PROCEEDINGS REPORT

TECHNOLOGICAL INNOVATIONS FOR A LOW CARBON SOCIETY CONFERENCE

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FOREWORD

This symposium on Technological Innovations for a Low Carbon Society was hosted jointly in October 2012 by the national science academies of South Africa and Germany, ASSAf and Leopoldina respectively, as one of many initiatives of the German-South Africa Year of Science. It presented an opportunity to highlight partnerships between Germany and South Africa and to intensify cooperation between the two academies in an area of strategic importance to both countries.

The challenge of finding sustainable, low carbon solutions to a global problem, such as climate change, is pertinent for both Germany and South Africa, notwithstanding their different developmental stages and different socio-economic and political contexts. Themes addressed included the energy-water-food nexus for resilient societies; low cost, low carbon innovations for poverty alleviation; smart city innovations; new and emerging technologies, such as carbon capture and storage and *The Beauti-fuel Project* aimed at converting biomass to liquid fuel, and the potential for solar power in South Africa.

It was noted that South Africa can be viewed as a 'playground' for finding innovative low carbon solutions due to the untapped wind and solar energy resources and the excellent research capability.

Some of the key messages for South African policymakers that emerged were:

- Technological innovation has to be complemented by building generic scientific and technological capabilities. Human capital development is a key underpinning factor.
- Technological aspects emerged as not necessarily the major factors to consider in the transition to a low carbon society in South Africa. A call was made to focus more on social developmental and human behavioural aspects.
- The job creation potential of low carbon technologies needs to be scrutinised and low carbon technologies that support development and alleviate poverty need to be encouraged.
- It was also recognised that there is a need for transition management and that much work is required in terms of setting regulations and standards, accessing international financing opportunities and exploring innovative business models.
- The importance of links between government and the private sector were stressed and it was noted that public private partnerships should be developed to include all stakeholders in society.
- The transition to a low carbon economy should not be the sole responsibility of government. Civil society and the private sector have an equally important role to play, although government has an enabling role.

- It is necessary for a more integrated and coherent government-wide approach to the low carbon economy and technological innovation, including the identification of the priorities in this regard. Policy incoherence, institutional challenges and the lack of prioritisation at a national level were noted as problems.
- In the energy sector, there is a danger of the agenda being driven by interest groups favouring one particular energy source over another and a failure to recognise that all resources have a role to play in the energy future of the country. A 'symphony' of renewables, all contributing to energy security, the creation of jobs and economic development, was favoured.
- It was emphasised that carbon should not be the dominant factor in decisions regarding energy options for South Africa. Current policies refer to the need to de-carbonise energy supply, the cost of different energy sources and the need for energy security, but fail to recognise water as a major constraint on energy supply choices. The water footprint of some of the alternative energy technologies, including some biofuels, can be significant.
- According to the Integrated Resource Plan for Electricity 2010, government intends to reduce dependence on coal as an energy resource from almost 100% to 56% between 2010 and 2030. The continued reliance on coal into the future underlines the need to find clean coal technologies. The use of poor-quality coal in South Africa poses challenges in terms of improving combustion efficiency.
- In order to improve quality of life, it is necessary to increase access to energy. However, efforts to increase access to energy will have to take cognisance of the worldwide pressure to reduce CO_2 emissions while supplying affordable energy.
- Climate change policies and energy policies need to take into account the energy-food-water nexus.
- The choice of technology for South Africa should not be an academic choice, but should be a choice taken together with an industrial supplier, perhaps an international supplier initially. It is important to choose the appropriate industrial partner for technology that is already in the market and where financing is possible, and try to develop further.
- Renewable energy in South African needs a champion in government to nurture the cause and ensure that aspects, such as localised requirements and sharing of knowledge, are taken into account in the procurement processes, and that the country derives maximum benefit from new projects.
- Energy efficiency is the first and the cheapest step to a low carbon future.

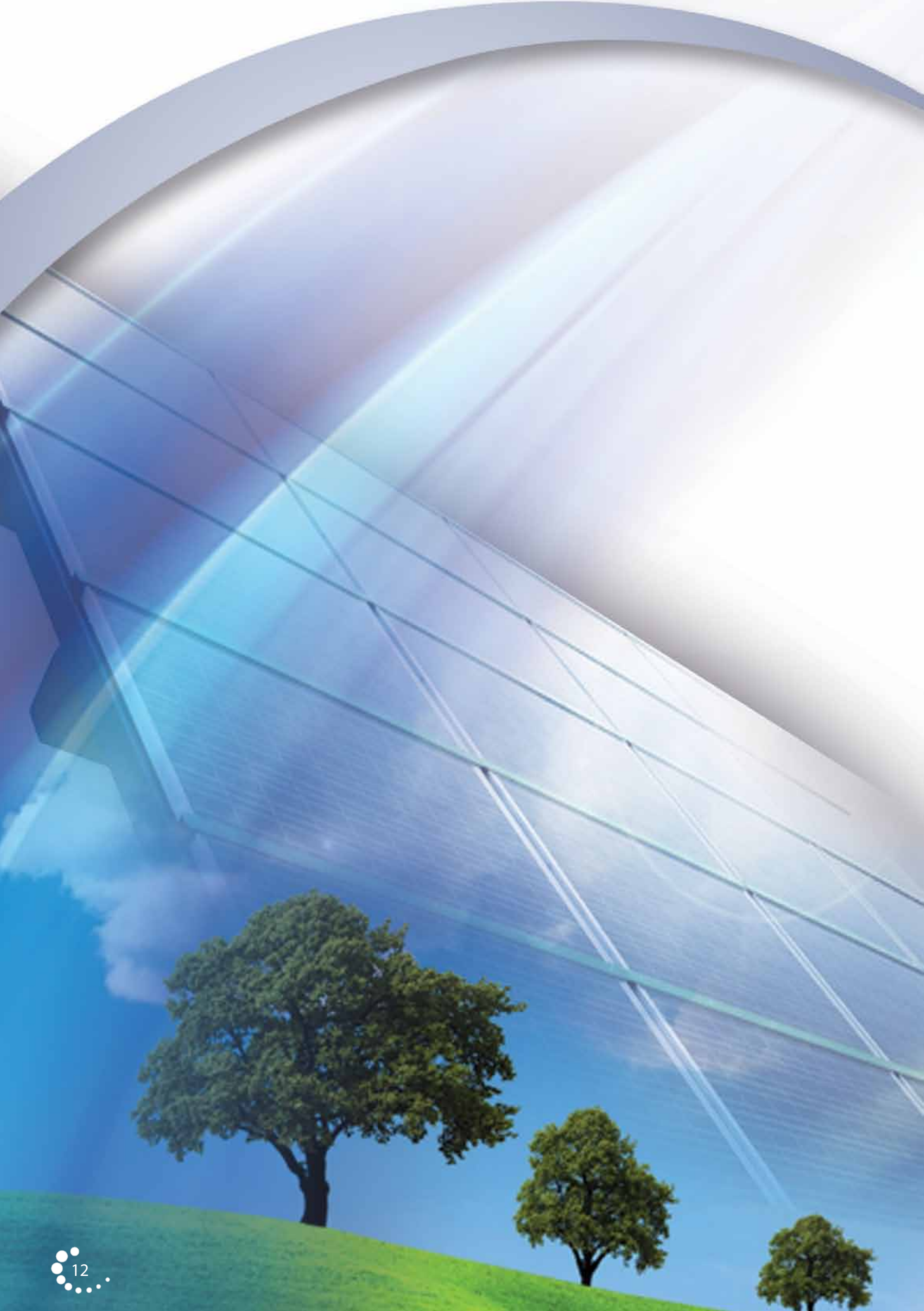
ACRONYMS

ASADI	African Science Academy Development Initiative
a-Si	Amorphous silicone
ASSAf	Academy of Science of South Africa
BMBF	Federal Ministry of Education and Research, Germany
C:B	Cost-to-benefit (ratio)
CBP	Consolidated Bio-processing
CCS	Carbon capture and storage
CCT	Clean coal technology
CDP	Carbon Disclosure Project
CdTe	Cadmium telluride
CIGS	Copper indium gallium selenide
CO_2	Carbon dioxide
CoER	Chair of Energy Research
COMPS	Centre for Material and Process Synthesis
COP17	Conference of the Parties (to UNFCCC)
CPUT	Cape Peninsula University of Technology
CRSES	Centre for Renewable and Sustainable Energy Studies
c-Si	Crystalline silicon
CSIR	Council for Scientific and Industrial Research
CSP	Concentrated solar power
DC	Direct current
DEA	Department of Environmental Affairs
DHET	Department of Higher Education and Training
DLR	German Aerospace Centre
DoE	Department of Energy
DRC	Democratic Republic of Congo
DST	Department of Science and Technology
EASAC	European Academies Science Advisory Council

EPI	Environmental Performance Index
EU	European Union
FET	Further education and training
FT	Fischer-Tropsch
GDP	Gross domestic product
GHG	Greenhouse gas
GIZ	German Development Corporation
GSB	Global Sustainable Bioenergy Project
GW	Gigawatt
HEI	Higher education institution
HVDC	High-voltage direct current
ICT	Information and communication technology
IDC	Industrial Development Corporation
IEA	International Energy Agency
IMF	International Monetary Fund
IP	Intellectual property
IPR	Intellectual property rights
IRP 2010	Integrated Resource Plan 2010
kg	Kilogramme
kW	Kilowatt
kW/m	Kilowatts per metre
kWh	Kilowatt hour
LEC	Levelised electricity cost
LaDePa	Latrine Dehydration and Pasteurisation
MDGs	Millennium Development Goals
MIT	Massachusetts Institute of Technology
MW	Megawatt
MWh	Megawatt hour

NASA	National Aeronautics and Space Administration (USA)
NBI	National Business Initiative
NDP	National Development Plan
Necsa	South African Nuclear Energy Corporation
NEPAD	New Partnership for Africa's Development
NGOs	Non-government organisations
NMMU	Nelson Mandela Metropolitan University
NPC	National Planning Commission
NRF	National Research Foundation
OECD	Organisation for Economic Cooperation and Development
PE2	Puerto Errado
PPPs	Private public partnerships
PV	Photovoltaics
R&D	Research and development
RDP	Reconstruction and Development Programme
REI4P	Renewable Energy Independent Power Producers Procurement Programme
S&T	Science and technology
SACCCS	South African Centre for Carbon Capture and Storage
SADC	Southern African Development Community
SANEDI	South African National Energy Development Institute
SAWETC	South African Wind Energy Training Centre
SHCC	Solar hybrid combined cycle
SMMEs	Small, medium and micro enterprises
STERG	Solar Thermal Energy Research Group
SU	Stellenbosch University
TIA	Technology Innovation Agency
UCT	University of Cape Town
UDDT	Urine diverting dehydrating toilets

UJ	University of Johannesburg
UKZN	University of KwaZulu-Natal
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UP	University of Pretoria
US	United States
USA	United States of America
USPTO	United States Patent and Trademark Office
VIP	Ventilated improved pit
W	Watt
WBCSD	World Business Council on Sustainable Development
Wits	University of the Witwatersrand
WRC	Water Research Commission
WWF	World Wildlife Fund



DAY 1

OPENING SESSION

FACILITATOR: DR TAKALANI RAMBAU, ACADEMY OF SCIENCE OF SOUTH AFRICA, ASSAf

Welcome, Prof Roseanne Diab, ASSAf

Prof Roseanne Diab, Executive Officer of ASSAf, welcomed all the delegates to the conference, noting that it was a collaborative effort between the national science academies of South Africa and Germany, ASSAf and Leopoldina, respectively. She thanked the participants from Germany who would share in this event.

2012 was the German-South Africa Year of Science, presenting an opportunity to undertake a number of initiatives that would highlight partnerships between Germany and South Africa. The idea for this joint conference was incubated on the shores of Lake Victoria during a meeting of African Science Academies in November 2011, when representatives from Leopoldina and ASSAf had an opportunity to plan the nature and focus of their proposed collaboration.

Prof Diab acknowledged the efforts of those who had compiled the programme for the conference and thanked the sponsors: the National Research Foundation (NRF), the Department of Science and Technology (DST), Leopoldina and particularly Nedbank for the use of the auditorium at their Menlyn Maine branch in Pretoria and for providing catering on both days of the conference. A report would be produced of the proceedings of this conference.

Opening Remarks, Mr Charl de Kock, Head of Group Property Services, Nedbank

Mr De Kock welcomed the delegates to the Nedbank Centre in Menlyn Maine, a Green Star-rated building, and expressed Nedbank's commitment to a low carbon society and its association with ASSAf in hosting this conference.

A video presentation was made on Nedbank's journey towards sustainability over the years, and the bank's contribution to assisting South Africa to reach its carbon emission reduction targets.

Opening Remarks, Mr Markus Bollmohr, German Embassy in South Africa

Mr Bollmohr acknowledged the level of scientific expertise among the delegates from Germany and South Africa and thanked ASSAf and Leopoldina for having organised the conference.

Pertinent questions would be discussed, such as how to couple economic growth with economic activity that is not damaging to the environment, how to create greener cities in times of increasing urbanisation and how technology can be used to alleviate poverty – not at the cost of the quality of life of future generations. The energy-water-food nexus, which forms a significant part of the conference deliberations, is a new notion that is strongly supported by the German government.

Germany places emphasis on bilateral and multilateral cooperation in the research sector and has signed scientific and technological cooperation agreements with more than 40 countries, including South Africa. This year marks a new phase in terms of bilateral relations with South Africa. The German-South Africa Year of Science was launched in April 2012, providing a platform to showcase the excellent and close partnerships that have existed for many years between institutions of the respective countries.

Germany views South Africa as a strategic partner in research, science, technology and beyond, and Germany's key objective for the joint Year of Science is to enhance and intensify cooperation with South Africa in specific areas of particular strategic interest and relevance to both countries: astronomy, bio-economics, humanities and social sciences, innovation in the health industry, climate change, urbanisation, and human capital development. The latter is a cross-cutting theme and forms an integral part of most joint activities. These areas relate to challenges that go beyond national borders and capabilities, and require international cooperation, which is the key to finding sustainable solutions to global challenges.

South Africa can be viewed as somewhat of a 'playground' for finding innovative low carbon solutions to the challenges related to climate change. There are different climatic, social and economic conditions than in most developed countries, such as the abundance of coal and its disproportionately high role in South Africa's energy mix, resulting in the necessity to mitigate the country's contribution to global climate change; excellent conditions for finding alternative ways to deal with entrenched challenges through a vast untapped potential for wind and solar energy, and the excellent research landscape and wealth of knowledge.

