account for approximately half of the global output of food, feed and feedstock crops. In some respects, genetic engineering is not much different from other types of genetic manipulation that are routinely carried out to create organisms with desirable characteristics. After all, conventional plant breeding also involves the controlled transfer between organisms of genes that code for economically valuable traits. Where genetic engineering differs from conventional breeding, however, is in allowing genes to be transferred more easily across taxonomic boundaries. With genetic engineering, genes can be transferred not only between closely related organisms (for example, when a gene coding for disease resistance is transferred from a wheat plant to a rice plant), but also between completely different organisms (for

[3] Ernst and Young South African Biotech Review: Discussions with industry stakeholders

example, when a gene coding for cold tolerance is transferred from a fish to a strawberry plant). In conventional breeding, biological reproductive processes impose limits on genetic recombination by erecting barriers against the successful crossing between biologically distinct organisms; either the crossing fails completely, or else the progeny are sterile. With genetic engineering, the "natural" limits do not always have to be respected. For this reason, some people consider genetically-modified organisms (GMOs) to be "unnatural" organisms that violate the laws of nature. Others consider this distinction arbitrary, countering that most foods consumed today have been radically modified over thousands of years through deliberate selection or accidental mutation.Industrial applications of biotechnology are growing rapidly to incorporate unique processes involving enzymes and probiotics technologies Furthermore, a partial shift from petroleum feedstocks to biomass will depend on the economic competitiveness of industrial biotechnology compared to other solutions. While in some regions biofuels could play a substantial role, local supply and geographic conditions may lead to other technologies, such as solar and wind, being deployed (these are more environmentally benign sources of carbon neutral energy). Policy will need to be carefully designed to promote the most environmentally and economically efficient solutions. [4]

KEY BIOTECHNOLOGY SECTORS

Current global biotechnology activities

1. ***Health***

   Research and development activities in human health are broadly directed at therapeutics (e.g., biopharmaceuticals such as biotechnology-derived proteins, antibodies and enzymes, and genetic therapies), medical diagnostics (e.g., tests for specific gene or protein markers), and preventives (e.g., new vaccines developed through recombinant DNA methods).

   Human tissue engineering is an emerging, multidisciplinary biotechnology technique focusing on the regeneration of diseased human tissues. The development of this novel biotechnology promises to change medical practice profoundly and heralds new treatment possibilities for patients.

   Important contributors to the total disease burden are infections like HIV/AIDS, tuberculosis, malaria, respiratory infections and chronic diseases affecting the heart and blood vessels, neuro-psychiatric disorders, diabetes and cancer. The development of vaccines against infectious diseases will be guided by increasing knowledge about pathogen genomes and subtypes, host responses to infectious challenges, molecular determinants of virulence and protective immunity, a better understanding of the mechanisms underlying escaped immunity, and ways to develop novel immunogens. Translational research and the ability to rapidly evaluate multiple candidates in clinical trials can help accelerate the pace of vaccine development.

[4] OECD Biotechnology review

Biotechnology offers promising health solutions for the treatment and diagnosis of HIV/AIDS, tuberculosis and malaria, all of which are major diseases that mainly affect the poor. By understanding the cellular and molecular actions associated with these infectious diseases it is possible to produce more effective, efficient and safe treatment, prevention and diagnostic technologies.

Other emerging areas of biopharmaceutical research as seen in Europe, Canada, the US, Japan and Finland include:

- Prevention, diagnosis and treatments of diseases to improve public health
- Personalised or patient-targeted medicine
- Biodiagnostics, bioinformatics, and medical technologies
- Identification of biomarkers combined with molecular imaging (diagnosis and treatment uses)
- Development of broad reactive synthetic vaccines for human health, especially for the treatment of infectious diseases
- Regenerative medicine – disease-specific stem cells; precursor cells
- Therapeutics for heart disease, arthritis, and rare diseases
- New anti-aging and anticancer drugs
- Neurobiology and brain research.

2. Food

Despite the negative consumer response to GM foods in Europe and some other parts of the world, genetically modified crops are emerging to be an important technology with respect to food security and industrial opportunities. The first generation of genetically modified crops focused primarily on improving agronomic traits for the benefit of the farmer, such as herbicide tolerance and pest resistance. The second generation is expected to try to improve food attributes such as nutritional value, colour, texture, flavour and processing properties.

Several US-based biotechnology companies are involved in agroprocessing. Many products are created by applying natural or engineered microbes to products in order to preserve, extend shelf life or enhance nutritional characteristics.

In India there is significant food biotechnology research being undertaken, including the development of:

- tools for evaluating food safety;
- rapid diagnostic kits for the detection of various food borne pathogens;
- analogical methods for the detection of genetically modified foods and products derived therefrom;
- nutraceuticals, health food supplements, and functional foods for holistic health;
- pre-cooked, ready-to-eat, nutritionally fortified food for school-going children;

- suitable pro-biotics for therapeutic purposes;
- biofood additives.

Reducing micronutrient malnutrition of the poor is possible through enhancing the iron, zinc, and vitamin A content of basic food grains. Fortified crops can significantly improve the health, immunity and well-being of the poor who cannot afford to eat more expensive foods for these nutrients.

3. *Agriculture*

India, together with many African countries, is conducting extensive research on agriculture, soil and water conservation, animal husbandry, fisheries, dairying, forestry and agricultural education. Special research activities on plant biotechnology have been established at several research institutions where work on staple crops such as soyabean, maize, cassava, potato, rice, cotton, brasica and brinzal is being carried out. Many countries, including India, South Africa, Tanzania, Uganda, Kenya, and Ethiopia, have a growing seed industry where the main type of activity is the production of hybrid seeds for improved crop production and pest resistance. Some research institutions within these countries are beginning to enter the field of DNA fingerprinting, and they also provide identification facilities for viral diseases in plants and animals. Some are starting to employ data mining techniques to harvest additional value from their existing databases. Other areas of research include the production of biofertilisers, as well as the development of better formulations and cost–effective, commercially-viable biopesticides including microbial pesticides, parasitoids and bacteria.

The application of modern biotechnology methods to agriculture has been hailed as the next agricultural revolution, capable of sustaining agricultural production to meet the dietary needs of an expanding world population, as well as increasing demands for improved food and environmental quality. Most commercial agricultural biotechnology products have production-enhancing traits that complement or replace traditional agricultural chemical inputs. Crops generally are designed to be herbicide-tolerant or pest-, virus-, or fungus-resistant. Biotechnology is also used to improve agronomic characteristics of crops, including crops that use nitrogen more efficiently or are developed to better tolerate stress, such as drought, alkaline soils, or frost. Nutraceuticals and health benefits from agricultural products are another growing research area. Such applications play an important role in enhancing food security and access to nutritional crops in developing countries.

In the US, agricultural biotechnologies are increasing crop yields significantly while reducing reliance on chemical herbicides and pesticides. For example, the addition of vitamin A to rice has the potential to save the lives of millions of children in the developing world each year. Similar advances in bioagriculture will help feed a rapidly growing world population with healthier foods.

The US and Canada in the developed world, and China, India, South Africa, Argentina and other Latin American countries in the developing world, are showing a wider adoption of transgenic crops and transgenic crop cultivation. Across the globe, biosafety regulations are being established and implemented to monitor the large-scale and commercial application of GMOs.

Applying biotechnology to marine "farming" (aquaculture) also promises to improve aquaculture production, a goal that has become more critical for meeting increased consumer demand as natural seafood stocks have dwindled.

4. *Animal biotechnology*

The broad objectives of biotechnology applications related to animal health are largely the same as in human health applications, that is, applying advances in genetics and molecular biology to discover and create new and more powerful:

- therapeutic products (proteins, antibodies, enzymes, genetic therapies),
- diagnostic tools (e.g., for gene or protein markers of disease conditions), and
- preventive measures such as vaccines.

Infectious diseases such as foot and mouth, SARS, avian flu and BSA are a great public health concern due to the increasing emergence of diseases transmitted from animals to humans.

In addition, biotechnology is providing powerful new tools for improving farm animal breeding programmes, including genetic mapping methods to identify both disease-resistant animals and certain specific genes related to animal health weaknesses and defects. In livestock production, biotechnology is being used to develop animals that have better growth and muscle mass and improved disease resistance, and that can utilise feed more efficiently.

Two complementary initiatives have been launched by the European Commission in the area of animal biotechnology. The one is a project aiming at stimulating an informed, public debate across Europe on farm animal cloning and ensuring public participation in the forming of policies. The second is a study on animal cloning and genetic modification and derived products. The studies aim to provide a comprehensive, worldwide picture of research and commercial activities involving animal cloning and/or genetic modification and current and future products that may be obtained, and:

- to identify the potential benefits, risks and socio-economic impacts;
- to compare regulatory frameworks worldwide, and
- to assess new policy implications of the developments of these technologies and of the commercialisation of their products in the EU.

The next phase of agricultural biotechnology products promises improved quality and end-user traits. Some examples of quality-enhanced foods that are being developed include foods with lower saturated fats, increased vitamin content and improved flavour and shelf life. Biotechnology applications in aquaculture will be able to produce larger fish with less feed, improve spawning, and reduce the time for fish to gain market weight.

On the laboratory side, genetically modified mice and other laboratory testing animals are important tools in modern biomedical research. They provide valuable information on gene functions and serve as models for human diseases. Countries such as Finland have established laboratory facilities for the physiological analyses of transgenic animals. The focus of such facilities is to develop methodologies for small animal physiology studies with an emphasis on the investigation of, for example, cardio-vascular function *in vivo* and *in vitro*.

5. *Industrial biotechnology*

Industrial biotechnology refers to the use of biotechnology techniques and processes in manufacturing (chemicals, materials, energy) at every stage in the process, from the supply of raw materials to end-of-pipe and clean-up. For instance, industrial biotechnology research is expected to provide a smooth transition from a fossil-based economy to a bio-based economy. Canada, the US and Japan are providing strong support to industrial biotechnology while several European countries have launched their own initiatives and public-private partnerships to promote industrial biotechnology. An international dialogue is also taking place at the OECD level.

One aspect of industrial biotechnology (also referred to as white biotechnology) involves the use of biological systems for the production of useful chemical entities. This technology is mainly based on biocatalysis and fermentation technology in combination with recent breakthroughs in molecular genetics and metabolic engineering. This new technology known as biorefinery, has developed into a main contributor to so-called green chemistry, in which renewable resources such as sugars or vegetable oils are converted into a wide variety of chemical substances such as fine and bulk chemicals, pharmaceuticals, biocolorants, solvents, bioplastics, vitamins, food additives, biopesticides and biofuels such as bioethanol and biodiesel. The biorefinery concept is analogous to today's petroleum refinery, which produces multiple fuels and products from petroleum. By producing multiple products, a biorefinery takes advantage of the various components in biomass and their intermediates therefore maximizing the value derived from the biomass feedstock. A biorefinery could, for example, produce one or several low-volume, but high-value, chemical or nutraceutical products and a low-value, but high-volume liquid transportation fuel such as biodiesel or bioethanol. The biorefinery simultaneously could generate electricity and process heat, through combined heat and power (CHP) technology, for its own use and perhaps enough for sale of electricity to the local or national grid. A significant amount of research is taking place in the area of biomaterials, especially of biomaterials that display multiple uses and biodegradability.

A European – US collaboration has been established to bring together experts from plant and industrial biotechnology to identify opportunities with respect to plant-based bioproducts. Research that is taking place includes enhancing plants for the purpose of producing bio-based products and bioenergy as well as creating value from renewable biological resources. As a renewable energy source, biofuels can supplement hydrocarbon fuels, assist in their conservation, as well as mitigate their adverse effects on the climate. Two major biofuels for the transport sector, bioethanol and biodiesel, are fast becoming popular in many countries around the world. While bioethanol (called ethanol) is produced from raw materials such as molasses, beet, sugarcane juice, grains and tubers, biodiesel is produced from oil (derived from oil-bearing seeds such as *Jatropha curcas*, *Pongamia pinnata* i.e.karanja).

Given Finland's abundant forest resources, it is well placed to utilise biomass as an energy source. Finnish technology is already in use to make efficient use of biofuels. Botany and plant breeding as well as genetic engineering are being harnessed for the development of biofuel production. South Africa is also making use of biotechnology to improve the quality of forest trees, however in this case, for higher-quality paper and furniture production.

Advanced measurement methods and technologies are used both in bioprocesses for purposes of producing chemicals and new materials, for quality control purposes in the food industry and in studies on the state of the environment. In industry, new measurement technologies are needed for instance in bioenergy production.

Biological processes offer the prospect of cheap and renewable resources, lower energy consumption and less waste products. They also raise opportunities for zero greenhouse gas emissions, reduced dependence on (imported) petroleum and new markets for agriculture.

6. The Environment and Natural Resources

Biotechnology has tremendous potential for application to a wide variety of environmental issues including the conservation and characterisation of rare or endangered taxa, afforestation and reforestation. It can help in many ways, including:

- the rapid monitoring of environmental pollution,
- eco-restoration of degraded sites such as mining spoil dumps,
- treatment of effluents discharged by industries (oil refineries, dyeing and textile units, paper and pulp mills, tanneries, pesticide units etc.),
- treatment of solid waste.

In the US, biofuels represent an important avenue, not only to reduce dependence on oil, but also to improve the quality of the environment. In addition, enzymes identified or designed through biotechnology offer ways to clean up waste while reducing pollution caused by industrial processes or accidents.

Several companies in the US are actively researching bioleaching, biopulping, biobleaching, biodesulfurization, bioremediation and biofiltration. The economic and social impacts of environmental applications can include greater manufacturing efficiency and lower production costs, less industrial pollution, and resource conservation. Enzyme-catalysed processes are generally more efficient than chemical processes because input yields are higher and fewer steps are involved. Much of the current environmental biotechnology research is focused on the manipulation of enzymes or enzymatic reactions. However, research groups, especially in the US, are working to create new industrial products from engineered bacteria or cells. In the immediate future, the most promising applications may be in plastics and fuels.

Examples of biotechnology applications that have impact on the environment and natural resources include:

- Air, water and soil quality (e.g., biofiltration, diagnostics, bioremediation, phytoremediation)
- Energy (e.g., microbiologically enhanced petroleum recovery, industrial bioprocessing, biodesulphurization)
- Mining (e.g. microbiologically enhanced mineral recovery, industrial bioprocessing, biodesulphurization)
- Forest products (e.g., biopulping, biobleaching, biopesticides, tree biotechnology, industrial bioprocessing)

The conflict between food and fuel is, at base, an environmental issue. There are many ad hoc initiatives that are attempting to address usually one or other of these, but are in reality counterproductive, at least in the long term. There are also already moves towards much more integrated and coordinated strategies, such as the IAASTD.

EMERGING DISCIPLINES

1. Bioinformatics. genomics and proteomics, pharmacogenetics, bioimaging

Bioinformatics:

India, Korea, and to a lesser extent South Africa, have established substantial infrastructures for bioinformatics. Specific techniques include gene shuffling, protein engineering, extremeophiles, molecular breeding, high-level gene expression and protein expression, high-throughput screening, fermentation research, creation of DNA libraries, and subsequent assay development. Bioinformatics holds out strong possibilities of reducing the cost and time of development of new products such as new drugs and vaccines, plants with specific properties and resistance to pests and diseases, new protein molecules and biological materials. As the full genome sequences, data from micros arrays, proteomics as well as species data at the taxonomic level became available, integration of databases formed during genome research require sophisticated bioinformatics tools. Organising these data into suitable databases and developing appropriate software tools for analyzing the same are some of the research challenges.

Genomics and proteomics:

Genetic testing is a growing discipline within the genomics field. Genetic profiles are used to determine an individual's health predisposition. In Europe new applications of genetics are emerging that lie at the interface between *in vitro* fertilisation techniques and pre-implantation genetic diagnosis. Amongst others, Korea is involved in extensive genome and gene therapy research (e.g., gene identification, gene constructs, and gene delivery).

Japan has been concentrating on the development of functional genomics related to health and food and to regenerative medicine and post-genome research. Several countries in Europe (Denmark, Norway, Estonia and Sweden) and also some in the developing world have established biobanks to store information generated during genetic tests.

Pharmacogenetics:

Pharmacogenetics is the study of inter-individual specific genetic variation related to response to medicines. It is often said that pharmacogenetics might enable the pharmaceutical industry to significantly enhance the productivity of drug discovery and development, allowing also the re-evaluation of drugs that have failed because of low response rates in the general population.

India has elected to focus on programmes for understanding the processes underlying molecular genetics and control of gene expression, genetic manipulation of microbes, recombinant DNA products, engineering new protein molecules/new chemical entities, development of immuno-diagnostics and biotechnology of prospective medicinal and aromatic plants.

One important area of research is disease susceptibility gene identification, especially for communicable diseases like leprosy and tuberculosis, noncommunicable diseases such as rheumatic fever, and genetic diseases such as thalassemia.

Bioimaging:

Bioimaging research is an interdisciplinary area that concentrates on developing imaging techniques ranging from molecular to cellular, from single molecule to whole animal imaging, from single-cell analysis of sub-cellular events to high-throughput screening. Living systems have the ability to respond to changing environmental and physiological conditions in a dynamic fashion. Imbalance of these processes leads to disturbed development and disease. The complex cellular and molecular signalling and regulatory processes underlying development and homeostasis can only be understood comprehensively by analysis in the intact living organism. Molecular interactions are frequently transient and context-dependent, necessitating *in vivo* analysis to generate relevant insights into the molecular mechanisms. Biomedical research and drug development have thus an increasing need to analyse and monitor these dynamic processes in cellular physiology, development and disease in the living organism using bioimaging technologies.

Molecular imaging technologies are being developed to examine the integrative functions of molecules, cells, organ systems and whole organisms. The organisms range from viruses to bacteria to higher order species, including humans, and in each case, molecular imaging is used to examine the structure and regulatory mechanisms of their organised functions.