The South African government has committed to climate protection and the transition to a green economy, and has formulated ambitious goals in terms of putting in place policy and financial investments to support these goals. Germany's cooperation with South Africa contributes to the creation of an environment that fosters the technological innovation necessary to ensure a successful transition to a green economy. Some of the collaborative programmes between the two countries are:

- Supporting the Department of Environmental Affairs (DEA) in drafting a National Climate Change Response Strategy.
- Providing technical support to the Department of Energy in rolling out the Renewable Energy Independent Power Producers Procurement Programme (REI4P).

- Providing concessionary funds to Eskom for building one of the largest concentrated solar power (CSP) tower plants in the world.
- Developing a Green Skills Programme together with the Technology Innovation Agency (TIA) and other partners.
- Supporting research towards innovative economic and environmental management solutions for an integrated water management concept for the greater Olifants River catchment area.
- EnerKey, a programme that focuses on managing sustainable energy solutions for megacities following economic, environmental and social objectives, implemented jointly by the Universities of Stuttgart and Johannesburg.

This conference is unique in that it brings together an outstanding mix of both German and South African experts, not only from academia but also from non-government organisations (NGOs) and the private sector, providing a competent scientific exchange that is deeply rooted in the practical reality of the current challenges. Mr Bollmohr thanked Nedbank for hosting the conference in their ground-breaking, Green Star-rated building, and wished the delegates a fruitful and enriching exchange.

Keynote Address: Science and Technology Requirements and Responses for a Low Carbon Society, Mr Imraan Patel, Deputy Director-General, DST

Mr Patel highlighted the growing role played by ASSAf in terms of drawing on and galvanising the brains' trust that exists in South Africa to assist the DST and other government departments in addressing key challenges that face the country. The focus of his presentation was on the science and technology (S&T) requirements and responses to a low carbon society, areas of the programme that require more attention as part of the broader challenge from a S&T perspective, and achieving the targets for the reduction of carbon emissions.

The low carbon economy is knowledge and technology intensive. The debate around a low carbon economy is dominated by a particular environmental challenge relating to carbon and energy, while solutions need to focus on a variety of challenges, such as those relating to water security, biodiversity conservation and management, as well as sustainability of a low carbon economy. Fundamental changes to the way we produce, consume, work and live, and a deeper understanding of human and social behaviour and dynamics are essential considerations in working towards a low carbon economy.

The DST's focus is on the S&T requirements and challenges in the long-term transition towards a low carbon economy. It is difficult to focus solely on technological innovations without transition management to deal with issues of funding, finances, regulation and standards, and it is important for the DST to begin to invest in understanding and supporting transition management, technological innovation and global cooperation in S&T. The scale and speed at which transition towards a low carbon economy must take place is unprecedented in human history. This conference is therefore of importance to the DST, as it is linked to the German-South African Year of Science and to a broader requirement for South Africa to partner with other countries in terms of developments towards a low carbon economy.

DST is currently involved in:
- Supporting research development in innovation where there is market failure, such as low cost energy solutions for rural communities, incorporated into the environment and working closely with the communities.
- The Green Information and Communication Technology (ICT) project on the role of ICTs in supporting sustainable consumption and reduction of carbon emissions. The DST has completed an ICT road map and is working with IBM on the smart cities project. ICTs have a significant role in the green economy in terms of decreasing the cost of processing, acquiring and processing information and the management of infrastructure, as well as allowing for changes in human behaviour and providing green skills.

South Africa remains an extractive economy where mining plays a significant role. The National Development Plan (NDP) identifies the need to improve energy efficiency of mining and minerals beneficiation by at least 15% by 2030, with a focus on beneficiation within South Africa. This issue has been highlighted as an area of cooperation with the European Union (EU) in the context of the South Africa-EU programme, where South Africa has been identified as having competitive advantages. This is another area requiring more focus in the debate about a low carbon economy.

In terms of the S&T response, technological innovation has to be complemented by building generic scientific and technological capabilities, such as testing facilities for wind turbines, customised for the local environment. Much more work is required in terms of setting standards and building general scientific and technological support services for a green economy.

The South African government has made a long-term commitment to explore, not only technological innovation, but also innovative business models and new approaches with an emphasis on using projects to inform policy. The Green Fund is an attempt by government to set aside funding that allows for innovative experimentation to provide lessons and solutions, and requires a stronger partnership with the private sector to finance, upscale and grow projects. International financing instruments should be leveraged to support South Africa’s efforts towards a green economy and could be used to provide the ability to share technological innovations and to try large scale demonstrators.

The focus of this conference should not only be on technological innovations for a low carbon society, but should embrace a broader view of innovation to support the transition to a low carbon society.

Keynote Address: Green Technologies for Job Creation and Economic Development – Challenges and Opportunities, Ms Joanne Yawitch, Chief Executive Officer: National Business Initiative, NBI

Ms Yawitch presented the perspective of a lay person within the low carbon context, reflected on some of the issues relevant to the private sector and the emergent private sector responses. In the South African context, the low carbon economy should be linked to the green economy because it concerns the power of leveraging and sustainable development beyond the notion of low carbon to a more comprehensive approach involving systemic linkages.

The economic and environmental challenges facing society globally are significant, rapidly increasing, yet difficult to comprehend fully. Nevertheless, it is evident that very little will change for millions of people in the world. This disjuncture has to be taken into account by global technological innovations. Looking towards 2050, when the planet will be inhabited by 9 billion people, challenges are about ensuring ecological integrity, access to food, water, health services, employment and social services, combined with the challenges of the rapid pace of environmental changes. It has become necessary to rethink the governance, policy, institutional approach to technology and to reconsider business models and their relationship to government and broader society.

The role of technology, new technologies and their transformative potential is uncertain. The deeper question concerns the approach to technology, the efficiency of deployment of existing technologies and the integration with a different approach to the use of technology, technology dissemination and deployment into strategy across the board. South Africa has bought into the notion of low carbon technologies as those that deal with renewables, recycling and cleaner production processes, but equally important is the notion of existing technologies deployed in more thoughtful, lower impact ways for low carbon and green purposes. There are numerous examples of this type of innovation in the private sector.

In terms of the argument about the ecological base of the planet and the limits to growth and the exponential rate of growth of the world's population and the need for another planet, there is also social vulnerability, unsustainability of the world economies, as well as demographic challenges emerging in developed economies. Underpinning green technologies, their use and their relationship to economic growth is an understanding of the necessity to change the paradigm of growth.

The developed, first world patterns of growth need to change, while developing nations need to improve human development indices without increasing the environmental impact. Decoupling particular forms of development from growth is an important part of the growth paradigm. The current business models of the private sector do not provide for the paradigm change.

On the international front, although the Rio+20 conference showed little achievement at a governmental level, engagements between civil society and the private sector saw the beginnings of a move towards the collaborative development of new business models and an understanding that the solutions for the future will come from an integrated and multi-stakeholder process. Progressive business internationally viewed itself as having to take a leadership role in terms of sustainability rather than following governments. There has been a different set of understandings of technology in the context of the limits to growth, one of which was to use new technologies that provide technological solutions to problems.

However, a South African challenge is to find technologies that reduce consumption while extending access, supporting development and addressing the needs of the poor, which poses the following set of challenges:

- Access to technology and intellectual property (IP). Technology solutions are often inaccessible and unaffordable. The resolution of this issue is crucial for the rollout and wide-scale use of low carbon technologies. While the IP regime should be protected, it should not prevent access to technology.
- Short-term focus linked to a lack of awareness and skills, particularly at a leadership level. Although low carbon technologies might make sense into the future, the measurement systems within the particular contexts are short term. This is particularly relevant to South Africa where it is necessary to balance short-term returns with long-term goals and allow for innovation. This issue should be argued at a leadership level, particularly in South Africa, and within business across the world.
- Job creation potential of low carbon technologies. Increasingly extensive literature asserts either huge or no job creation potential for low carbon technologies. A nuanced debate and more modest expectations are necessary. The argument against low carbon technology development in the South African context is based on job losses that will accrue from those currently employed in energy-intensive industries. The proponents of low carbon technologies have been forced to elaborate on their job creation potential. The benefits of low carbon economy interventions should be argued in their own terms, and the issue of job creation should be argued in terms of the timeframes. There is no national plan identifying the investments that would leverage the maximum set of benefits of low carbon and green economy interventions linked to technology.
- The neglect of environmentally and socially driven externalities, leading to radical increases to energy prices in South Africa. If R300 billion is to be spent over the coming years to deal with the deficits in terms of water infrastructure and maintenance of infrastructure, water prices will also increase. In addition, increased food prices, driven by factors that are climate-linked, affect consumers. Business models and production processes that are less dependent on environmental inputs are therefore necessary, with technology playing a key role. The food-water-energy nexus should be viewed from an economic perspective in order to find the appropriate response.

There is an increasing recognition in the private sector that those who do not rethink their business strategies and models and who do not use current and future technology to the optimum get left behind. While considerable thought should be given to risk, technological innovation also creates opportunities for companies. International companies that have accepted change are the globalised powers of the future. The Carbon Disclosure Project (CDP) in South Africa, run by the National Business Initiative (NBI), has inspired changes in production processes in mining and other companies as they began to understand and manage carbon emissions, resulting in significant savings and greater efficiency in their operations. There are also significant potential opportunities for technological innovation in biotechnology and the bioeconomy.

Considerable progress has been made in South Africa in terms of technological innovations, as well as policy for a low carbon society. The work done by the DST over the last five to ten years has elevated the status and the understanding of S&T and research and development (R&D) as crucial factors in this country and more is being spent more usefully. The recommendations of the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa are important, as are the proper incentive structures to support R&D and building public private partnerships (PPPs). However, a more integrated and coherent government-wide approach to the low carbon economy and technological innovation, including the identification of the priorities in this regard, are essential in order to progress further. Financial issues and implementation challenges should be resolved, policy incoherence and institutional challenges should be addressed, and PPPs should be pursued and developed to include all stakeholders in society.

In order to realise the potential of technological innovations for a low carbon society, resource efficiency, renewables and path-breaking technology, it is essential to address ‘the pain of transition’, describing the move from ‘dirty’ to ‘clean’ technology and the support required by industries to provide clean, green solutions.

Facilitated Group Discussion, Panel: Mr Patel and Ms Yawitch

Questions and Comments:
Thomas Roos: Both keynote speakers expressed what South Africa is trying to do to address the transition to a green economy, and captured the difference between the requirements from private *versus* public institutions. The Council for Scientific and Industrial Research (CSIR) has been considering how to frame a response within a limited budget and the different roles and priorities of government departments in achieving a low carbon economy. A collective response is necessary in order to move forward.

Harold Annegarn: Points raised by the keynote speakers were pertinent and relevant, particularly in terms of the emphasis on community engagement in energy solutions. However, there is confusion, particularly in academia, as energy research was neglected for four years while the DST and the Department of Energy (DoE) had separate areas of responsibility for energy research. The DST is now expressing worthy aims of involvement in the energy carbon emission reduction debate. How and when will the departments collaborate in terms of R&D and where will research support and funding be available?

Emile van Zyl: Mr Patel referred to the Green Fund and other initiatives of the DST. The challenge is that South Africa has pockets of excellence where proof of principle can be done. However, the agencies, such as TIA, do not operate in the chasm between proof of principle and commercialisation. How will it be possible to move from proof of principle to demonstrate commercialisation?

Dhesigen Naidoo: The most encouraging statement made by a speaker was that civil society and the private sector had a dialogue during the Rio +20 conference without needing to talk through government. The over-reliance in South Africa, and perhaps in other countries, on government being the necessary bonding agent and funding agency to move a societal agenda forward is as outdated as the carbon economy. Numerous partners are available to everyone, although government has a catalysing role. This forum should discuss how to organise for partnerships to be potentiated so that we can move forward.

Responses from the Panel:

Imraan Patel: The DST accepts that the overall level of investment in R&D and the innovation chasm is inadequate. This is an ongoing struggle, as people in National Treasury do not understand the long-term benefits and value of R&D. Currently half of the R&D expenditure comes from government and the other half from international sources in the private sector. It is unlikely that significant improvements will be made in the short term and private sector funding needs to be effectively unlocked and leveraged over the long term. Various ideas on this matter are being considered.

Prof Annegarn's question about energy research will be referred to the Department of Energy (DoE). The areas of energy research in which the DST is involved are clearly defined. The challenges concerning commercialisation are common to many countries around the world. There is a view that TIA is not doing as well as it is could be doing. However, the current funding provided to TIA is inadequate and does not address the scale of the challenge. Funding instruments and structures of previous entities that were integrated into TIA are being clarified. Funding that is available needs to be unlocked for R&D by working closely with the private sector. The DST is working with a number of companies in particular contexts concerning funding and is making efforts to understand the broader policy issues around these public private partnerships (PPPs).

Joanne Yawitch: In terms of Mr Naidoo's comment, both inside and outside of government there is a lack of funds to do things that are new and different, but the bigger question is how to create the conditions, the momentum and the will to allow resources to be mobilised. The lack of prioritisation at a national level is a serious problem because it leads to a proliferation of people doing hundreds of small things. In the economic context and the context of the immediate challenges of government, a small number of main priorities would create a platform and a basis rather than trying to do too many small things. However, this would require high levels of conversation, will and collaboration.

There is space for collaboration between the private sector, the public sector and civil society. In South Africa these sectors do not converse sufficiently with each other in ways that are exploratory and non-judgemental. Efforts should be made to reverse this situation and to find a common basis for cooperation.

The Green Fund is perhaps a missed opportunity as a means to provide funding for R&D and technological innovation, although its design provides for a certain level of funding to be set aside for this purpose.

INNOVATION PROCESSES IN SOUTH AFRICA: HOW IS TECHNOLOGY DRIVING GROWTH?

FACILITATOR: PROF EMILE VAN ZYL, SU

Keynote Address: Contextualising the Need for Low Carbon Technological Innovation – Climate Change Response: Leader or Luddite? Mr Peter Lukey, Chief Policy Advisor: DEA

Mr Lukey's presentation focused on challenges concerning innovation, particularly in the context of the *status quo*.

Lukey noted that South Africa's renewable energy resources far outweighed fossil fuel resources and argued that this fact alone provided a strong motivation for innovation to take place in the area of renewable energy resources.

The National Climate Change Response Policy specifically mentions innovation, including:

- The Policy's 'Overall Approach', describes a 'win-win' strategic approach that is, among others, "transformational, empowering and participatory" which involves "implementing policies and measures to address climate change at a 'scale of economy' that enables and supports the required level of innovation, sector and skills development, finance and investment flows needed to reap the full benefit of a transition to a lower carbon, efficient, job creating, equitable and competitive economy…"
- The Policy's 'Strategic Priorities', including technology research, development and innovation, which means that South Africa must "prioritise cooperation and the promotion of research, investment in and/or acquisition of adaptation, lower carbon and energy-efficient technologies, practices and processes for employment by existing or new sectors or sub-sectors".
- The Policy's 'Roles and Institutional Arrangements' sections note that the consistent implementation of the National Climate Change Response Policy requires a long-term framework for institutional coordination to, among others "coordinate research and development and promote innovation".
- The Policy's section on 'Carbon Pricing' notes that "carbon taxes can help to internalise …negative externalities and create the correct incentives to stimulate behavioural changes among producers and consumers in favour of cleaner, lower carbon technologies, promoting the uptake of energy efficiency measures and research, development and technology innovation".
- The Policy's section on 'Science and Technology Development' describes various ways in which, among others, innovation will be encouraged and supported.

With regard to the latter point, the Policy states that, "South Africa needs a robust and highly functional climate change science and technology platform to enable the development and implementation of appropriate actions to minimise the negative impacts of climate change on the economy and the people of South Africa" and, importantly, that "…with such a platform, South Africa can become a significant global player in the green economy. More specifically, South Africa should aim to be a leading supplier of climate change knowledge, technologies and services…".

Despite this strong policy direction, the question remains whether South Africa will be a leader or luddite in terms of its response to climate change.

The research project, Environmental Research and Technologies in South Africa, commissioned by the Department of Environmental Affairs (DEA) during the climate change policy development process looked at, among others, international trends in low carbon technology innovation using patent applications at the United States Patent and Trademark Office (USPTO) as its measure. Although the study showed a dramatic increase in patent innovations in the area of green and low carbon technologies from about the year 2000, South Africa's contribution to the patents in the last 20 years had been dismal, particularly considering the country's immense solar and other renewable energy resources.

This raises the question about how South Africa could possibly be a leader in its response to climate change. The major resources and the real wealth of the nation appear to be ignored, and there is a continued focus on what used to be the wealth of this country. The core of innovation is change and the resistance to change is dramatic. Four scenarios from an innovation point of view were mapped out in the research report, namely:

- An enabling implementation environment combined with a high level of climate change research, technology development and human capital. In this scenario, South Africa has a good chance to be a regional and global leader in the policy arena as well as in areas of knowledge production, capacity development and the provision of technological and other solutions.
- A favourable political environment that has a high priority placed on climate change responses but with low S&T capacity. The response to climate change will require imported knowledge and know-how, using technological solutions from abroad, implemented and managed by foreign expertise.
- An unfavourable implementation environment generates two challenging scenarios. In both cases, the country will not be able to implement effective adaptation and mitigation measures. In addition, South Africa may become an international outcast having initially demonstrated strong leadership in the context of the United Nations Framework Convention on Climate Change (UNFCCC) and then failing to replicate that leadership in the implementation of national climate change response strategies.

- Strong science in an unfavourable political environment would mean that the knowledge generated would primarily be expressed in academic publications. This knowledge would be harvested abroad and converted into valuable technologies that South Africa would then import. This would further exacerbate the innovation chasm with the outflow of both intellectual capital and hard currency.

The above scenarios illustrate the importance and the need for innovation in terms of proper and effective climate change response that is not only a response to climate change but also a response to global change in the way the world does business and the way that society lives.

In this, innovation should not only focus on the supply side, but should also concentrate on energy efficiency and general demand-side innovation.

A Systems Perspective on Low Carbon Technologies, Dr Jörg Lalk, UP

Introduction

The Free Dictionary defines a ‘system’ as a group of interacting, interrelated, or interdependent elements forming a complex whole. We tend to focus on islands of innovation and neglect integration. However, it is not simply about integration, but also about understanding the interrelationships, the interfaces and the boundaries as part of a complex system.

Peter Senge, in his well-known book, *The Fifth Discipline*, wrote that “Systems thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static ‘snapshots’...”.

In South Africa, we have become accustomed to wonderful ideas coming from Europe or North America, yet the driver behind systems thinking was developed in South Africa by General JC Smuts and described in his book, *Holism and Evolution*, published in 1927. In 1968, C West Churchman made an interesting observation that policymakers don’t know what they are doing simply because they have no adequate basis to judge the effects of their decisions and citizens have begun to suspect that the people who make the major decisions that affect our lives don’t know what they are doing. One wonders whether anything has changed in almost half a century.

Is there Value in a Systems Approach?

There have been numerous evaluations and studies done about the value of the systems approach. A number of studies by the National Aeronautics and Space Administration (NASA) and the Massachusetts Institute of Technology (MIT) provide evidence that both cost and risk increase substantially if a systems approach is not followed (Figures 1 and 2). Other studies show that the failure to use a systems approach typically leads to the majority of projects not achieving most of the technical requirements. The systems approach involves concept, design, development, productions test and operations through to disposal. It is better to spend substantial time in understanding the problem first or there will be costly changes during the lifecycle.

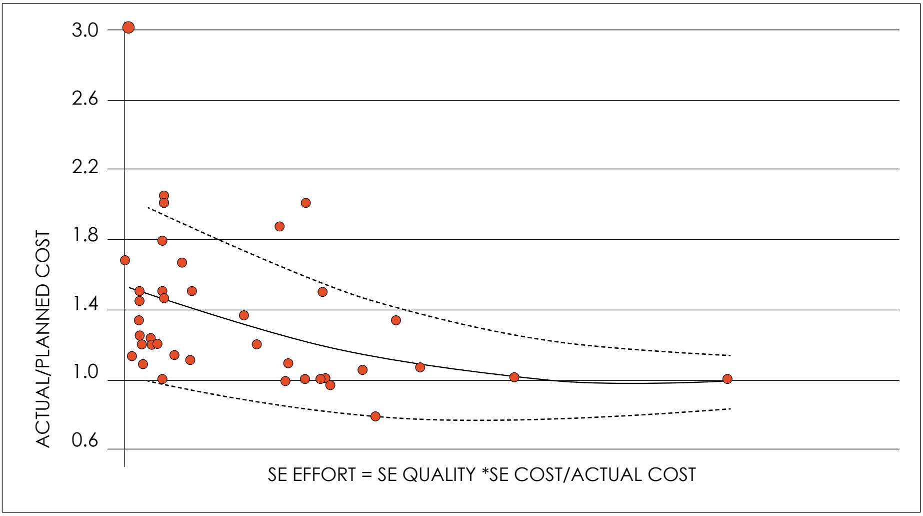


Figure 1: Diminishing cost with increasing systems engineering *(Source: NASA)*

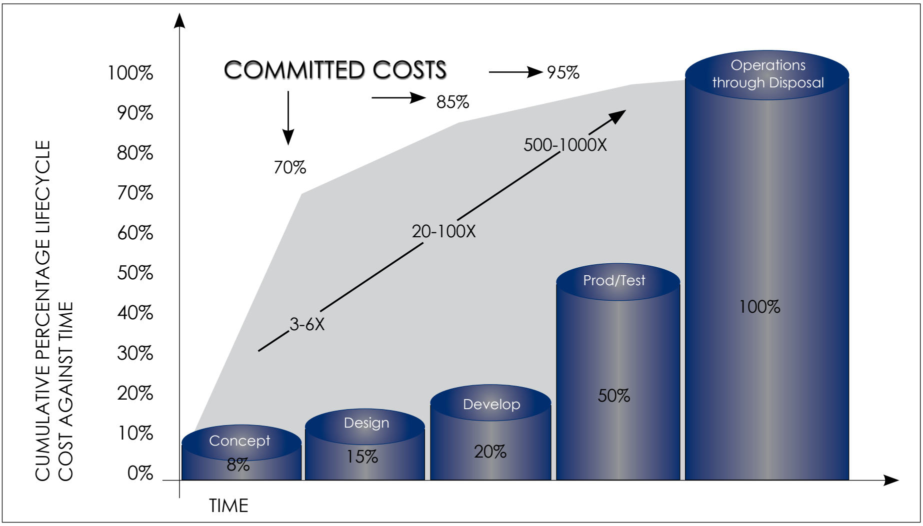


Figure 2: Impact on project cost by late changes *(Source: MIT, 2010, MITOpencourseware)*

What is Wrong with Current Thinking?

Current thinking is restricted to the small picture, driven by personal likes, dislikes and trends without understanding the bigger picture and the impact in the wider domain. In terms of energy, current thinking tends to give preference to one particular energy source over another, yet all resources have a purpose in the bigger picture.

The National Development Plan (NDP) states that "South Africa has taken major steps to formulate and implement measures to adapt to and mitigate climate change. These steps are informed by the country's commitment to reduce its emissions below a baseline of 34% by 2020 and 42% by 2025". However, the 2012 Yale Environmental Performance Index (EPI) report lists South Africa as one of the worst decliners in terms of addressing pollution control and natural resource management. This is an indication that South Africa is focusing on the 'small picture' and forgetting the 'bigger picture' (See Figure 3). A systems lifecycle tends to follow an S-curve from R&D, demonstration, pre-commercial, supported commercial to fully commercial phases. The highest capital intensity and the highest use of unskilled labour are usually found at the fully commercial phase of projects, yet projects such as the Pebble-bed Modular Reactor and Joule were cancelled in the demonstration phase and after substantial investment from government, because a commercial investor and a client could not be found (Figure 4).

It would be prudent to take the government's claims of hundreds of thousands of jobs to be created by the green economy with a large pinch of salt as this is not supported by either local experiences in other high-technology endeavours or low carbon projects elsewhere on the globe. Perhaps our decision-makers (still) suffer from 'small picture' thinking and need to progress to 'big picture' thinking?

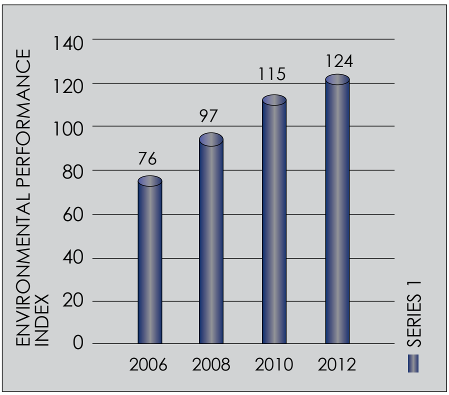


Figure 3: Change in South Africa's EPI *(Data source: Yale)*

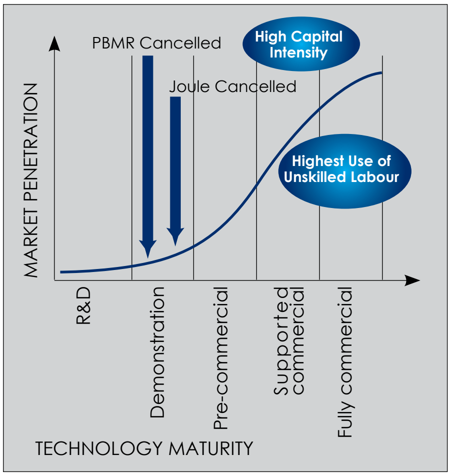


Figure 4: Cancellation trend of high-impact projects

Conclusion

The power of systems thinking comes from a focus on systemic structures, which is where the greatest leverage for problem-solving and positive change lies. A systems approach can help shed light on current problems, especially those that seem to be repetitive, by viewing them from a different perspective. A systems approach offers a range of tools for gaining deeper insight into problems.

What is Needed to Increase R&D and Innovation in Low Carbon Technology, Dr Tsakani Mthombeni, General Manager: Energy, TIA

The Organisation for Economic Cooperation and Development's (OECD) definition of cleaner technologies concerns the lifecycle of a product, from low carbon efficiency of extraction and fabrication, to recyclable and recoverable end-use.

TIA plays a specific role in R&D and innovation, all the way to commercialisation of low carbon technologies, by contributing to migration technologies across the value chain, reducing the risk of the technology. In South Africa and other countries of comparable economies, investment in R&D does not correlate with outputs in terms of innovation. Substantial effort and investment, as well as strong institutional collaboration, are required in supporting R&D to ensure that products are brought to the market.

Although South Africa is successful in funding and supporting some of the steps of the R&D and innovation value chain, success is measured by the number of patents registered instead of by the number of products and services commercialised. There is a lack of continuity in terms of research projects undertaken by universities. Too many projects are defined without any inclination towards their marketability. Discussions with various stakeholders are providing insights into the status of patents and are intended to lead to the extraction of value from existing patents in order to promote a product development environment in South Africa. TIA is conversing with partners in industry to find ways to bridge the gap between R&D and commercialisation.

The view taken of R&D is often too narrow and should be broadened towards migrating IP into other areas, particularly areas for immediate application, as a response to the needs of our society. Space must be provided for innovation to take place in a directed manner. The space in which TIA functions is an area of high risk. Venture capitalists and private equity funders indicate that they consider approximately 50 potential deals a year, of which only three or four deals are concluded and over time one or two are regarded as successful.

Key challenges are:

- Intellectual property rights (IPR): In TIA's experience of guiding innovations into the market, discussions with researchers take place once the

know-how and the uniqueness of their product has been shared in the market, diminishing the value of the product. A strategic approach is crucial when communicating with the scientific community and in finding partners to commercialise products.
- Capacity: Public research institutions now have technology transfer offices that are able to assist in the IPR strategy process to ensure that IP is exploited locally to the benefit of our society. In terms of policy and regulation, the government needs to make clear statements regarding the direction and decisions that TIA should take, for example, in terms of supporting particular sources of renewable energy. Government should relax numerous regulations to promote locally developed innovations.
- Funding: Funding requirements should relate to a specific phase in the R&D value chain and be explicit.
- Awareness: Customers, as well as end-users, should be knowledgeable about a product. Institutions, specifically government institutions, should intentionally be involved in testing and incubating new technologies in preparation for the market.
- Private sector interest in and commitment to new technology development and commercialisation: The private sector should become an active partner in investing in or testing products, particularly those that are developed for industry. A proportional mixture of blue sky research and research driven by industry needs is essential in order to drive the interest of the private sector. Over time, government and the private sector should share funding and risk related to R&D and innovation.

TIA's market position is focused throughout the value chain, from R&D to market diffusion, and the agency puts considerable effort into aligning appropriate partnerships between the NRF, science councils and higher education institutions (HEIs) and industry, often through the Industrial Development Corporation (IDC) and venture capitalists. TIA's mandate is not to fund basic research but to bridge the chasm that exists between R&D, patents and the commercialisation of products, processes and services. TIA also works with technology partners from abroad to forge partnerships with local entities.

The Energy Unit of TIA focuses holistically on the energy value chain, from resources generation, transmission, distribution to end-use, and stimulates certain areas of the global energy debate as a means to generate solutions. TIA also has a strong interest in new technologies in respect of clean coal technologies and ocean power, and is closely monitoring developments with regard to geothermal and micro-scale hydropower sources.