Biomedical imaging refers to methods that open new ways to see the body's inner workings, measure biological functions, and evaluate cellular and molecular events using less invasive procedures. While X-ray imaging is a familiar example, it represents only one aspect of this fast growing field. Biomedical imaging allows physicians to detect disease and injury at their most curable stage and enables the delivery of less invasive and highly targeted medical therapies. Cellular and molecular imaging techniques combine new molecular agents with traditional imaging tools to capture pictures of specific biological pathways and processes in a living organism. These approaches help researchers study normal biological processes and to diagnose and manage diseases.

Advanced, multimodal imaging techniques, powered by new computational methods, are changing the face of biology and medicine. These new imaging modalities produce information about anatomical structure that is linked to functional data, as described by electric and magnetic fields, mechanical motion, and metabolism. This integrated approach provides comprehensive views of the human body in progressively greater depth and detail, while gradually becoming cheaper, faster, and less invasive. As a result, imaging becomes more common and more familiar, which in turn produces new scientific specialties that rely on particular combinations of imaging, computer science, and medicine.

2. Marine and terrestrial microbial biotechnology

In the US, Canada, Germany and Japan, there is a growing number of institutions involved in the research of microbial biotechnology applications. The application of biotechnologies to micro-organisms is a relatively new area in the discipline. In the expanding search for biological organisms that can be used in the prevention, diagnosis, and treatment of diseases or for industrial applications, companies are investigating marine and terrestrial organisms that have adapted to extreme conditions such as high pressure or heat, or total darkness. In the oceans and in extreme conditions on land, these types of "extremeophiles" and other, better-known types of microorganisms are beginning to provide some commercial biotechnology products. For example, recent studies and research suggest that products derived from diverse microorganisms, including green algae and a painkiller derived from snails, have the potential to be potent weapons in fighting cancer. Other applications include:

- processes related to fermentation, bioprocessing, and biotransformation extractions, purifications, and separations;
- microbiology, virology, and microbial ecology; and

- diagnostic tests and antibiotics.

Inspired by the mechanisms of sea urchins and Venus flytraps, researchers in the US have developed a new gel that could be used to make microscopic drug releasing devices and water-repellent clothes.

The economic potential of the sea as a source of novel genes and gene products, biopolymers, novel enzymes, new therapeutic leads, and other value-added products such as osmo-tolerant crops, has hardly been explored. Marine organisms also present immense potential as biosensors for pollution monitoring as well as bioreactors for production of novel products. The study of deep-sea organisms including marine microbes may well have tremendous implications for human health. Bioprospecting from marine bioresources are common research activities in South Africa, Korea, New Zealand and Australia.

In Finland, facilities have been established to offer support and services in bioprocess development and production of biomolecules by way of different fermentation strategies with micro-organisms, plant cells and eukaryotic cells. The activities include molecular genetic work, production of recombinant proteins and purification of cellular components.

3. Nano-biotechnology

Nanosciences and nanotechnology are important for underpinning the advances in life sciences and biotechnology. The convergence of inorganic nanotechnology and biotechnology into nano-biotechnology has the potential to yield breakthrough advances in medical diagnosis, targeted drug delivery, regenerative medicine and chemicals screening.

Europe is establishing a nanotechnology research platform and the priority research areas chosen include:

- nanodiagnostics including medical imaging
- targeted drug delivery and release
- regenerative medicine.

Integrated nanotechnology research is increasing. An example of such research is the application and integration of nanotechnology, advanced materials and computer science. Nearly every country with a biotechnology strategy is targeting nanotechnology research initiatives that mainly comprise activities in medical applications.

Researchers in India and South Africa are working on developments in novel biomaterials for micro-particle and nano-particle encapsulated drugs, proteins and other molecules. These offer improvement in quality of many therapies with minimal side effects. Nanoscale structured materials and devices hold a great promise for advanced diagnostics, biosensors, targeted delivery and smart drugs. The application of nanotechnology in bioengineering together with biotechnology offers a wide new range of advanced biomaterials with enhanced functionality; and combined with tissue engineering, it has the potential to provide true organ replacement technology.

4. Other

Bionics:

Bionics is an area related to biotechnology where ideas are taken from nature and implemented in new applications and machines. Bionics (also known as biomimetics, biognosis, biomimicry, or bionical creativity engineering) is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology. Examples of bionics in engineering include the hulls of boats imitating the thick skin of dolphins; sonar, radar, and medical ultrasound imaging imitating the echolocation of bats.

In the field of computer science, the study of bionics has produced artificial neurons, artificial neural networks, and swarm intelligence. Evolutionary computation was also motivated by bionics ideas but it took the idea further by simulating evolution in silico and producing well-optimized solutions that had never appeared in nature. Countries such as Korea have invested extensively into biosensors, biomimics and biomems.

Biodiversity:

Biotechnology is widely utilised to add value to traditional knowledge, as well as to tribal and folk medicine. Medicinal plants are the prime targets of bioprospecting initiatives. The tools of biotechnology are being used for conservation and genetic characterisation of plants. Research efforts of this nature are taking place in Korea, South Africa, India and many other countries in Africa and Latin America. Most research effort is directed at special programmes for the collection, assessment and preservation of the genetic sources of biodiversity.

Stem cell Research:

Stem cell research continues to be a hotly debated and contentious area of biotechnology. Stem cell research involves taking human cells either from human embryos that are less than two weeks old that will never be transplanted into a woman's body, or from the blood in umbilical cords. These stem cells can be used to grow new cells to treat certain diseases in any part of the body. Embryonic stem cells hold promise for the development of organs of the body. Denmark, Italy, UK, Hungary and the Netherlands are the leading European countries in this area of research.

Stem cells are not only obtained from embryos, but can also be taken from adult tissues and organs such as bone marrow, fat from liposuction, regions of the nose, and even from cadavers up to 20 hours after death. These stem cells can grow or differentiate into different cells and tissues of the body. Stem cells have been used in cancer treatments either to grow new healthy cells or eliminate cancerous cells through inducing the generation of a "new" immune system. Thus said, the use of adult stem cells is limited by the fact that there are very small quantities of adult stem cells in the body and they are difficult to isolate. Furthermore, adult stem cells may not have the same capacity as embryonic stem cells to multiply in the laboratory, and they may only be able to develop into certain kinds of tissues.

Concluding remarks

The next generation of biotechnology research involves combining advanced technologies in fields such as nanotechnology, materials and electronics with technologies and know-how in the life sciences. Countries that have a high level of research expertise in biomaterials, bioenergy, bio-ICT and bioinformatics, and the integration of these different fields will be well-positioned to capitalise on opportunities that open up in the intersections of these fields.

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Glossary of terms

Bioinformatics	Bioinformatics derives knowledge from computer analysis of biological data. Such data can consist of the information stored in the genetic code, but it can also be experimental results from various sources, patient statistics, and scientific literature. Research in bioinformatics includes method development for storage, retrieval, and analysis of the data. Bioinformatics is a rapidly developing branch of biology and is highly interdisciplinary, using techniques and concepts from informatics, statistics, mathematics, chemistry, biochemistry, physics, and linguistics. It has many practical applications in different areas of biology and medicine.
Biomass	Plant material, vegetation, or agricultural waste used as a fuel or energy source.
Biopharmaceuticals	Simply put, biopharmaceuticals are drugs created by means of biotechnology, especially genetic engineering. They are products which are derived using living organisms to produce or modify the structure and/or functioning of plants or animals with a medical or diagnostic use.
Enzyme	A protein (or protein-based molecule) that speeds up a chemical reaction in a living organism. An enzyme acts as a catalyst for specific chemical reactions, converting a specific set of reactants (called substrates) into specific products.
Gene	The basic biological unit of heredity. A segment of deoxyribonucleic acid (DNA) needed to contribute to a function.
Gene therapy	The goal of gene therapy is to cure a genetic disease by repairing the damaged gene responsible for the disease. It involves introducing a normal copy of the gene into cells containing the damaged version. The cells then can produce the normal protein.
Genetically Engineered Microorganism (GEM)	This term refers to bacteria, fungi, yeast or other microorganisms that have been genetically altered using molecular genetics techniques such as gene cloning and protein engineering. GEMs are a subset of GMOs.
Genetically Modified Organism (GMO)	This term refers to plants, animals or microorganisms that have been genetically altered using molecular genetics techniques such as gene cloning and protein engineering.
Genome	All of the genetic information, that is the entire genetic complement and the hereditary material, possessed by an organism. It is the total DNA present in the nucleus of every cell of an organism.
Genomics	The study of genes and their function. Genomics aims to understand the structure of the genome, including mapping the genes and sequencing the DNA. Genomics examines the molecular mechanisms and the interplay of genetic and environmental factors in disease.