In order to increase R&D and innovation in low carbon technology, it will be necessary to:
- build institutional capacity particularly to generate a large IP pool for exploitation;
- communicate inventions that have been successfully commercialised, as well as failed attempts at innovation;

- support R&D, specifically in the low carbon technology arena, beyond the proof of concept stage through a strategic fund;
- understand current and future market trends, and progressive thinking in this regard;
- stimulate a vibrant venture capital industry to share the investment risk with government.

Facilitated Group Discussion, Panel: Mr Lukey, Dr Lalk and Dr Mthombeni

Questions and Comments:
Thomas Roos: The CSIR agrees with the need for systems engineering. Systems engineering saves money in the long term but to perform system engineering requires funding. The risk in the research community is that funding comes in little pockets, which often prevents researchers from completing a product to the commercialisation phase. Different areas of government must have a coherent policy and funding perspective so that the research community can deliver low carbon technologies.

Mike Muller: Mr Lukey's and Dr Mthombeni's presentations do not have any relation to the capacities that we have in South Africa. It is necessary to be more focused on what is possible to do with limited resources. Is there a systems engineering approach to identifying how many niches we can profitably focus on developing with the resources we have in South Africa?

John Hofmeyer: Dr Mthombeni showed an S-curve suggesting that innovative ideas were restricted to academia. Some of my novel electro-chemical configurations to draw electricity out of moving water have never been tried. How do I get these ideas developed through the various steps towards being funded as part of low carbon technology R&D?

Dhesigen Naidoo: There is a nuance in the patent figures shown by Mr Lukey. Although the patents over the last five years are limited, the same is not true for the last 20 years. At that time, South Arica had a reasonable track record in some areas including carbon storage. It is important to understand the nature of that trajectory, what has been lost and to find what has been lost. One of the biggest constraints to investing in renewable energy in South Africa is that we have a large amount of coal and we are a coal dependent economy. Is it useful to invest more in carbon beneficiation? If we had an alternative way to use this resource, it would be possible to remove a very large obstacle.

Responses from the Panel:
Peter Lukey: TIA has been of great benefit to me personally. For many years, DEA would receive good ideas from a variety of individuals, but because DEA was never able to test any of the ideas, even the good ideas were lost. TIA is a home for these good ideas. I agree that we cannot do everything. From a national perspective there have to be priority areas and these will increase innovation. Mr Naidoo's point about carbon beneficiation could be one such priority area.

Jörg Lalk: It should not be assumed that a systems engineering approach is expensive. It is less expensive in terms of the benefits. Looking at a systems approach for a particular project is one aspect. Another aspect is using a systems approach at the highest level of government decision-making and priority-setting processes. There are a few areas of concern in the Integrated Resource Plan (IRP) 2010. It is almost silent on the issue of energy transmission, indicating a disregard for the systems perspective. The NDP is in many aspects in direct conflict with the IRP 2010. Stakeholders are being asked to comment on a variety of strategies and national plans that are being formulated by government, yet they are not involved in the process of developing the strategies. On a small scale, the University of Pretoria (UP) initiated an energy institutional research theme, which is novel for an academic environment as it is trans and multi-disciplinary. Each government policy document referring to energy was studied as part of developing this theme, and although the policies conflicted in many areas, areas of commonality were matched with ongoing research and led to a number of focus areas. It is of utmost importance that the highest levels of government understand interrelationships between, for example, job creation, capacity building, education, energy, and water and food security.

Tsakani Mthombeni: Much work is required to harmonise the conflicting policies. It is necessary to identify and focus on several areas where there will be impact, instead of one big idea that could fail because the market can shift significantly. This is a role of bodies such as the National Planning Commission (NPC). In terms of Mr Naidoo's comment on coal, we should be building competencies that can look at value-addition to coal as a resource, combustion issues and emissions control. This is an opportunity that can be driven by the NPC. TIA has found that innovative ideas are not only coming from universities, but also from small, medium and micro enterprises (SMMEs). There is a need for those with capacity to do research to be in contact with business.

Energy-Water-Food Nexus for Resilient Societies, Facilitator: Mr Dhesigen Naidoo, WRC

Managing the Nexus for a Low Carbon Future, Prof Mike Muller, NPC

Scientific cooperation should explicitly seek mutual benefit between the parties cooperating, recognise their conflicts of interest and identify and narrow the areas of uncertainty. The history of cooperation between South Africa and Germany includes enriching uranium, which Germany required in order to break the stranglehold of various other countries on the fuel market and South Africa required in order to build nuclear weapons in the 1960s. Both achieved their goals and subsequently abandoned them, highlighting the necessity to carefully choose goals and have clear reasons for cooperation.

In many senses, the nexus is not a new concept as the integration of water and linkages between energy, food, and water were raised at the United Nations Mar del Plata Water Conference in 1977 and in the South African Commission of Enquiry into Water Matters in 1970, which represented the best practice of that time. Globally, there was a diversion into drinking water and sanitation issues and the natural resources issues were neglected, as highlighted in the World Economic Forum of 2008. Commercial interests of several companies in managing water helped to put the nexus and the integrated nature of water back onto the agenda. Water is complex, important and needs to be on the agenda. A systems approach is required for water and its management, assisted by the nexus approach.

Water is linked to carbon and climate through a series of linkages.

- Water is essential for all development, especially in agriculture and food.
- Water can help to reduce emissions through hydropower and pumped storage of energy.
- Water is a contributor to emissions through the operation of water services systems and wetlands that are prolific generators of methane.
- The impact of low carbon strategies on water (such as biofuels through agriculture).

Water resource development and management support economies through a variable flow of rivers, as well as floods. Water management interventions aim to produce a higher reliable flow and a lower flood flow, resulting in higher productivity and more investment, benefitting both the economy and livelihoods. This was demonstrated in 2002 when South Africa, Swaziland and Mozambique signed an agreement to use water in a cooperative manner, resulting in the European Union funding a fairly large irrigation project which currently supports approximately 10 000 livelihoods. However, there are several contentious areas of cooperation, where the interests of the cooperating parties are not necessarily mutual. Germany's interests are in low carbon renewables, 'smart technologies' and competitiveness. South Africa's interests are in decent livelihoods, structural change in the economy and society, and regional development. The challenge is for these aspirations to bear fruit and to find the right boundaries of analysis through a systems approach.

In terms of regional approaches to lower carbon technologies, it is interesting to note that since doing away with nuclear and its nuclear power plants, Germany has been constrained by transmission of energy generated by wind in the north that has to be transferred to the south of the country, and has had to be supported by French nuclear and Austrian hydropower plants. It would be useful for South Africa to enhance regional cooperation in order to achieve food security and water security through expanding boundaries presenting huge potential for food production and less water stress.

The drought vulnerability of southern Africa should be addressed by developing the regions' infrastructure. A study done by the World Bank shows that the optimal development of the Zambezi River could provide electricity equivalent to five nuclear power stations and could produce 750 hectares of reliable irrigation, while simultaneously protecting the environment. Substantial gains could be made through regional cooperation and large-scale infrastructure development while balancing interests between power, irrigation and ecology, and social issues. South Africa would not require six nuclear power stations to generate energy for the country if the region cooperated in building hydropower plants. In his report on water's response to the Washington Consensus, Muller explained how the donor community imposed external preferences on the region. The outcome of donors' refusal to build dams or infrastructure in the region is the construction of either five nuclear power stations or two very large coal-fired power stations. Although there is agreement that a low carbon society is important, the lack of a coordinated systems approach results in substantial damage.

The nexus emphasises the systemic importance of water and its linkages to food and energy, people, the environment and the economy in general. The nature of the linkages varies greatly and the boundaries of analysis are critical. Although controversial, it needs to be said that German input into the Southern African Development Community (SADC) has been deeply negative, with the German Development Corporation (GIZ) Water Resources Office in Gaborone consistently undermining the SADC agenda to promote cooperation in infrastructure development, preventing appropriate regional approaches from being adopted largely because of donor partnerships that drive the content of the work done by SADC. Donor preferences have prevented the optimal use of systems. Southern Africa offers substantial water-based opportunities for food security for livelihoods and low carbon hydro-based energy, and it is necessary to find areas of cooperation where there is mutual advantage.

South Africa was wise to have not invested in the photovoltanic (PV) sector as PV factories all over the world are closing down. Serious cooperation on water management in southern Africa requires a common agenda of mutual advantage. However, it is unclear whether this reflects the German domestic political agenda, which is strongly environmental. It is necessary to think carefully and critically about the way South Africa cooperates and the areas in which it cooperates.

Integrated Energy, Water and Food Approach: Understanding the Meganexus, Prof Alan Brent, SU

Policy and decision-makers now recognise that a paradigm shift in thinking about sustainability is necessary. The impacts of low carbon technologies were previously considered in terms of the economy, environment and society – the triple-bottom line – but it is now understood that technology is embedded in the economy that forms but a part of socio-political systems, which, in turn, are embedded in the larger ecosystem. This integrated system needs to be governed as a whole.

The Polycrisis and the Meganexus

No single challenge can be considered in isolation. For example, the World Business Council for Sustainable Development (WBCSD, 2010) highlighted that climate change is integrally linked to affordable energy and fuel, material resource scarcity, water scarcity, population growth, urbanisation, wealth, food security, ecosystem decline and deforestation. Similarly, KPMG, in its report of 2012 – *Expect the Unexpected: Building Business Value in a Changing World* – refers to climate change as a 'megaforce' that directly impacts and interacts with all other challenges.

The business sector has called for water to be identified as the next big issue, after carbon and energy, since it is clear that water is needed for energy and energy is needed for water. To this end, the water risk areas of the globe by the year 2030 have been established. Several reports in the business sector now also indicate that if food systems are addressed, all other factors in the meganexus will inevitably receive attention. Exorbitant increases in food prices, particularly in the context of climate change and water scarcity, and subsequent impacts on South African livelihoods and the economy as a whole, are predicted for the next two decades.

The Challenge of Decoupling the Economy and the Transition to a Low Carbon, Resilient Economy (the Green Economy)

South Africa has a broad range of strategies, frameworks and policies in different phases of development. However, the realisation of the policies, strategies and targets implies physical, regulatory, reputational, competitive, social and litigation risk. Examples are energy efficiency requirements and standards, carbon taxes, emissions cap-and-trade systems and fuel tariffs; these are all currently being debated in South Africa and drive certain innovations. Another issue relates to the vulnerability of regions; an important factor from an investment perspective. The Climate Change Vulnerability

Atlas, indicating varying degrees of vulnerability of countries and the need to deal with challenges, could also highlight opportunities for innovators. To this end, large financial resources, such as the Green Climate Fund, are being made available for investment in low carbon technologies.

To prepare for the risks and to capitalise on the opportunities, KPMG (2012) indicates that new approaches to understand interconnectedness in a global world are required, most notably the systems and nexus approaches to address sustainability challenges, to analyse systems and technologies (Brent, 2012) in terms of the:

- Footprint Nexus: The forces driving the escalating 'footprint of mankind on the planet'.
- Erosion Nexus: The resulting changes in the natural systems on which society depends.
- Innovation Nexus: The opportunity to address sustainability challenges through innovation (Figure 5).

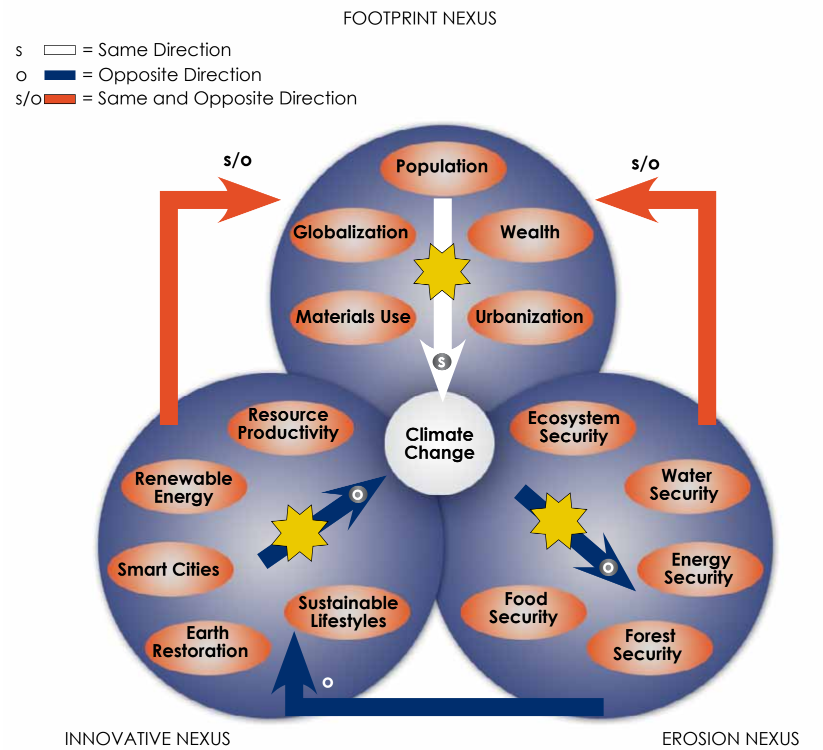


Figure 5: The systems and nexus approaches to address sustainability challenges *(Source: KPMG, 2012)*

This illustrates the interaction in the nexus around climate change as the megaforce and the flows between the different components of the nexus. Although the direct impacts of climate change are often understood, delayed effects in terms of decision-making and outcomes of decisions need to be understood better. Innovation becomes more complex as low carbon technologies do not necessarily mean that the technologies are sustainable. Innovation also needs to address the risk and readiness matrix for different business sectors, which shows that most of the sectors active in the South African economy have a high risk and low readiness to react and adapt to changes resulting from climate change.

The effective transition to a green economy involves both supply and demand interventions, driven by business, the government and public-private partnerships across all sectors (Figure 6). It will be necessary to shift demand from resource intensive to sustainable goods and services, and reduce the environmental impact of production on the supply side. However, balancing the interfaces between government, science and society remains a challenge, and requires a trialogue approach that has been proposed (Turton *et al*., 2007).