Human tissue engineering	Tissue engineering / regenerative medicine is an emerging multidisciplinary field involving biology, medicine and engineering, and entails restoring, maintaining, or enhancing tissue and organ function. In addition to having a therapeutic application, where the tissue is either grown in the patient, or outside the patient and then transplanted, tissue engineering can have diagnostic applications where the tissue is made *in vitro* and used for testing drug metabolism and uptake, toxicity, and pathogenicity.
Immunogen	A substance that produces an immune response when introduced into the body.
Nano-biotechnology	Nano-biotechnology sits at the interface between the chemical, biological and physical sciences. It is concerned with nanometre-scale systems that may be produced from either a top-down approach, where larger units are disassembled, or a bottom-up approach involving component assembly. Utilising nanofabrication and/or processes of molecular self-assembly, nanotechnology allows the preparation of a range of materials and devices including tissue and cellular engineering scaffolds, molecular motors, and arrays of biomolecules for sensor, drug delivery and mechanical applications.
Pharmacogenetics	The merger of pharmacology and genetics into a field that pertains to the hereditary responses to drugs. It is the is the study of how the actions of and reactions to drugs vary with the patient's genes
Probiotics	Bacteria that are beneficial to a person's health, either through protecting the body against pathogenic bacteria or assisting in recovery from an illness. Probiotics counter the decimation of helpful intestinal bacteria by antibiotics. Probiotics given in combination with antibiotics are therefore useful in preventing antibiotic-associated diarrhoea.
Proteomics	The study of the proteome, the complete set of proteins (their roles, their structures, their localisation, their interactions, and other factors) produced by a species, using the technologies of large-scale protein separation and identification. Proteomics analyses, for example, the proteins of human fat cells , corn leaves, or an organism like the bacteria .

Annexure 4: Three Proto-Scenarios for Gauteng – 2030

Non-Zero-Sum Development
Knowledge Ecology • Innovation • Foresight • Information Society

COFISA
Cooperation Framework on Innovation Systems between Finland & South Africa

Three Scenarios for Gauteng

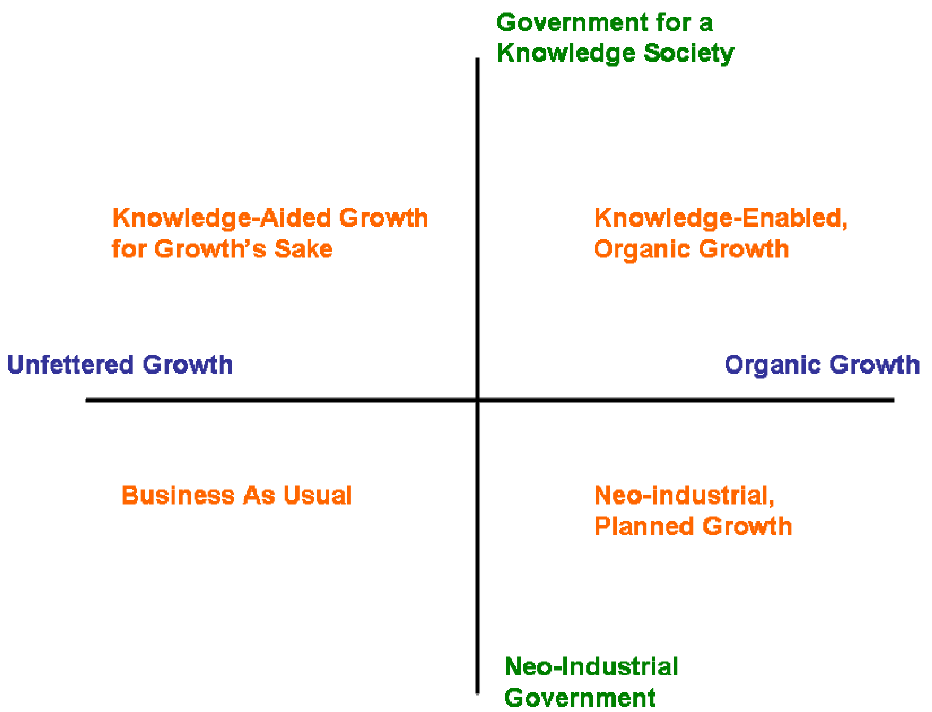
27 October 2008

Introduction

Between November 2007 and February 2008, COFISA undertook a Foresight exercise involving a series of three workshops to investigate realistic and implementable futures in the context of the development of a regional system of innovation in Gauteng. In the first of these workshops, each of six working groups produced a "Futures Wheel" providing their combined insights into Gauteng in 2050. The contents of these futures wheels were combined and synthesised, revealing two major areas of contrast, i.e.:

- Neo-industrial Government *versus* Government for a Knowledge Society;
- Unfettered Growth *versus* Organic Growth.

These axes were then used to create the following quadrant diagram. The three scenarios set out below in this document are based on three of these quadrants.



It is important that the delegates familiarise themselves with each scenario prior to the workshop, since they form the basis of several activities to be undertaken which are intended to result in three Gauteng Biotechnology Scenarios. These activities are highlighted in yellow in the following preliminary agenda:

Workshop agenda

Day 1

In plenary

- Overview of COFISA
- Explanation of process to be followed
- Presentation of biotechnology trends review

In working groups

- Contextualise and consolidate the biotechnology trends review
- Plenary report back

In plenary

- Presentation of the provincial macro-scenarios

In working groups (each focused on one macro-scenario)

- Develop a futures wheel from a biotechnology perspective.
- Plenary report back

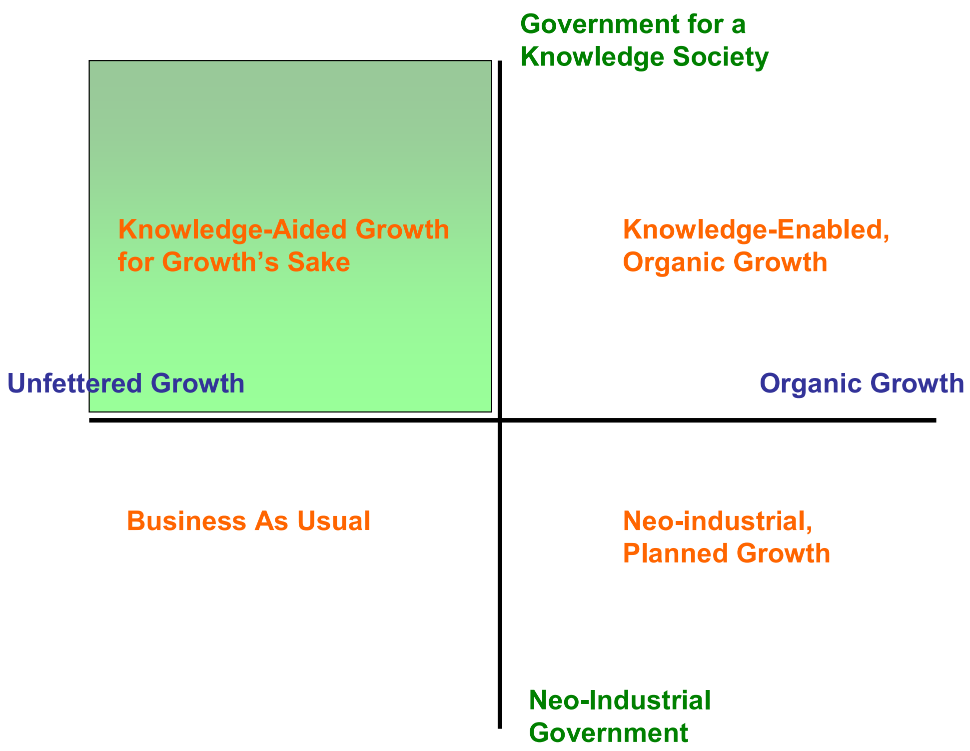
Day 2

In working groups (each focused on one macro-scenario)

- Consolidate the main biotechnology futures issues;
- Write proto-scenario fragments.
- Plenary report back and wrap up discussion.

Please note that it is also important that each delegate spend time prior to the workshop on the trends analysis document which was distributed a few days ago. Your insights and additions to this document as we contextualise it for the circumstances (now, *and in the future*) of Gauteng are the basis of the other main process during the workshop (highlighted in green).

Scenario 1: Knowledge-Aided Growth for Growth's Sake



The years: 2009 to 2019

The Gauteng Provincial Government (GPG) was very growth oriented. Their vision was to push for ever-increasing economic growth, as this growth (it was believed) served to undergird the growth of the whole country. It was also very good for Gauteng! While the poorer sections of Gauteng's society were not forgotten, it was believed that they would benefit indirectly: all segments of the population, including those on the periphery, would benefit in the wake of surging growth.

In 2009 the (new) national Government took the strategic decision that the key to a better future for all South Africans was the establishment and development of a knowledge society, at all levels, in the country. This strategy was then implemented by an initial focus on Gauteng (being by far the most economically advanced province), and the Eastern Cape (which was severely under-developed).

The GPG embraced this strategy, both for the way Government operated and delivered services, and for the province as a whole. They recognised that promoting the knowledge society was essential to achieving the high growth rates that they had targeted, and so they set about implementing the strategy with great energy. However, the level of understanding on the part of the GPG of the implications of moving towards a knowledge society left something to be desired, although this was not readily evident at the time. Everyone's enthusiasm led to hasty decisions and an obfuscation of the fundamental issues.

The GPG set up a forum with the private sector, although this meant in practice large companies, not SMMEs who did not have resources to devote to forums. The purpose of the forum was to achieve a consensus between the public and private sectors as to the best way to pursue the goal of a knowledge society. A sophisticated strategy was developed and agreed to, which emphasised the role of technology. This consensus unlocked a large amount of energy and enthusiasm for making the desired future happen.