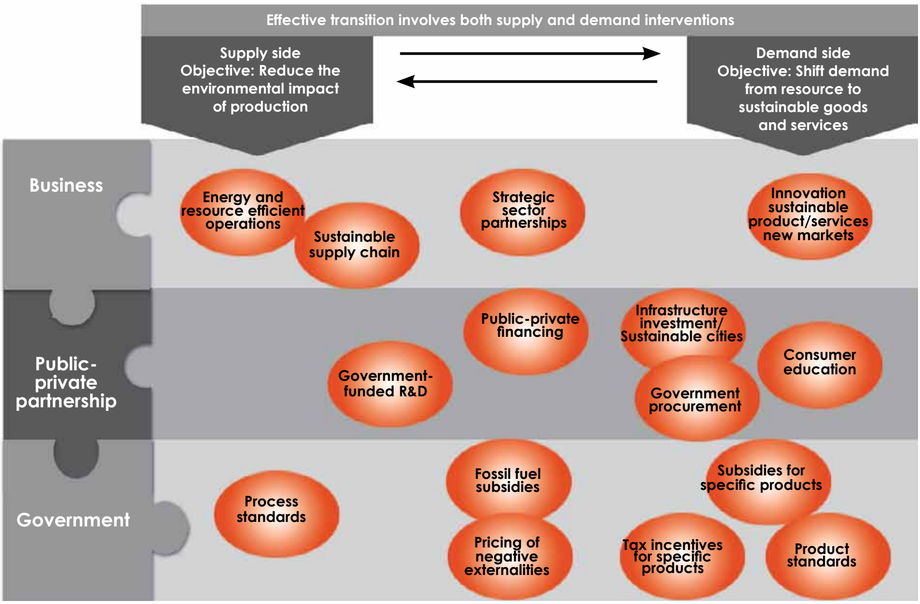


Figure 6: The interaction of business, the government and public-private partnerships across all sectors for the effective transition to a green economy *(Source: KPMG, 2012)*

Food Security in South Africa: Looking through the Food-Energy-Water Nexus Lens, Ms Manisha Gulati, Energy Economist, WWF South Africa

This presentation derives from WWF South Africa's new research initiative, together with the Water Research Commission and the National Agricultural Marketing Council. The research initiative has a two-fold objective:

- to ensure long-term resource sustainability of food, energy, water and land in South Africa;
- to enhance food security for South Africa.

This presentation deals with the latter.

The Growing Challenge of Food Security for South Africa

Largely deemed a food secure nation, producing enough staple food or having the capacity to import food if needed in order to meet the basic nutritional requirements of its population, South Africa is, by and large, able to meet the food needs of its people.

The national food self-sufficiency index illustrates that South Africa is food self-sufficient or nearly self-sufficient in almost all the major food products, with the ability to import when necessary (Du Toit *et al*., 2011). However, in recent years, the affordability and availability of food as well as nutrition, have become a growing national concern.

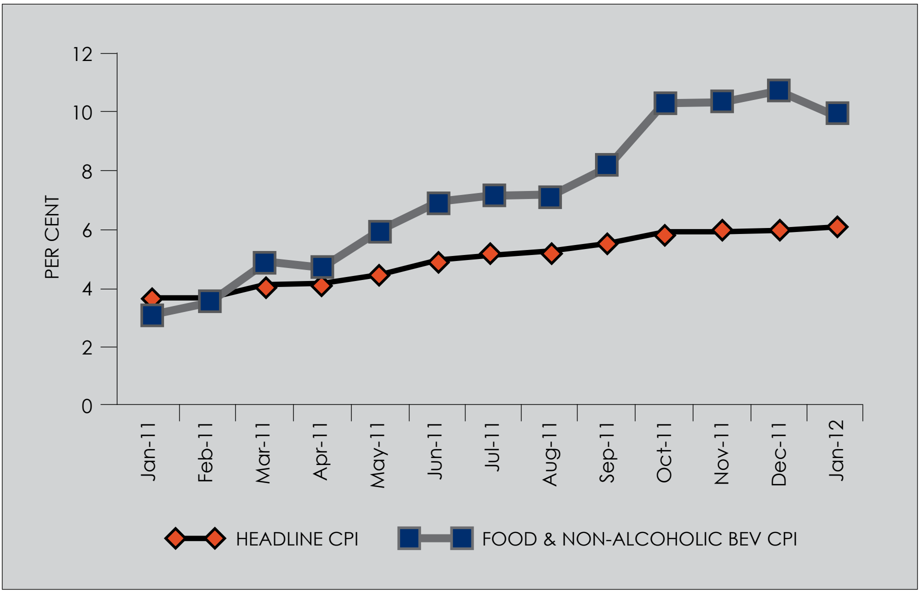


Figure 7: Food inflation in South Africa *(Source: NAMC and Stats SA)*

On the affordability front, rising food prices have become a subject of sharp focus in recent years, though the role of food prices in generating inflationary episodes in South Africa has been increasing significantly over the last two decades. In recent years, the year-on-year inflation rate for all food items rose from 1.2% in September 2010 to 10.3% in January 2012, which was well above the general inflation level (Figure 7). On the availability front, South Africa imports agricultural products such as rice, sugar and poultry, which are part of its national food basket. A review of the country's unprocessed and processed agriculture imports indicates that rice (721 415 tons), poultry (117 629 tons) and sugar (both raw and refined) (103 454 tons) are among the top seven products imported in terms of quantity (NAMC, 2010).

The challenge is further complicated by the the level of household food insecurity. Studies show that 60% of local households in South Africa are food insecure (Landman, 2004 in Du Toit, 2011 and Development Bank of Southern Africa, 2011). Additionally, the impact that rising food prices have on the poor is staggering because the poor spend more on food than the rich. Food expenditure accounts for 80% of the income of the lowest income households, as opposed to only 9% for highest income households.

Growing more food, a common response, is not an ideal option because only 13% of South Africa's land is arable (i.e. land suitable for crop production), and most of this is only marginal for crop production (i.e. it has low-production potential) (Laker, 2005). Only 3% is considered to be high-potential land (Laker, 2005). Hence the solutions lie in finding the reasons for food inflation and managing food availability, and increasing the productivity through the use of agricultural technology, noting that the technology is sometimes water and energy intensive.

Decoding the Challenges to Food Security: The Food-Energy-Water Nexus Lens

Several factors can be held responsible for the increase in food prices. These can differ from country to country and can be generic to the food value chain or specific to different food commodities. Further, the reasons can be found at either the production level or through the different stages of the food value chain. In South Africa, current research suggests that the factor common through all stages of the food value chain and across commodities is input costs (Jooste, 2012; Joubert, 2011). A deeper investigation into the role of input costs in driving food prices in South Africa emphasises the role of energy prices in driving food prices.

Energy is an important input in petroleum-based fertilisers, growing crops, raising livestock and accessing marine food resources, as well as throughout the value chain in processing, packaging, distributing, storing, preparing, serving, and disposing of food. Therefore, the stability, affordability, and assurance of energy supply have a direct bearing on food prices. Globally, discussions indicate that rising energy prices could be one of the main emerging factors behind rising food prices (Van Braun, 2011; *Food Price Watch*, 2011).

South Africa has been affected by manifold increases in energy prices over the last few years. The country imports 95% of its crude oil requirements. The prices of crude oil have been rising. Prices rocketed from the early part of 2007 to reach a peak of USD 145 per barrel in July 2008. The average price per barrel in 2008 was USD 97.55. The average price decreased by 36.65% to USD 61.80 per barrel in 2009. However, this downward trend did not continue during 2010 and the crude oil price increased from less than USD 76 a barrel in September 2010 to USD 118 in April 2012.

Rising oil prices impact the food sector in many ways. This impact can be illustrated by taking the example of fertiliser prices. Trends in oil and fertiliser prices indicate that rising oil prices in recent years have led to increases in fertiliser prices. The South African fertiliser industry is fully exposed to world market forces given the completely deregulated environment in this sector, with no import tariffs or government sponsored measures. Being a net importer of potassium and importing approximately 40% of the nitrogen requirements, South Africa's fertiliser prices are severely impacted by international oil prices, as well as shipping costs. The depreciation of the Rand against the US Dollar has exacerbated matters.

Like crude oil, electricity prices have also been rising. Electricity prices have increased by over 24% since the financial year 2007/08. The food sector has not been immune to the impacts of these increases. For example, the primary agricultural sector consumes only 3% of total electricity generated in the country and this consumption has risen at 3% per annum between 1999-2000 and 2010-2011. However, the annual electricity bill for the agriculture sector has increased by over 20% since 2009/2010 (Joubert, 2011).

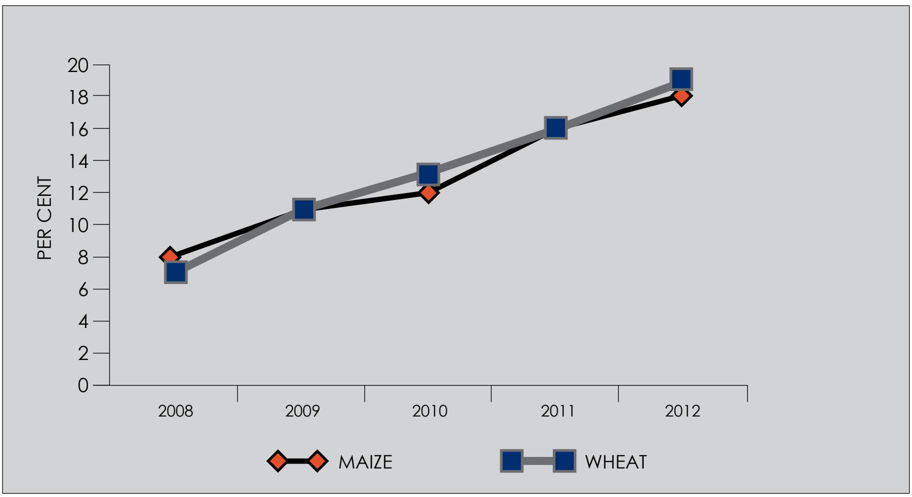


Figure 8: Share of electricity in variable costs for maize and wheat production in Northern Cape in South Africa *(Source: Joubert, 2011)*

An analysis of changes in costs at food production and processing levels confirms the above impacts. For instance, a breakdown of cost increases for food crops, such as wheat and maize, a staple food in South Africa, indicates that the cost of electricity as a percentage of other variable costs has been rising steadily over time (Figure 8). Similarly, analyses of costs involved in the production of poultry indicate that electricity costs for the production of a kilogramme poultry have gone up by 134% between 2008 and 2012. The cost increase for the livestock sector and the production of animal feed is as much as 200 -250%.

In the case of bread, a staple diet of South Africans, the price of domestic wheat as a commodity came down by about 12% between April 2011 and April 2012, yet the price of brown bread and white bread increased by about 12%. An analysis of the selected costs involved in baking one loaf of bread indicates that energy prices in the form of electricity and gas have played an important role in the price hikes.

Energy prices are expected to continue to rise in South Africa given the huge capacity addition planned to meet the growing electricity demand and the growing demand for transportation, coupled with high and volatile oil prices. Therefore, there will be continued input cost pressures in the food value chain; putting increased pressure on profits and resulting in lower returns on investment. In addition, the fact that South Africa is a coal-based economy will have serious ramifications for food security. Coal-based deposits coincide with the best agricultural land and sources of all inland rivers, and addiction to coal will impact food production because of acid mine drainage, affecting the quality and availability of water, as well as the quality of soil.

An energy-related aspect that has the potential to complicate food security challenges for the country is that of biofuels. Food crops for energy will compete for land and water, and threaten food security. A significant amount of research is available showing how biofuels affect food prices and how they will affect food prices in future. Growth in worldwide biofuels production accounted for a 12% increase in the International Monetary Fund's (IMF) food price index over two years ending June 2008. Some studies criticise biofuels as one of the factors responsible for the food crisis of 2008. These studies concur that the diversion of the United States (US) corn crop to biofuels is the strongest demand-induced force on food prices, given that the US accounts for about one-third of global maize production and two-thirds of global exports. The expansion of maize area in the US by 23% in 2007 entailed the contraction of soybean area by 16%, leading to lower soybean output and playing a part in the 75% rise in soybean prices from April 2007 to April 2008.

In South Africa, the government has recently announced regulations for biofuels blending in petroleum fuels transportation. In addition, the aviation sector is obliged to de-carbonise in order to meet the European Union's Aviation Levy requirements and biofuels are expected to play a major role in this de-carbonisation. The demand for biofuels could therefore be significant. It is imperative that the environmental, social and economic implications of biofuels, as well as the potential conflicts between biofuels and food security, are carefully managed.

The other aspect of the food-energy-water nexus that will affect food security is water. Water is crucial for and inter-linked with food security, and water shortage will have a direct impact on food security. South Africa is approaching physical water scarcity (Figure 9). The country's water supply is currently dependent on inter-basin transfers and the WWF estimates that by 2025 the country will be water deficient. This water shortage could affect food security in the following ways. First, there could be increases in food prices. Second, sectors such as energy and industry will compete for water for food production. With the productivity of water use in agriculture, in terms of the gross domestic product(GDP) contribution, being very low (at 3%), the temptation to allocate water to sources such as energy, which have a higher impact on the GDP could be real. Third, shortage of water could affect energy production. With energy being required at all stages of the water use cycle, any energy shortage will affect water supply to the food sector.

However, the policymaking processes on energy supply choices do not include water as a constraint. These policies refer to the need to de-carbonise energy supply, the cost of different energy sources and energy security, but not to water requirements of energy production. The IRP 2010 considers the addition of 50 000 MWh by 2030 from a host of technologies, including

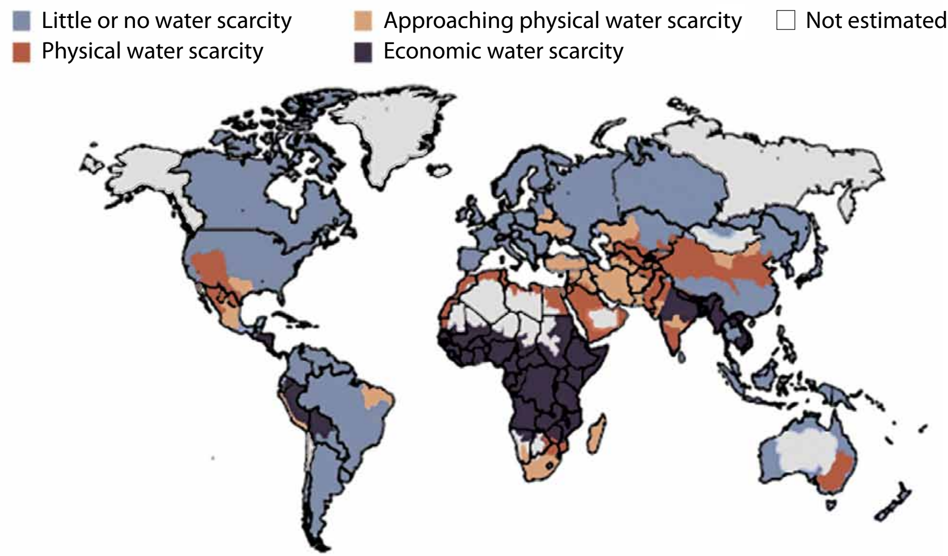


Figure 9: South Africa is approaching physical water scarcity *(Source: Institute for Agriculture and Trade Policy)*

low carbon technologies. However, not all low carbon technologies are sustainable and the water footprint of some of these alternative energy technologies, including some biofuels, can be significant.

The final dimension of the food-energy-water nexus that affects food security in terms of the water link is that of water quality. It is well known that water pollution affects the economic productivity of agriculture by destroying crops, reducing crop quality, and/or diminishing yields. In the case of South Africa, the risk is higher given that South Africa is a mining economy. Water pollution caused by mining activities will threaten food security because water is used at every step of the food production chain. A study conducted in Zimbabwe on the impact of mining on agricultural soil and water showed the accumulation of heavy metals in irrigated agricultural soil and in crops. This indicates that South Africa will experience problems in complying with food safety and quality norms both locally and in terms of export markets. Continued access to the latter depends on the capacity of food producers to meet the regulatory requirements of importing countries in terms of food safety and quality, as well as any voluntary standards. Consequently, producers and processors have few alternatives but to make the necessary investments to comply with standards. However, most mitigation technologies are expensive and energy intensive. If farmers cannot afford to implement mitigation technologies, they could stop producing food, affecting food security.

Risks to Food Security from the Impact of Climate Change on the Nexus

The threat posed by climate change will exacerbate the challenges of addressing the food, water and energy needs of the growing world population. Climate change will have a significant impact on food availability, food accessibility and the food system's stability in many parts of the world.

It will increasingly pose a significant risk of increased crop failure, loss of livestock and impact on local food security. In some areas, drier and warmer conditions are predicted, elsewhere wetter conditions are expected and will affect agricultural practices.

Most of Africa relies on rain-fed agriculture. As a result, Africa is highly vulnerable to changes in climate variability, seasonal shifts, and precipitation patterns. Agricultural production in many African countries and regions is projected to be severely compromised by climate variability and change areas suited for agriculture. In Africa, climate models also warn especially about the immediate impact of changing rainfall patterns on grain yields, runoffs, water availability, and the survival of plant species that are expected to shift production seasons, alter productivity, and modify the set of feasible crops. According to the United Nations Environment Programme (UNEP), climate change is a very real threat to food security in South Africa.

South Africa's ability to protect its food security from climate change will depend on the understanding of risks and vulnerability of its food, energy and water sectors to climate change; specifically from the nexus perspective. Simultaneously, its climate policies will need to take an integrated perspective across the nexus to avoid maladaptation and negative externalities.

Conclusion

Addressing food security requires a new dimension in South Africa – the food-energy-water nexus. This dimension has to go beyond simply water footprinting food production, carbon footprinting water supply chains, or analysing new energy supply sources and climate adaptation strategies *vis-à-vis* water consumption or its impact on land availability; and therefore food prices. It needs to look at the interdependence of resources – how demand for one resource can drive the demand for another, and similarly, how the cost of one resource can determine the efficiency of production of the other – and the manner in which this interdependence can impact food security.

Facilitated Group Discussions, Panel: Prof Muller, Prof Brent and Ms Gulati

Questions and Comments:
Robert Pitz-Paal: If solutions to the threat of increasing energy prices and water affordability and availability in food production were focused on energy and water efficiency, many of the problems would be resolved. South Africa has abundant solar resources for energy. Water scarcity could be resolved by desalination, thereby addressing food security.

Sigmar Wittig: Prof Muller was critical of the German cooperation and contributions to South and southern Africa. Germany has been highly criticised for being partners in some dam projects, such as one on the Nile River in Egypt. The flow of the Rhine River was diverted about 150 years ago, presenting opportunities for shipping, electricity generation and methods to combat mosquitos, yet it has not been accepted by everyone. Other similar, environmentally sound projects have been widely accepted. There should be opportunities for cooperation. What would be your suggestion for a specific area of cooperation between South Africa and Germany? Much has been heard in terms of diagnosing the problems, but we have not heard qualitative solutions that would make a difference.
What is the Panel's view of a country producing large quantities of items using imported technology? For example, cars that are produced in the Eastern Cape, based on German technology, and exported to other countries. This is an opportunity to create employment.

Harold Annegarn: In response to Prof Pitz-Paal's comment, a proposal was put forward by a consortium of several South African universities, as an area of cooperation with Germany, for a project for solar energy and water purification in small to medium-sized plants located in smaller capital installations around the country where there is brackish water and sunlight. The consortium remains interested in this project, even though the DST has declared that this area is not a national priority.

Jürgen Werner: Prof Muller said he was happy that South Africa had not invested in PV. If you do not like PVs then you should be able to offer an alternative. Currently, there are not many options. Germany made the decision to use all available resources and technology.

Emile van Zyl: The nexus is complex. The reality is that it is essential to move forward and look at renewable energy seriously. How can we use the complexity to work out a roadmap of where we want to be and ensure that what we do in future is best practice and sustainable?

Responses from the Panel:
Alan Brent: Water efficiency is a crucial aspect and there is emphasis on the matter. Water desalination is also being considered in this country. A big desalination plant is to be built in Cape Town, hopefully using concentrated solar power (CSP) to drive the plant. There is an opportunity for a small demonstration desalination plant with PV systems in Namibia, aimed at the needs of rural communities. Developing these technologies will be an area of emphasis for South Africa.

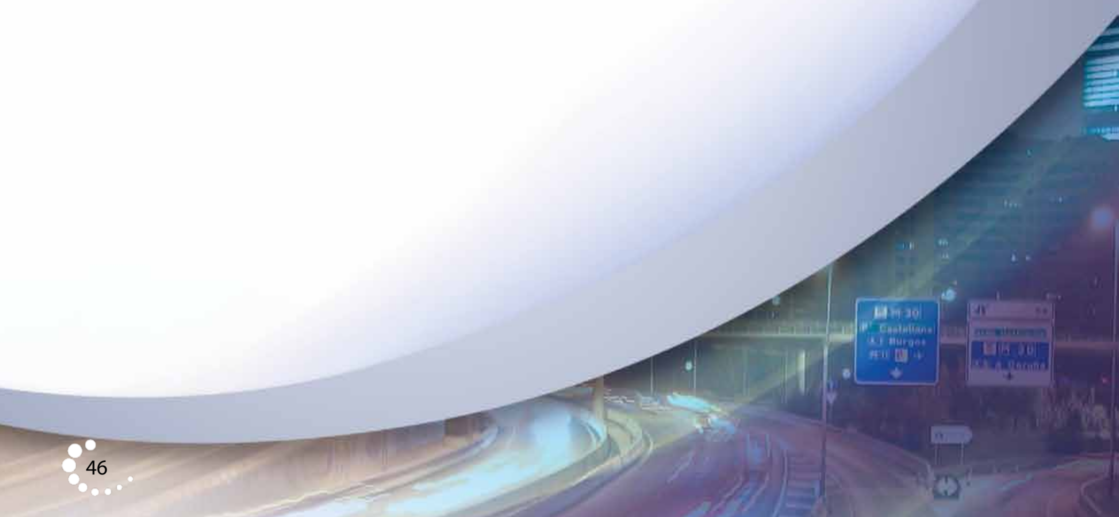
Manisha Gulati: In terms of energy and water efficiency, the WWF's experience as part of the research is that there is no understanding of or information and statistics about water and energy efficiency levels. We are trying to include this aspect in our research, identifying the energy intensity of each part of the water and energy chain in order to be able to target efficiency. Similarly, in the food value chain, there is no information that maps the value of water and energy efficiency, and where interventions are required. In most cases the container in which we buy food is more expensive than the food itself. This is a challenge which it is hoped will be overcome in the research. A holistic approach, including all entities, is necessary in order to find a solution. We are trying to see how we can help the government achieve policy cohesion on some of the issues and we aim to show then the problems and offer some solutions and support.

Mike Muller: The question is not whether or not solar is an important resource, but whether South Africa has a particular advantage in solar PV. It is important to have a global view. South Africa has very little advantage in either production or consumption in terms of developing new solar technology. If many countries are closing solar PV factories because of the challenges and reducing their subsidies into solar PV, then there is a huge oversupply of the technology and the product, and South Africa should not be under the impression that it can create a solar PV industry. However, if the price is reasonable, we may buy and use the technology. Similarly, the cost of desalination will limit its use to grow food. There will never be a shortage of water for urban use along the coastal fringe of South Africa because there will be desalination technology and there are potential sources of energy to drive the technology. It is also necessary to think creatively in order to be innovative and find solutions. Water use efficiency is very important but water flushed away in the city ends up in a hydrological system that allows the water to be reused elsewhere in the country. This requires a systematic approach within the right boundaries.

In terms of where South Africa and Germany should cooperate, it is difficult for Germany to support hydropower because there are political obstacles. There are no subsidies for large-scale hydropower. If Germany cannot support hydropower then it should withdraw from the sector. However, there are win-win opportunities for cooperation in the area of solar and CSP, as the technology requires less specialisation than nuclear or PVs, and South Africa is well adapted to solar technology.

The challenge with the nexus in its complexity is how to identify those areas and linkages that are sufficiently significant to focus on. South Africa will have to make choices about the low carbon technology in which it invests. In terms of areas of innovation for South Africa, I would exclude PV, wind power and a number of related sources. We have demonstrated our limitation in nuclear energy. The capital and the technical requirements of CSP are substantially less than the requirements of a new nuclear system. This is a good reason for a medium-sized country to invest in CSP. Mr Lukey's presentation showed that there has been big growth in IP in fuel cells over the years. South Africa has 80% of the world's platinum, but many of the patents eliminate platinum from fuels cells. This is an area of opportunity, which could be lost to this country. It is necessary to think in terms of South Africa's niche and opportunities that are not high-risk and high-capital in order to target resources in ways that are likely to be helpful. I would focus on a balance of CSP and platinum-based fuel cells, as these are areas in which South Africa could lead. In terms of other technologies, South Africa should follow innovations of other countries and learn from their mistakes.

Prof Wittig's second question relates to a bigger economic issue that goes beyond the nexus. A good paper by Justin Lin, the Chinese Chief Economist of the World Bank, suggests that in pitching their aspirations for manufacturing sector business, countries should look at those slightly richer than them, which are about to become uncompetitive, and begin to produce what they are producing.



SMART CITY INNOVATIONS

FACILITATOR: DR CHARITY MBILENI, THE INNOVATION HUB

Smarter Cities: Creating Opportunities through Leadership and Innovation, Mr Wolfgang Zinssmeister, IBM South Africa

In 2007, for the first time in history, the majority of the world's population lived in cities. City dwellers are expected to make up 70% of earth's total population by 2050.

This unprecedented urbanisation is a sign of our economic and societal progress, especially for the world's emerging nations, and places a huge strain on the planet's infrastructure and resource sustainability. This presents a challenge to governments and municipalities in terms of controlling development and responding to public demand for service delivery, safety, education, healthcare and a better quality of life for all. Our cities will have to become smart if they are to provide for effective regulation, economic growth and sustainability.

IBM views the city as a microcosm of the major challenges and opportunities facing the planet today, particularly those relating to government services, transport, education, healthcare, energy, public safety, and information and communication technology ICT. IBM's vision is to bring a new level of smart intelligence to improve efficiency and productivity in respect of how the world works and how individuals, businesses, organisations, governments, as well as the natural and human-made systems, interact. Smart systems create opportunities for new, meaningful possibilities for economic growth and sustainability.

Information is required in three major areas in order to develop a smart city:
- Planning and management that brings together a plan that will realise the full potential of a city for its citizens and for business.
- Infrastructure services that deliver basic services, such as water, energy, transport and environmental services that make it possible to live and work in a city.
- Human services that provide services that support the individual needs of citizens, such as social, health and education services.

IBM's Intelligent Operations Centre for Smarter Cities collects information from all sources, including cell phones, and turns data into information that provides the basis for cities of all sizes to be able to:
- leverage information across all city agencies and departments;
- anticipate problems and minimise the impact of disruptions by responding proactively;
- coordinate resources to respond to issues rapidly and effectively.

IBM is involved in over 2 000 projects and has developed best practice in terms of offering intelligent solutions for water (including conservation and management), transport (including traffic flow and management) and infrastructure (including energy, operations and space management). IBM is working towards developing smarter cities all over the world, as well as in South Africa.

Smart cities are not only more efficient and more productive, but are also cost effective and use low carbon technologies. A smarter water concept is to be developed for the City of Tshwane in the next few weeks and will include concepts for education about the usage of water.

Building Resilient Societies through Innovation, Prof Chrisna du Plessis, UP

Introduction

The sustainability discourse has gradually shifted from the achievement of a specific idealised optimal goal state, to the acceptance that a sustainable human society cannot be static but needs to allow for change and growth and be 'adaptable, robust, and resilient' (Murray Gell-Mann quoted in Waldrop, 1992: 351). However, the theoretical constructs describing resilience and how these apply to human societies and their settlements still require some clarification.

The objective of this paper is to explore how these constructs relate to urban systems and how they can be used to foster innovation in the design and development of our cities and other human settlements.

The Meaning of Resilience

Resilience is a concept found originally in engineering, psychology and ecology where it refers to the ability of a system to bounce back to its initial state after a disturbance or absorb stresses and shocks without losing functionality or changing structure. A recent literature review undertaken on behalf of the Rockefeller Foundation (Martin-Breen and Anderies, 2011) identifies three categories of resilience current in the discourse. The first is 'engineering resilience', which is described as concentrating on maintaining stability near an equilibrium steady state by focusing on efficiency, control, constancy and predictability.

The main focus of engineering resilience is on the persistence of system structure and function. Although sometimes used in the field of psychology, this understanding of resilience is mainly relevant to mechanical assemblies and systems that can only function if their structures stay the same or return to their original form. However, in complex systems it is often not possible to restore the system to its original state and promoting an equilibrium model of resilience can result in systems becoming trapped in a sub-optimal equilibrium state as a result of increasing institutional 'lock-in' to a specific development pathway and even lead to system collapse.

The second category of resilience, termed ‘systems resilience’ is equated to the concept of robustness. This view of resilience focuses on maintaining critical system functions in the face of both sudden crises and slow pressures, but the way these functions are provided and the system components and structures providing these functions can change. Used initially in ecology and ecosystem management, this view of resilience is more appropriate to living systems which respond to change and perturbation by adapting to and absorbing stress in order to keep functioning. However, the robustness of a system is usually tested over short time frames in fixed systems exposed to fixed external shocks.

The third category of resilience is the resilience found in complex adaptive systems such as ecosystems and social-ecological systems (e.g. cities), and it is differentiated from systems resilience by the quality of adaptability and its focus on system conditions that are far from equilibrium. The emphasis is on the opportunities created for “generating new ways of operating and new systemic relationships” (Martin-Breen and Anderies, 2011:7) through “recombination of evolved structures and processes, renewal of the system and emergence of new trajectories” (Folke, 2006).