So, for example, the GPG set about (as it thought) reforming its processes to bring them into line with the requirements of a knowledge society. It did so by entering into a few strategic partnerships with IT companies who impressed the Government with a range of the latest IT solutions. They were offered some superb deals in which the cost of software licences were heavily discounted for two years, on condition that a full solution was deployed, including server-side applications. These solutions were implemented with great speed and commitment from the top, but staff at an operational level experienced the exercise as a huge frustration and inconvenience. Some attempt was made to re-engineer processes followed by the several Government departments, but this was most often related to the need to change processes to fit the limitations of the IT solutions.

It was not only the ICT sector that was seen by the GPG to be a key to the growth that it sought. High-tech companies in a range of sectors were wooed to the province in the belief that their presence would boost the economy, and also that they were most compatible with the desired knowledge society. Biotechnology companies were given special preference and several multinationals in this sector established manufacturing operations in Gauteng. One innovation introduced by the GPG towards stimulating technology companies was to give preference in their procurement processes to companies that had implemented specified technology solutions for enhancing their own business processes. This encouraged the growth of technology-intensive business services (TIBS), which reinforced the technology-led attempt at creating a knowledge society, but did not especially favour knowledge-intensive business services (KIBS) as the latter were not focused on particular technology systems.

Nevertheless, results from the GPG's policies and initiatives were initially impressive, particularly in respect of Gauteng's first-world economy, and the poorer sectors benefitted from the growth through the creation of jobs. However, the major flows of money were within the top layers of the economy, and there was very little direct stimulation of the informal sector.

Several of South Africa's leading knowledge specialists, while admiring the spirit of the GPG's vision of a knowledge society, raised grave concerns about the way it was being implemented. They pointed out that the approach being taken was superficial and was missing the mark. They found an unexpected ally in Gauteng's financial services sector who, being well-integrated with the global system in which the role of knowledge was increasingly well understood, were more aware than most that the attempts in the province were fundamentally flawed. In fact, they had come to the realisation that their own models were based on industrial-paradigm assumptions, and were therefore out of date. But in the face of the successful growth being achieved, the voices of the critics were played down.

The growth resulted in a steady stream of immigrants to Gauteng, from other parts of South Africa and the rest of the world. Consequently, Gauteng's infrastructure began to take strain under a load that it was never designed to carry. The most concerning factor in this regard was Gauteng's ballooning use of water, of which there was a limited supply. The GPG tackled this problem with energy and vision, and successfully implemented measures that both reduced water consumption and water wastage. A water crisis was avoided, at least for the moment.

In 2016 Gauteng suffered a financial crisis. Many South African banks had strong ties to banks overseas, and this was certainly true for ABSA in which Barclays had a strong interest. Through a series of ill-considered actions and unforeseen circumstances (which brought memories of the financial crash of 2008) Barclays ended up in a precarious position and had to be propped up by the British government. This sent shockwaves through South Africa's banking industry in general, and through ABSA in particular. What aggravated the situation was that certain sections of ABSA had been operating outside of company guidelines, and the result was that they overextended the bank by lending money to people who were unable to afford the loans. ABSA was liable, and this combination of circumstances resulted in a run on ABSA's money. Depositors withdrew their savings in droves, and ABSA started to topple. Other banks were also in danger of folding. ABSA was rescued by a buy-out by a Dubai-based bank, who in short order moved top management control of what had been ABSA to Dubai. In addition, they moved ABSA's listing to the Dubai International Financial Exchange (DIFX).

At the urgent insistence of the GPG, the national Government responded by shoring up some of the other banks who were in danger of going under, in effect partially nationalising them. This move brought welcomed stability to the sector, although there were dire warnings of its long-term consequences.

Despite the intervention, ABSA's move from the JSE had a knock-on effect a few months later when several other financial services companies, attracted by the benefits that erstwhile ABSA was enjoying, also moved to the DIFX. A trickle turned into a steady flow, and by the end of 2018 the number of companies listed on the JSE had dropped by 6% (the figure was 22% for the financial services sector), and more than half of the companies that moved had above-median turnover (as determined in 2016).

Towards the end of the decade there were more and more complaints coming from spokespersons of the informal sector and the poorer areas of the province that the growth was in fact not benefitting them as had been the assumption. Yes, Gauteng's per capita output had grown in leaps and bounds for six of the previous nine years (the last three years had been flat due to the financial crisis), but even in the years of high growth the hard reality was that the gap between rich and poor had widened, there was even some evidence that poverty was worsening in some areas, and these trends showed no signs of abating.

The years 2021 to 2030

As the teens rolled into the twenties it became clear to everyone involved that the technology-led 'knowledge society' of the GPG had not delivered anywhere near what the expectations had been. There were some bright spots, such as the learner registration system for entrants into Grade 1, but none of the transformations in service delivery in the areas of education and health, to name but two, had been realised.

The lack of progress placed the relationship between the public and private sectors under strain. The GPG began asking hard questions as to why the benefits of the IT systems were not being experienced, particularly by those on the periphery. After a considerable muddle and confusion, the IT companies began speaking with a coherent and consistent message: what was missing (they said) was IT infrastructure deployed within the poorer communities. This would enable them to link in to the systems already deployed. It was more of the old technology-led approach and was roundly criticised by the academic community, and knowledge experts in particular.

This time many in the GPG listened to the criticism and did not simply accept the arguments for buying more technology, but their analysis continued to be superficial. For most their new perspective was as simplistic as their initial adoption of the knowledge society strategy: instead of seeing that technology-led transformation was fatally flawed, many in the GPG came to the conclusion that it was the concept of a knowledge society *per se* that was a pipedream. There was therefore a swing away from the knowledge society strategy on the whole, and in particular, a backlash against ICTs and against the notion that science and technology had an important role to play in poverty reduction.

Others in the Government tried to point out that a knowledge society strategy had in fact never been attempted, that the goal of a knowledge society was still valid but that the means of getting there had to be changed. Yet others began pushing for a more centralised and planned approach to achieving the social goals that all were agreed upon. The issue became hugely politicised and polarised, and given Gauteng's place in South Africa's economy, the whole country felt the impact in some or other way.

One specific consequence of the growing disillusionment was that a commission was set up to investigate whether the IT companies had fulfilled their obligations when they implemented the Knowledge Society projects. The conclusion was that they had failed to deliver properly, and the GPG then took the far-reaching decision to withhold payment on the ongoing contracts. This action provoked the anticipated response, namely litigation by the IT companies, which is not yet resolved.

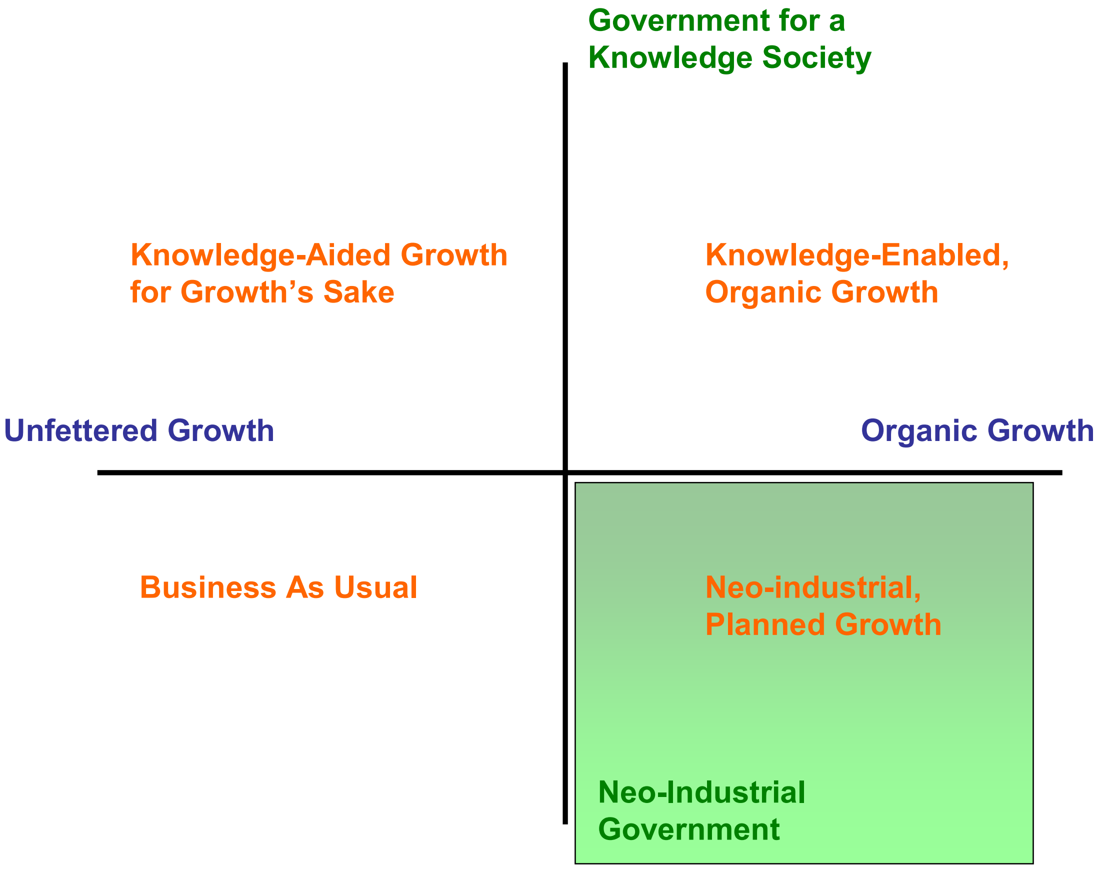
The financial services sector, having shrunk due to the crisis, continued to run counter to the general trend. Perhaps in response to the crisis they realised that innovative thinking was essential to their survival. Having realised that their financial and business models needed reworking to reflect the assumptions and dynamics that were appropriate for a knowledge society, and that by doing so they would be well-positioned to address what was an emerging opportunity, many of the leading companies in this sector undertook programmes to revise their models. They were entering new territory, and although many of them made use of international expertise, the task of adapting to local conditions was anything but straightforward.

The population of Gauteng continued to increase, although there had been a lull in the aftermath of the financial crisis. The strain on Gauteng's infrastructure became more and more evident, but now, in the context of the fallout of the failed knowledge society strategy, the GPG did not exercise the leadership that they had done in earlier years. Signs of reaching breaking point were noticeable in many areas (e.g. sanitation, energy, roads) but once again it was the water shortage that held centre stage.

By 2025 even the significantly improved industrial and household water systems that had been implemented in the previous decade could no longer cope with the growing demand for water by the population of now 12 million people, along with a mining industry that continued to boom. . The populace had become wearily tolerant of water rationing for 2 to 4 months in bad years, but then two full years of drought in 2023 and 2024 led to rationing for a whole year. This proved too much for even the most patient. Public protests took place in various forms, often accompanied by violence from unruly elements.

Permanent water rationing, affecting 12 million people, was introduced in Gauteng in 2028. In 2029 the crisis reached a breaking point. Serious civil strife erupted. The Government was forced to choose between household usage and industrial usage. Out of fear of further civil strife, they placed the most onerous restrictions on the mining industry, which cried foul because of the huge investments that they had made in water systems, at the government's insistence, during the previous 10 years. They argued that the Government had not kept their commitment, made in 2019, to cap the population in Gauteng below 12 million. Repeated legal action ensued, in which the mining industry was usually successful. However the conflict did not abate. It has damaged seriously the much-vaunted public-private partnership relationship in South Africa, with severe impact upon FDI, and on South Africa's international image. It has also undermined the credibility and effectiveness of the Government as it has resurfaced at regular intervals, tending to dominate our political discourse.

Scenario 2: Neo-industrial, Planned Growth



The years 2009 to 2020

The Gauteng Provincial Government (GPG) was very growth oriented, but they recognised the need for organic, balanced and equitable growth if it was to be sustainable and avoid social dysfunction. Their vision was to create a prosperous and equitable Gauteng through the execution of carefully-conceived development plans.

In 2009 the (new) national Government took the strategic decision that the key to a better future for all South Africans was the establishment and development of a knowledge society, at all levels, in the country. There was only minimal support in the GPG for this approach of the national Government, and they argued that it should be phased in, and that Gauteng should not be actively involved until the relevant mechanisms had been tried and tested in other provinces. The knowledge society approach was far too amorphous in their view. Such an approach would allow the GPG insufficient control to achieve their goals for Gauteng. The national government reluctantly conceded that, with so much depending on the success of Gauteng's economy, 2010 may not be the best time to experiment.

The GPG followed a strict top-down approach to achieve equitable growth and development, using a tight-loose-tight management style. Each department was given clear targets and expected to attain them. In practice, each department went off independently and put policies and programmes in place without consulting colleagues in other departments. What on paper were good policies in areas such as alternative energy, town planning, rural development and education, proved a nightmare in practice because there was no integration between them or coordination in implementation. The lack of transparency was marked.

Nevertheless, the GPG brought much energy to executing their development plans, and they had the financial resources to make things happen. However, their approach was control-oriented. They spoke of entering into partnerships with the private sector, but in practice these were unequal partnerships with the GPG wanting to call the shots. Their relationship with big business suffered as they tried to get major companies to follow policies in the name of 'organic' growth that made little business sense in the short term. As for SMMEs, after an initial attempt at harnessing SMMEs as part of their development plans, the GPG decided this approach was a lost cause. Those SMMEs that complied with their instructions were hopelessly inadequate when it came to delivery, while SMMEs that had good experience and capacity were reluctant to toe the "top down" line and were constantly motivating for significant changes in the GPG's plans.

Throughout this period, the GPG maintained a strong emphasis on the role of BEE in achieving socio-economic equity, and it was included as a core component of every development initiative. The GPG viewed many private sector organisations as merely paying lip service to the BEE concept, instead of adopting its spirit, and their relationship with many big businesses deteriorated even further. It also proved particularly difficult for many KIBS-oriented SMMEs to meet BEE requirements due to the historical shortage of appropriately qualified black people, and hence more and more chose to provide their services in other African countries.

Over time, the GPG also lost patience with Gauteng's academic sector, given their image of being elitist, "old guard", and self interested. Although in the early days inputs were sought from many academics, their growing level of criticism of the GPG's development approach amplified the lack of empathy and trust between the two sectors. The GPG was inclined to neglect most critical inputs from the academics, no matter how well their research was reviewed internationally, because they did not trust their motives.

Given its wish to turn Gauteng into a "green" province, the GPG decided to make a major impact in renewable energy. Nuclear power was a national initiative, and there were few opportunities in Gauteng's mostly urban and comparatively restricted open spaces for wind farms or hydro-electric power. So they focused on urban solar power, and worked hard on building relationships with international companies with established leadership and expertise in these markets. Initially there were promising results in converting some of Johannesburg's largest buildings to become energy independent. But cracks in the process appeared as relationships soured between the multinational suppliers and local distributors.

The first wave of local distributors, which were fairly small companies, were knowledgeable about the local circumstances in SA and pointed out that many of the imported products would not work sustainably without significant changes. But the multinationals wanted immediate sales rather than advice (especially from what they saw as a technological backwater), and employed alternative distributors who, because of their lack of knowledge in the area, asked few difficult questions, and advised only on sales rather than on technology. The net effect was to under-exploit the potential of solar power in Gauteng, and, in the longer term, to stifle the growth of a local solar power industry.

Generally, the GPG's drive to make Gauteng a "green" urban province focused on a "leap-frog", technology-push approach. It did not extend, as many researchers advocated, to investigating all aspects of Gauteng's carbon footprint, and particularly the urban province's current and future impact on the rural environment, near and far, which is its primary source of such resources as food, water, energy and manpower. A case in point was their reaction to the water crisis which surfaced in 2015. An investigation by overseas experts highlighted several areas for improvement (some of which were questioned by the "untrusted" local experts) which could ameliorate the problem, at least in the short term. Excellent plans were drawn up based on these recommendations, but in practice their measures were poorly implemented by uncoordinated departments with little relevant expertise. So water shortages continued to occur at regular intervals through to 2030.

In 2016 Gauteng suffered a financial crisis. Many South African banks had strong ties to banks overseas, and this was certainly true for ABSA in which Barclays had a strong interest. Through a series of ill-considered actions and unforeseen circumstances (which brought memories of the financial crash of 2008) Barclays ended up in a precarious position and had to be propped up by the British government. This sent shockwaves through South Africa's banking industry in general, and through ABSA in particular. What aggravated the situation was that certain sections of ABSA had been operating outside of company guidelines, and the result was that they overextended the bank by lending money to people who were unable to afford the loans. ABSA was liable, and this combination of circumstances resulted in a run on ABSA's money. Depositors withdrew their savings in droves, and ABSA started to topple. The situation was rescued by a buy-out by a Dubai-based bank, who in short order moved top management control of what had been ABSA to Dubai. In addition, they moved ABSA's listing to the Dubai International Financial Exchange (DIFX).

The GPG lobbied the national Government to intervene, but there was no agreement as to what the nature of the intervention should be. A wide-scale and wide-ranging debate ensued, characterised by more heat than light. What did become clear were the fundamental differences in outlook that existed between the national Government's knowledge society approach compared with the GPG's neo-industrial approach. Eventually, after four months, a compromise was reached, and the national Government agreed to intervene, but by this time it was a case of too little too late.

ABSA's move from the JSE had had a knock-on effect a few months later when several other financial services companies, attracted by the benefits that erstwhile ABSA was enjoying, also moved to the DIFX. In the hiatus that resulted from the disagreement between the GPG and the national Government, this trickle turned into a flood, and by the end of 2018 the number of companies listed on the JSE had dropped by 15% (the figure was 35% for the financial services sector), and more than half of the companies that moved had above-median turnover (as determined in 2016).

The scale of the financial crisis was such that Gauteng's economic growth was flat to negative in the last three years of the decade. The loss of jobs was a social disaster for the province, and in 2019, for the first time in living memory, there was a net outflow of population from the province.