As such it can be described as transformative and regenerative. This category of resilience is possible because of the ability of the components of a system to self-organise and it is the type of resilience that requires innovation. It is the type of resilience that most closely conforms to the requirements of sustainable development for a deliberate shift to a different system state in the social system, while preventing global ecosystem services from tipping into a system regime that will no longer support and enhance human life

Resilience is not about restoring something to its original state, robustness, redundancy or preventing failure. The emphasis of resilience is on either a specific disturbance, as in disaster and crisis management, or on a press disturbance, which is in the domain of general resilience, as in slow climate change, poverty, service delivery, and the effects of transition period on our social structures in South Africa.

‘Transformative resilience’ accepts the cyclical nature of change and the acceptance that life is about change and adapting to that change – a concept described as the adaptive cycle (Gunderson and Holling, 2002), a metaphor for the recurring cycles of rapid growth, conservation, release and reorganisation found in nature. The adaptive cycle plays out across what has been referred to as the panarchy – seen as a set of nested adaptive cycles within which change happens at different rates, and whose dynamics are connected across the different levels and scales. For example, the life-cycle of a city can begin with a disturbance at one level of the social-ecological system, such as political change, which initiates a process of spatial reorganisation towards the development of an urban system that eventually breaks down, releasing potential for new urban forms.

The Rules of Resilience

There are a number of system characteristics or requirements that contribute to the resilience of a system which can be used to construct a rudimentary guiding framework for developing urban resilience (Figure 10) and it is within these 'rules' that technological innovation comes into play. The rules are:

- Do not to put all your eggs in one basket: It is necessary to build diversity and a level of redundancy into the system to provide space for failure, and to structure the system with modularity.
- Work your connections: Understand and be aware of being part of a system by getting feedback in real time about matters such as obstructions in the urban system and use connections at smaller scales to self-organise solutions and enable the emergence of new system configurations.
- Design for graceful failure: Allow for flexibility and reversibility in the system, instead of focusing on predictability.

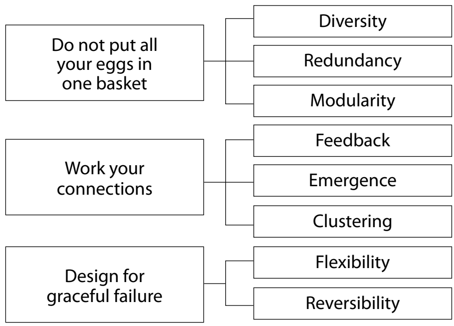


Figure 10: Rules and requirements of resilience

Focusing on Diversity

Diversity is proposed as one of the key characteristics of a resilient system, as it increases the range of options available to a system when adapting and reorganising (Walker and Salt, 2006). Diversity can include species in ecological systems, diversity of technical or economic systems, as well as social diversity. South African cities provide a good example of how an ideological system (apartheid) has decreased diversity in cities by creating spatially divided monocultures – first of race and later of economic status. Both of these have had major implications for the social resilience of the country's urban areas and for entrenching the city in certain system regimes, especially the structural poverty experienced in large areas of the city (Du Plessis, 2012). The townships created first by the apartheid government and now being perpetuated by the concentration of people who are in the same, low-income bracket. They cannot help each other or build a functioning system out of their neighbourhood as there is not sufficient income diversity to provide employment where people live. However, too much social diversity can also reduce the resilience of cities. Recent studies concerning cultural diversity have shown that when a neighbourhood becomes too culturally diverse, social cohesion disappears because common bonds between people do not exist.

In ecosystems there are two types of diversity, namely functional diversity and response diversity. In nature the functional diversity of species are described by three categories: those that produce (e.g. plants), those that consume (herbivores, carnivores and omnivores), and those that decompose waste products (fungi, bacteria). These three functions are critical to the working of the ecosystem at whatever scale of the system and they are interdependent. Response diversity is the presence of, for example, a variety of predators that could operate at different scales (e.g. a lion and a spider) providing for a certain specific function.

Cities also have functional categories/groupings which are determined by the users and resources of the urban environment. In a city, different functional categories can be identified, for example business and commerce, residential, industrial, infrastructure, social facilities and green users, among others. Within each of these groups there are different responses and categories of responses at different scales. For example the function of commerce can be fulfilled by a range of responses from the informal street vendor, to large shopping centres. Table 1 illustrates examples of different responses at different scales for a number of urban functions. However, these are not only at different scales, but also represent different levels of formality.

Table 1: Diversity of Responses to Different Urban Functions

Residential	Industry	Green	Commerce	Energy
Shack	Seamstress	Window Box	Pavement	Building PV
Townhouse	Cooperative	Garden	Spaza Shop	District
Mansion	Factory	Local Park	Formal Shop	Distributed
Apt Building	Multinational	Reserve	Chain	Centralised

For example, the function of commerce can be fulfilled by a range of responses from the informal street vendor to large shopping centres. Residential responses range from a shack to multi-storey apartment blocks or large mansions, while transport can range from highways and railways to bicycle paths. Increasing the response diversity to critical urban functions is a critical area of innovation for the creation of resilient cities and societies.

Innovation for Resilient Societies

As the focus of this conference is on technological innovations for a low carbon society, let us explore the notion of using diversity to build resilience in the energy system. One way to increase the diversity of responses to the function of energy provision is through a modular approach that introduces different responses at different scales. For example, a solution to energy provision would look at on-site measures, such as demand management and domestic solar water heating, neighbourhood solutions, such as district heating and cooling or distributed generation capacity, such as small-scale wind, hydro or solar, as well as bulk services from large power stations. There may be a lot of redundancy built into the system that would appear inefficient, but a basket of options for meeting energy needs would ensure that if demand on the bulk supply cannot be met for any reason, there are local alternatives available that can meet a basic level of service. Conversely, while the bulk of energy needs can be provided for on-site through renewable resources, the link to a larger facility can ensure an energy supply during the times when renewable energy sources are unreliable.

An example of using the characteristics of resilient systems, including a diverse network of low carbon technologies to develop resilient communities is described in Du Plessis *et al*. (2010). A model for sustainable municipal service delivery was developed by the CSIR, based on distributed generation of electricity from renewable resources linked to the food-energy-water nexus that can be used as a catalyst for improving the resilience of small rural towns.

However, urban resilience requires not only technological innovation, but also social innovation. This necessitates innovation in education, decision-making, behaviour change, governance and communication. The resilient societies of the future will only be created by going beyond the obvious and beyond what is currently considered the only viable and permissible avenues for development.

Facilitated Group Discussion, Panel: Mr Zinssmeister and Prof Du Plessis

Questions and Comments:
Louis Roux: How can opportunities be created in the South African monoculture society?

Unknown Person: How do we translate the thoughts and ideas in Prof Du Plessis' presentation to practice and persuade policymakers and implementers?

Responses from the Panel:
Chrisna du Plessis: We will have to wait for the system to begin breaking up. This will create new spaces. Eventually those areas that break down will start consolidating and new people will move into the areas and get jobs, or the system will collapse and people will move out and the areas will be broken down and rebuilt by other people. In Mexico City, the citizens began to create their own intervention points usually initiated by a few wealthy residents of that area. This is a slow process. Another option is to consider ways to improve the market of the monoculture areas, such as townships, by creating employment, or home industries.

In terms of getting the ear of policymakers, fortunately resilient societies happen mostly through self-organisation. We should not necessarily talk to policymakers but use social networks to catalyse efforts and motivate people by showing them what others have done in various parts of the world. There are numerous examples of initiatives taken by individuals and small organisations having made a difference and eventually forcing decision-makers to take action. Decision-makers are not very powerful as they serve their shareholders, the market and their voters. If individuals begin to understand that they can use the power they have to change things around them, then the actions of individuals or small groups will be catalysts for larger change. Attempts to persuade decision-makers to make changes that require risks and adaptive capability at this point in time will be difficult. The role of educators is to get the next generation of leaders to think differently.

LOW COST, LOW CARBON INNOVATIONS FOR POVERTY ALLEVIATION

FACILITATOR: PROF JÜRGEN WERNER, UNIVERSITY OF STUTTGART

Low Income, Low Carbon Energy Solutions, Prof Harold Annegarn, UJ

Prof Annegarn's presentation emphasised community engagement on sustainability or resilience rather than on supply of low carbon innovations, and brought in the ethical dimension. Although previous presenters appeared to embrace the notion of a low carbon future, the question is whether all carbon is equal, and for what and for whom it is equal.

An outline for the argument concerning the justification for state intervention was presented as follows:
- Supposition 1: Greenhouse gases (GHGs)/carbon concentrations in the atmosphere are increasing due to anthropogenic emissions.
- Supposition 2: There is a causal link between phenomena of global change and increased concentrations of these gases in the atmosphere.

The proposition that (1) external costs of GHG/carbon emissions (in the form of global change) require state interventions to reduce such emissions is made given the above suppositions. The following questions are posed with regard to proposition (1):
- What are the relative cost-to- benefit (C:B) ratios for various types of emissions?
- Are these benefits uniformly distributed among all users of carbon emissions?
- Who ought to pay for the carbon emission reductions?

If the principle from proposition (1)is accepted, then:
- Are there other externalities associated with carbon use (e.g. domestic coal combustion)?
- Are the C:B ratios of these other technologies greater than for those of GHGs?

If the answer to the latter question is positive, then proposition (2) follows from proposition (1) that the state ought to intervene in improving the C:B ratios of such technologies (with equal or greater vigour than to reduce total GHG emissions). It is then asked whether the near term costs of carbon use technologies are severe and/or unfairly distributed, affecting the lowest socio-economic sector the most. If the answer to this question is positive then state mitigation efforts ought to be prioritised to reduce such costs (ahead of mitigation of total GHG reductions) (proposition (3)).

Proposition (4) is that there are cost-effective and feasible low income, low carbon energy solutions to mitigate some of the externalities of domestic energy use. If so, what are these technological and administrative low income, low carbon energy solutions? If proposition (4) is true, what are the barriers to implementation, and if it is false, what additional technological and administrative mechanisms have to be researched/implemented to mitigate the externalities?

Proposition (5), a developmental proposition, is that there is a severe imbalance in the current national (and international) mitigation effort on GHG emission reduction, to the neglect of improving technologies for carbon (and alternative energy) use among the lowest socio-economic sectors. Proposition (6) is that the obsession with imposing solar water heaters on RDP houses is a distortion of the developmental needs of this sector.

In terms of supposition (1) above, the historical record of carbon dioxide in the atmosphere from 1957 shows a steady increase. Supposition (2), referring to the causal link between global change and GHGs, leads to proposition (1), that external costs of GHG/carbon emissions (in the form of global change) require state interventions to reduce such emissions, is accepted for the purposes of argument. Questions are asked about what the relative C:B ratios are for various type of carbon emissions/uses, and whether these are uniformly distributed among all users of carbon emissions.

Data from research under the EnerKey programme, looking at the energy supply and use and GHG emissions from different sectors, indicates that the residential sector is emitting 16% of carbon dioxide in Gauteng and there is inequality in access to energy, with severe disparity between the poor and high-income groups. The Gini coefficient, which measures the disparity between the highest 10% and the lowest 10% income should be adapted to a 'carbon Gini coefficient' to show the benefits received by the top 10% and the lowest 10% income in terms of tons of carbon emitted.

A new, scalable concept, the concept of energy poverty, has been introduced. A household is said to be in energy poverty if it spends more than 10% of disposable household income on energy services. Other aspects of energy poverty are:

- A higher incidence of disease through exposure to domestic energy-related emissions.
- A higher incidence of accident through use of domestic energy services (domestic fires, scalding and paraffin ingestion).

Proposition (4), is that there are cost-effective and feasible low income, low carbon energy solutions to mitigate some of the externalities of domestic energy use. An example of such a solution is the 'top-down alternative method' of lighting fires that drastically reduces smoke emissions. The reality is that shacks in informal settlements are a very high fire risk with little chance of emergency response. Administrative steps to enforce spacing of shacks in high-density areas are necessary in order to respond to the extreme risk of uncontrolled fire. Possible interventions include passive energy-efficient housing, which are north-facing and stand-alone units. Although several products are under development, no valid, certified, standardised stoves that are safer and cleaner are yet available on the South African market.

In conclusion, alternative energy and renewable environmental solutions to help address the issues that hold communities in poverty are required. A focus on climate change is the wrong message for developing communities. Climate protection will rather happen as a consequence of local action to provide safe, efficient, affordable energy services.

Low-cost Innovation in Water and Sanitation at a Local Level, Prof Chris Buckley, UKZN

Prof Buckley's presentation was based on a set of creative and diverse research efforts towards meeting the water and sanitation needs of different areas of eThekwini Municipality (Durban).

EThekwini Municipality is an extraordinarily large metropole in terms of area, with a large population and a variable density. Some people live in ideal conditions, while others live in informal settlements where there is open defecation that leads to disease, where sewers fail and ventilated improved pit (VIP) toilets need to be emptied. Deaths from cholera were reported around the peripheral parts, as well as the centre of the city in 2000-2001.

The composition of excreta in terms of yearly production is 50 kg per person of wet faeces, 11 kg of dry faeces, and about a half of ton of urine and 21 kg of dry urine. This amounts to between 20 and 250 litres of excreta per person per day or 18 tons per day that enters a water-borne system. Sewage is treated for public health reasons. Faeces contain pathogens and contact between people and excreta (pathogens) must be eliminated. Piped systems could be used to remove faeces and it is necessary to find alternatives to institutional open defecation.

The history of excreta management from before the Roman Empire involves urbanisation and city-wide planning. The theory was that disease was spread through air-borne vapours and that the disposal of excreta in water removed disease. However, the basic understanding of sanitation was incorrect as it was found that disease was caused by bacterial microbes. Processes were added to what was a bad system. Waste water was discharged into rivers and underwent a series of chemical purification processes and endocrine disrupting compounds, advanced oxidation, membranes, adsorbents and wetlands to manage excreta. The challenges provided by meeting the needs of developing countries will set new standards and solutions to these challenges could become the way in which waste water and sanitation disposal will be viewed in future.

Currently, there are Millennium Development Goals (MDGs), rigid discharge standards, increasing water stress, energy interruptions, poverty, and a problem with sewage. In future, there may be sustainability targets, risk-based approaches for regulation, water conservation, high-energy costs, food security, excreta as a resource and smart cities.

Water supplied to a plot has to be discarded in a way that takes into account rising bulk tariffs and free basic water of 300 litres per day per household (instead of the current allocation of 200 litres), full cost recovery (for an efficient service), and sanctions for water theft and non-payment.