The years 2021 to 2030

In 2021, a joint report by the World Bank and the EU entitled "The Emergence of the Knowledge Society in the Developing World" provided an in-depth chapter on South Africa's approach in general and Gauteng's results in particular. The report praised the GPG's genuine desire and commitment to promote organic development, but highlighted the mistakes associated with their reluctance to adopt the national Government's preferred knowledge society approach. The report went into some depth to provide evidence that after ten years, the GPG's retention of a rigid hierachical government structure had failed to successfully implement what the authors judged to be mostly well-conceived strategies. The report further pointed out that the top-down approach of many GPG departmental silos, despite the emphasis on shared policies and approaches, actively prevented an integrated, coordinated approach, leading to much duplication and waste. The report voiced concern that the use of monitoring and evaluation merely to "tick off" what had been done, rather than to attempt to measure any longer term impact of the initiatives, meant that little learning could be gleaned from ten years of significant investment of people, funds and expertise.

This report revived local criticism, particularly from the local researchers and experts, but with growing support from the SMME sector and the poorest communities. However, the long standing distrust between the GPG and the academic sector made it hard for the government officials to back down. Instead, they continued with their approach, with a few cosmetic improvements, and in 2024 a public relations campaign was launched "to create better understanding by the ordinary man in the street of the extreme challenges faced by the GPG, and its substantial achievements to date". This expensive three-year exercise convinced very few, even within the GPG, and the widespread disapproval eventually ruined many promising public sector careers.

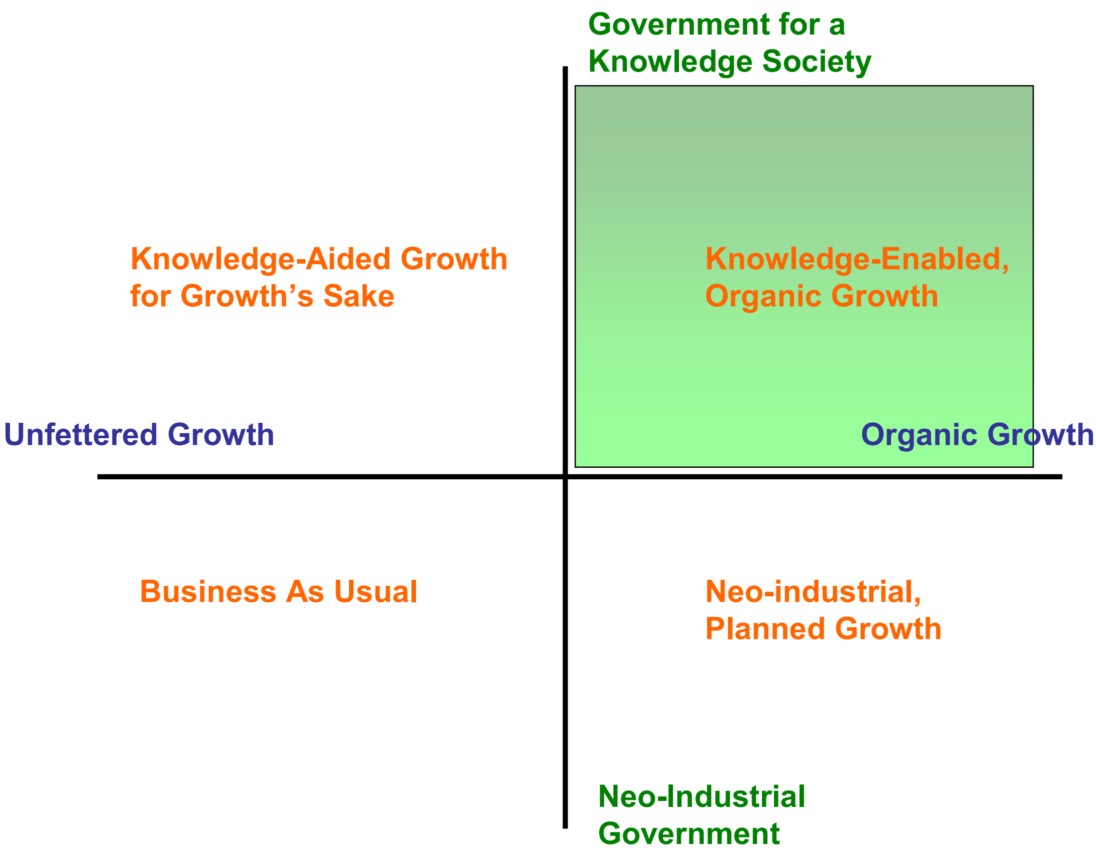
In 2028, following a substantial purge of staff (some of whom were later seen to have been innocent bystanders, with valuable expertise and experience) the GPG at last recognised that their development strategies were failing. But instead of identifying the cause as being their inappropriate neo-industrial structures, they found fault with the organic growth approach, which was then abandoned. There was universal criticism of this decision, which simply entrenched the polarisation between the various sectors of society that had developed over the previous 20 years.

A particularly sad note: a bloom of SMMEs were beginning to emerge at this time in a delayed response to the well-devised strategies of the GPG, despite their dysfunctional structures and implementation plans. But the abandonment of the organic growth strategy, and the polarised sectoral conflicts, meant that most of these SMMEs simply faded away.

On a different front, a water crisis had been growing in Gauteng during the teens, due to the increasing influx of people, and higher levels of industrial activity. Attempts had been made to improve the water infrastructure in 2015, and experts predicted that a major crisis would hit the province in the early twenties, on the assumption that current levels of economic and population growth were maintained. The financial crisis rendered those assumptions invalid. Throughout the twenties the population remained static or decreased, and so ironically, the disaster caused by the financial crisis meant that Gauteng avoided what would possibly have been a worse one: insufficient water.

Gauteng now has the opportunity of coming up with a long-term solution to its water supply needs, without the immediate crisis caused by a lack of water. This in itself is good news, but the wider implications are not as cheerful. The prospects of economic growth in the short term are bleak, and the experts say that fundamental changes are necessary to enable growth in the medium term. The dilemma is that there is no agreement as to what the changes should be.

Scenario 3: Knowledge-Enabled, Organic Growth



The years: 2009 to 2019

The Gauteng Provincial Government (GPG) was growth oriented, but not for its own sake. They sought mechanisms which would provide balanced long-term growth that would also be sustainable and avoid social dysfunction. Their vision was to create an equitable Gauteng without sacrificing (too much of) its prosperity. Many viewed the implementation of this vision as unfeasible and accused the GPG of being too idealistic, or dogmatic, or both.

In 2009 the (new) national Government took the strategic decision that the key to a better future for all South Africans was the establishment and development of a knowledge society, at all levels in the country. It was agreed that the first phase of this strategy would be implemented at the provincial level. Significant insights were anticipated by a two pronged approach, involving Gauteng (being the most economically advanced province), and the Eastern Cape (which was severely under-developed).

The GPG quickly embraced this strategy, deciding to facilitate the development of knowledge organisations and the adoption of knowledge-based processes and practices across all sectors and levels of society within Gauteng. This committed the GPG to transform itself not only in the way it delivered services, but especially in the way it operated within and between its many departments. This proved to be no easy task.

Especially during the initial stages the task of getting departments to willingly work together effectively and efficiently appeared to be almost impossible. Whereas most government officials were forthcoming in identifying flaws in and suggesting improvements to the processes and practices of other departments, they often became defensive at the suggestion that there might be similar flaws in their own. The entrenched culture of blame and risk avoidance, and the resultant covering up of mistakes and rejection of innovation proved a significant barrier to the adoption of open learning from mistakes that characterises the knowledge society. However, through innovative and dogged leadership, and the example set by a few early successes, the tide began to change and, despite many pockets of resistance, the commitment to learn, relearn and genuinely transform government became more and more widespread and persistent.

Perhaps the most tangible indicator of the willingness and commitment to transform in the first few years was the variety of mechanisms used to ensure that as many stakeholders as possible became actively involved in the long-term, rather than being used in cosmetic participatory processes.

Nevertheless, progress in transformation continued to be slower than anticipated. It was not uniform, but piecemeal, often occurring in fairly small groups within departments, and sometimes between officials with common goals working across two or more departments. In these circumstances, a common feature was that pockets of mutual trust developed which, in turn, transformed communication. Such groups tended to be more productive, and, although usually feeling over-loaded, appeared to enjoy their work.

Since the drive to transform was taking place in Gauteng at both the provincial and local levels, some examples of significant improvement to the interactions between these levels began to emerge, associated with the pockets of progress. In contrast, interactions often became even more problematic with the national level of government, which had decided to delay any transformation until it could gauge the results from the provincial level. An example of this disjoint was the lack of coordination concerning housing. Whereas the national government wished to push on with a "mass production" approach to delivering houses, the GPG, influenced by its active stakeholders from communities, research institutes and industry, was intent on giving potential homeowners choice and flexibility, introducing environmentally-friendly designs and construction methods, and involving local communities in the process of planning and implementation. The confusion and paralysis that resulted from this disjoint caused a slowdown in building houses that pleased no one.

The difficulty of measuring the impact of the slowly evolving transformation process is revealed by the complexity of its effect on initiatives aimed at sustainable poverty eradication. GPG departments that were resisting their own transformation, and persisted with the old "top-down" approach showed early success in projects in poorer areas. Only after three or more years did it become clear that most of these projects would not be sustainable, primarily due to the lack of community involvement and ownership.

By contrast, most GPG departments that were undertaking the transformation process to become more knowledge oriented showed little early success in such projects. Their efforts appeared more disorganised as they experimented with ways to involve communities and ensure ownership at the grass-roots level. Their focus on their own internal transformation usually left them slow to follow up on development projects, which inadvertently had a positive outcome regarding sustainability. Communities that were waiting on departments to follow up on initiatives had nevertheless been given a clear message that they were now empowered to be active agents in their own development. So they used the delays and waiting periods creatively, getting their own acts together, and even developing their own initiatives. And despite the delays, there was definite improvement in trust and mutual learning between the communities and the transforming departments.

By 2019 it was becoming clear that the level of transformation being attempted by the GPG could not and would not be achieved anytime soon. Those departments that appeared to have moved furthest on the path to transformation seemed most certain that they had not yet reached their goal. Indeed, some argued that the goal was not a "final fixed state of transformation", but the ability to continue to change in response both to current realities, and to a shared vision of the future. It seemed likely that there would be many more waves of transformation efforts to come.

The pockets in the GPG where sustained progress with transformation seemed to be taking place were displaying some common characteristics. They were usually less hierarchical, more interdependent, and more horizontally connected (including interdepartmental collaboration), with a pragmatic grasp of futures intelligence processes. They recognised their primary role as facilitators, rather than as implementers, and they promoted and implemented in practice transparency and increased trust, as well as working collaboratively with other government departments and all stakeholders. Another finding that was causing concern to some government employees was that the transformation process was revealing that certain long-standing processes, and even departments, were no longer necessary, since they could more efficiently and effectively be handled elsewhere.

In the private sector, the most obvious impact of the GPG's aim to create an equitable knowledge society was seen towards the end of the decade in the growth of SMMEs, both in the formal and informal economies. A flourishing sub-set of these SMMEs were delivering knowledge intensive business services (KIBS). There were two distinct types of these KIBS-oriented SMMEs: those that were helping the GPG with investigation and implementation of its policies and strategies across all sectors; and those emerging in the informal economy in poorer areas.

The government (national, provincial and local) was faced with a serious dilemma in its wish to stimulate these SMMEs, particularly in the informal sector. There were a large number of rules and regulations either inherited from the past, or imposed from the international community which stifled the development of many SMMEs. Especially for the informal sector, the government took a circumspect approach. It maintained a strong "no tolerance" approach to all forms of serious crime (although there were many heated debates regarding what constituted "serious crime", which remain unresolved in 2030). However, it practiced a "high tolerance" approach for infringements of minor rules and regulations by new SMMEs until they were on a secure financial footing.

The government encountered two areas of strong resistance from within South Africa to their "high tolerance" approach. One was in the area of environmental rules and regulations, which many argued needed to be strengthened rather than weakened. The government quickly "ring fenced" all aspects of the environment as a "no tolerance" area. The second was from large companies (especially multinationals) who felt the government was allowing SMMEs to become too successful before enforcing the rules and regulations. This remains a grey area in 2030, to the benefit of no-one other than South Africa's legal profession.

In 2016 Gauteng suffered a financial crisis. Many South African banks had strong ties to banks overseas, for example Barclays had a strong interest in ABSA.

Through a series of questionable actions and unforeseen circumstances (which brought memories of the financial crash of 2008) Barclays ended up in a precarious position and had to be propped up by the British government. This sent shockwaves through South Africa's banking industry in general, and through ABSA in particular. What aggravated the situation was that certain sections of ABSA had been operating outside of company guidelines, and overextended the bank by lending money to people who were unable to afford the loans. ABSA was liable, depositors withdrew their savings in droves, and ABSA started to topple. The situation was rescued by a buy-out by a Dubai-based bank, who in short order moved top management control of ABSA to Dubai. In addition, they moved ABSA's listing to the Dubai International Financial Exchange (DIFX).

Although unwelcome, this crisis did not come as a complete surprise to the GPG. For several years they had been investigating the opportunities for providing (micro-) financial support to emerging SMMEs in the informal sector. Research during this investigation had sensitised the GPG to several vulnerabilities among Gauteng's financial institutions. In response, the GPG held a series of high-level workshops in 2014-15 involving global experts and stakeholders to discuss Africa's financial needs and stability. During this process, a strong relationship developed between the GPG and Dubai, since it became clear that the Emirate shared South Africa's ambition to become a mainstay of Africa's financial capacity in what was hoped to be a much more successful African future. The 2016 crash created the opportunity to accelerate the development of this relationship, since Dubai recognised the experience that ABSA, and the JSE had gained of working in Africa.

ABSA's move from the JSE had a knock-on effect a few months later when a few other financial services companies, attracted by the benefits that ABSA was enjoying, also moved to the DIFX. However, the collaborative relationship between Dubai and the GPG prevented the trickle from becoming a flood, and by the end of 2018 the number of companies listed on the JSE had dropped by only 6%.

Gauteng's economic growth during this decade was modest, especially in comparison with the previous decade, and in the two years following the financial crisis, there was recession. Although there was a constant influx of people to the province, the rate of population growth was much lower than what had been experienced during the first decade of the century. Even so, Gauteng's infrastructure showed signs of strain under the increasing population, with the water supply for the province being a particular point of concern. The GPG implemented a range of measures to discourage population increase. In addition, the problem of water leakage and loss in the distribution and storage system was tackled with vigour. Apart from two periods of severe water shortage, water restrictions proved to be unnecessary during this decade.

By the end of 2019 there were definite signs of economic recovery, and the collaboration that had commenced with Dubai became one of the province's strengths.

The years 2021 to 2030

At the dawn of the twenties there was evidence that the strategy for building a knowledge society was just starting to work. This evidence was provided mainly by bottom-up initiatives that were owned and driven by local communities, with strong support form the GPG. At the same time, it was easy to point to unproductive, and even chaotic areas where little movement, let alone progress, was evident. The national Government was becoming increasingly frustrated at the slow progress and wanted the GPG to act in a more decisive and top-down fashion. In response, the GPG arranged an international conference on the knowledge society, at which they presented what had been achieved and not achieved, and the issues and challenges that were being dealt with. As might be expected, there was much that could be criticised, and several global experts did not hold their fire. But the surprising consensus of the global participants was one of being impressed with what had been achieved. This stamp of approval was significant enough to satisfy those in national Government who had been critical of the GPG.

In 2021 the GPG ramped up to a higher level their support for informal learning opportunities. In the previous decade they had spent much energy in trying to reform the education system in the province, and make it more suited to a knowledge society, but results had been poor. So they now started encouraging informal learning through SMMEs and community organisations. People had the opportunity to learn what they wanted, when they wanted, and at the pace that they wanted. A range of multimedia-based ICT learning tools were developed and used, but there was also an emphasis on learners having access to relevant human expertise. In other words, learning was aided through both interaction with technology and with mentors.

Also in this decade, the focus on triple helix collaboration (between tertiary educational institutions, and the public and private sectors) began to show real fruit. Levels of trust between people in these sectors had grown enormously. Local researchers were being used increasingly in advisory roles, while research agendas were more and more focused on problems in industry. It was true, however, that most of the collaboration by the private sector was driven by

SMMEs, not big business (the latter were more comfortable with an organised, top-down approach, rather than free-for-all networking and collaboration).

An ever-present threat to the province was the possibility of running out of water. Measures taken in the previous decade had helped significantly to reduce the demand for water, but as the population increased, so did the need for water. The GPG followed a double-pronged strategy to address this issue. First, they stimulated further reductions in water usage through a range of mechanisms, from variable water tariffs, to promoting the development and deployment of dry technologies to replace water based technologies (e.g. dry sanitation). Second, they lobbied the national Government to act to reduce the influx of people from other provinces, through for example awareness campaigns. These measures have certainly helped, but Gauteng is by no means out of the woods, and probably never will be. In fact, the effects of global climate change seem to be a reduction in precipitation in the areas that supply Gauteng with water.

By the end of the twenties the success of the knowledge society strategy appeared to be assured. There was a proliferation of small businesses in the province (400% increase since 2010), most of whom were KIBS-oriented. Only three townships in the province were now classified as having more than 40% of their inhabitants below the poverty line. A very significant indicator of success was the fact that, of the people in Gauteng's peri-urban areas who were entering the tertiary education system, 73% were doing so on the basis of informal qualifications rather than through qualifications gained within the formal education system, and the percentage was increasing.

Another significant development, seen by many but not all as positive, was a blurring in the roles of the provincial and local levels of government. Over the years there had been increasing collaboration between these two levels in the province, and the question as to why both levels were necessary or desirable became increasingly asked. There were those who felt threatened by the question, because of the perceived threat to their jobs, but consensus was building amongst the community organisations and the population as a whole that the province would be better served by having only one layer of government below the national level. By 2030 the local governments in Gauteng were actively lobbying the national Government for a change to be made in the Constitution to allow the option of Gauteng's provincial and local levels of government to be integrated. The GPG was not as enthusiastic on the matter, but were saying that the whole issue needed to be investigated. There was of course opposition to the principle from other provinces, but the arguments being offered by Johannesburg, Ekhuruleni and Tshwane for integration being necessary in the case of Gauteng were becoming increasingly difficult to counter.