The eThekwini Municipality has to develop a sanitation policy for the unserved people, incorporating:

- urine diversion toilets becoming the sanitation of choice for rural communities, replacing VIP latrines;
- community ablution blocks in informal settlements;
- decentralised systems for isolated communities;
- support for school sanitation.

The backlog in provision of sanitation in 2007, as a result of the migration to the city, was about 203 000 households in informal settlements and 21 500 households in rural traditional areas.

Solutions for sanitation in rural areas include urine diverting dehydrating toilets (UDDTs) (the contents of which can be useful) and VIP toilets in peri-urban and urban areas. Initially there were problems with emptying the VIP toilets and the process required trained teams of workers, special tools and health and safety measures. A process called Latrine Dehydration and Pasteurisation (LaDePa) was recently developed, which produces a crop remediate or fertiliser that can be used in food gardens.

Interim services that have begun to be installed in informal settlements in an attempt to meet the backlog of sanitation in the metropolitan area in the context of sustainable livelihoods include:

- communal ablution blocks, using modified shipping containers;
- basic road network footpaths;
- electricity connections;
- standpipes.

A smarter design for waste management, involving prefabricated septic tanks made in a factory according to standards, has been effective in replacing conventional septic tanks when the toilets are built away from water or a sewage system. Waste water from the community ablutions is treated in a pond effluent system and then flows through to community food gardens to be used beneficially in agriculture. Excess water flows through wetlands and into rivers. In principle, people ingest sufficient nutrients to be excreted and excreta should therefore be able to be used to grow crops that are required to build sustainable livelihoods.

A technical evaluation plant takes piped water from small communities through an anaerobic process, constructed wetlands and immersed membranes for agricultural reuse. The concept has been taken a step further to a low-cost housing development area where 250 houses will be built, with an anaerobic baffled reactor, wetlands and an agricultural area, to create a sustainable community.

The Bill and Melinda Gates Foundation is prepared to invest USD 65 million in 2013 into reinventing the toilet and finding a solution to the sanitation needs of 2.6 billion people. On-site sanitation is one of the most exciting fields of technological innovation. Water is life and sanitation is dignity.

Facilitated Group Discussion, Panel: Prof Annegarn and Prof Buckley

Questions and Comments:
Peter Lukey: If we are looking for a change from water-borne sewage then we would have to start by looking at rich households and not poor households because the poor will continuously aspire to a water-borne sewage system. We focus on technology for the poor but we do not give them what they want.

Chrisna du Plessis: Somehow the poor always get the on-site solutions and the small technology solutions. We are continuously reinventing cooking stoves and composting toilets for the poor. Is this where we should be focusing or should we be focusing on the intermediate-scale solutions that are more appropriate to the poor?

Responses from the Panel:
Harold Annegarn: We engaged poor communities to be part of the process and to work towards changing behaviour.

South Africa made huge advances in the Pebble-bed Nuclear Reactor and other important technology. How is it that we do not have the technological competence to design a safe, portable paraffin stove?

The use of carbon has a huge externality cost in safety in poor communities.

Chris Buckley: Mr Lukey’s question has been put to Bill Gates. Until Mr Gates has a UDDT in his house, we have not achieved anything. The challenge to reinvent the toilet is a different way of looking at how to have on-site sanitation and has drawn the attention of the leading universities in the world. The aspirational goal is to be able to treat one’s individual waste to produce drinking water, fertiliser and sufficient energy to charge a cell phone, at 2 to 3 American cents per person per day. The Bill and Melinda Gates Foundation is investing millions of USD in reinventing the toilet. It is necessary to develop social incentives that incentivise people to get value out of the nutrients in the excreta. This is one of the issues for discussion at the Faecal Sludge Management Conference that is to be held later in October 2012 in Durban.

It will be necessary to have a decentralised water-borne system with pipes to remove grey water in a densely populated environment so that the water can be used beneficially. If housing is provided to people who have difficulty in maintaining a house, they cannot be expected to maintain a septic tank.

Green Star-rated Building: Menlyn Maine, Mr Justin Bowen, Development Director, Menlyn Maine

The City of Tshwane's master plan for the city's development earmarked the new super node business district for Pretoria as part of decentralisation to arrest urban sprawl. Menlyn Maine is at the heart of the green precinct and takes up 165 000 m^2 of land made up of space for offices, retail, residential and hotels, and is set to change the skyline of Pretoria by 2020. The Nedbank building is a certified green building, one of the few in South Africa.

Menlyn Maine is one of 16 founding projects working with the Bill Clinton Foundation under an initiative called the Climate Positive Programme to develop a framework for sustainable urban development on a worldwide scale, addressing operational phase emissions.

Intelligent design has been used in respect of water usage, carbon emissions, lighting and air-conditioning systems, and material selection, ensuring sustainability and energy efficiency and lowering the carbon footprint of the building.

Delegates were taken on a tour of the building.

DAY 2

THE POTENTIAL OF SOLAR POWER IN SOUTH AFRICA

FACILITATOR: MS MARLETT BALMER, GIZ

Renewable Energy Resource and Research Base in South Africa, Prof JL van Niekerk, Director of the Centre for Renewable and Sustainable Energy Studies, SU

The Centre for Renewable and Sustainable Energy Studies (CRSES) was established about six years ago at Stellenbosch University (SU) after a contract was signed with what was then the South African National Energy Research Institute to be the national hub for the postgraduate programme for renewable and sustainable energy studies.

The hub has a number of flagship projects, is responsible for technology transfer and plays a coordinating role for renewable energy in the country. The three spokes of the hub are:
- Solar thermal energy: Based at SU, in cooperation with UP and UKZN
- Photovoltaic systems: Shared between Nelson Mandela Metropolitan University (NMMU) and the University of Fort Hare
- Wind energy: Shared between SU and University of Cape Town (UCT)

The Centre is funded by the DST and has received financial support from Eskom and Sasol.

The main research areas in renewable energy at various departments of SU are:
- Solar thermal energy (mechanical and mechatronic engineering)
- Wind energy (electrical and electronic engineering)
- Ocean energy (mechanical and mechatronic, and civil engineering)
- Biofuels (microbiology and process engineering)

The following flagship projects are driven by SU:
- South African Wind Energy Training Centre (SAWETC): Various partners are involved in this project that aims to establish a facility to train technicians, operators and artisans who will work in the renewable energy space. Funding has been made available by the Department of Higher Education and Training (DHET) for the new facility to be built on the campus of the Cape Peninsula University of Technology (CPUT).
- Southern African Solar Resource Map and Database: Fourteen high-quality solar irradiation measurement stations are being maintained and operated in partnership with a Slovakian company, as well as other organisations. Eskom has donated a set of equipment to this project and although national government has not yet committed funds to this project, funding is anticipated from various other sources.

- Solar Centre of Competence and Concentrated Solar Power (CSP) Pilot Plant: This will provide an international facility to do larger scale research and development together with various partners.

South Africa has a variety of renewable energy resources, such as:

- Ocean energy resource: Although this is a small research area in South Africa, there is potential for exploitation. The waves along the coastline could produce an average of between 15 to 40 kW/m crest length per year. South Africa is internationally recognised as a possible market for wave energy conversion devices. SU has developed a wave energy converter, a device conceived by civil engineers about 30 years ago and currently being refined for application. Ocean currents are also an attractive form of energy although no viable technological options are yet available in this area.
- Bioenergy resource: The potential for bioenergy is focused on the East Coast of the country.
- Hydro energy resource: The potential for hydro energy is limited as South Africa is a water-scarce country. Currently there are only two hydroelectric power stations in the country: one is at the Gariep Dam (a 360 MW unit) and the other at the Vanderkloof Dam (a 240 MW unit). Hydropower is imported from Mozambique and there is further potential for importing hydropower generated on the Kunene River, between Namibia and Angola. A number of pump storage schemes are in operation and under construction in South Africa. There are numerous opportunities for micro and small hydro schemes, such as the Bethlehem hydro scheme that produces 7 MW. The Inga hydro scheme in the Democratic Republic of Congo (DRC) could produce 40 GW of potential energy. However, a high-voltage direct current (DC) line would have to be installed between the DRC and South Africa in order to access the energy generated from the scheme.
- Wind energy resource: Government has given the go-ahead for several wind farms throughout the country, most of which are in the Eastern Cape, Sutherland, Beaufort West and on the Western Cape coast. Currently there are eight reasonably large wind turbines in South Africa. SU, UCT, NMMU and North-West University are involved in various aspects of wind energy research.
- Solar energy resource: South Africa has a 50% better solar resource than Spain where several CSP plants are being built. Currently three CSP plants are being developed, and numerous PV plants have been permitted or are in operation around South Africa. Thermal solar energy research is being undertaken by CSIR, UP, SU, UKZN, Sasol, Eskom and other organisations. SU is anchoring its research around specific aspects of an asynchronous combined cycle. The Solar Thermal Energy Research Group (STERG) made up of at least 45 members, is focusing its research on solar resource R&D, dry cooling, thermal storage and heliostats and receivers. PV research in South Africa is conducted at several universities. NMMU specialises in characterisation of PV cells and modules, as well as systems research.

Photovoltaic Technologies – Perspectives for South Africa, Prof Jürgen Werner, Institute for Photovoltaics, University Of Stuttgart

Photovoltaic technology has the advantage of being modular offering the possibility of small power stations, as well as large photovoltaic systems.

At the end of 2011, PV power of 75 GW was installed worldwide. The German installations amounted to about 25 GW, and will reach more than 30 GW at the end of 2012. The cost of electricity in Germany is about 12c per kWh, depending on the size of the PV system, and about R1/kWh in South Africa. The discussion about PV materials is no longer applicable as 85 to 90% of the world market for PV material is crystalline silicon (c-Si), and there are currently no alternative materials available.

Over the last 20 years, thin film materials had a market share below 20 %. Now, a PV module is a commodity product and will continue to develop. In future, PV research will be more focused on the integration of large area PV systems into the grid and not on PV materials. As at the end of 2011, 50% of all PV power worldwide was installed in Germany and Italy. Statistically, inhabitants of Germany each use about 400 watts of PV power, while South Africans each use less than 1 watt of PV power. PV power is cheaper to generate in countries where there is more sun. Since 1990, Germany has experienced an exponential growth in installed PV power, which is expected to reach 52 GW by 2020.

The four types of materials that are commercially available in PV modules are crystalline silicon (c-Si), amorphous silicon (a-Si), cadmium telluride (CdTe) and copper indium gallium selenide (CIGS). In 1983, 20 MW of PV modules were manufactured and sold worldwide, while in 2011, 37 GW were manufactured but only 27 GW were sold. The unsold 10 GW were responsible for the drastic drop in prices of PV modules. Crystalline silicon remains the material of choice for the production of PV modules. Thin films always had a small share of the market.

Since 1976, the price of c-Si PV modules dropped dramatically from about 80 €/W to today's 60 – 80 cents/W. At present, the installation cost for a medium-sized PV system (around 10 kWp) in Germany ranges at around €1 500 per kWp, the annual yield is about 1 000 kWh per kWp. At this price and yield, if the system is financed at an interest rate of 6% and operated over 20 years, the cost of electricity is about 12c per kWh in Germany. Under South African conditions and at a 12% interest rate, the annual energy yield would be approximately R1.00 per kWh.

Research has found that c-Si is the most effective material for producing PV modules for GW regimes.

Techniques in using silicon to produce PV modules have improved and been refined, and the product has become cheaper over the years. It is important that PV systems work properly and are effective in producing electricity. New techniques have also been found to detect and replace malfunctioning PV modules in a system.

Concentrating Solar Power: Its Potential Contribution to a Sustainable Energy Future, Prof Robert Pitz-Paal, DLR

The European Academies Science Advisory Council (EASAC) undertook a study and published a report entitled, *Concentrating Solar Power: Its Potential Contribution to a Sustainable Energy Future*. This presentation attempts to apply some of the results of that study to the South African situation.

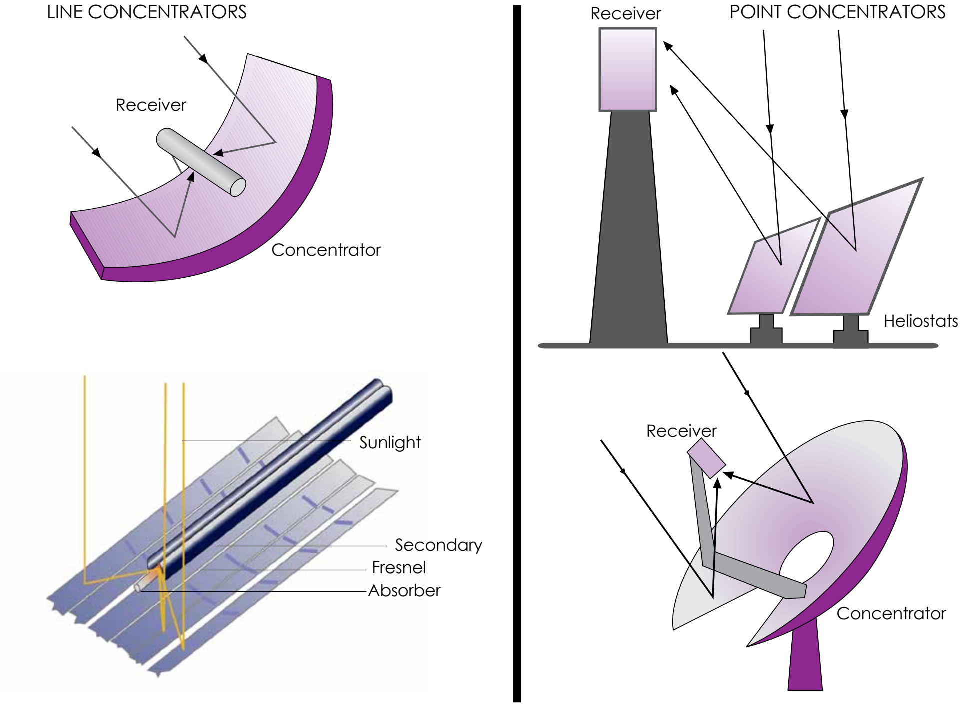


Figure 11: Technologies for concentrating solar radiation: left-side parabolic and Linear Fresnel troughs, right-side central receiver system and parabolic dish *(Source: DLR)*

Concentated solar power (CSP) is a simple technology. Instead of using fossil fuel or nuclear fusion, solar collectors (Figure 11) are concentrated to achieve high temperatures in a heat transfer fluid and create a conventional power cycle. The essential component is the concept used, such as parabolic troughs and solar towers. Both are made of similar materials and comprise mirrors. The mirror in the parabolic trough needs to be curved, precise and robust for effective reflectivity of a period of 20 years.

It is aligned on a steel structure that tracks the sun and the energy is transferred to and concentrated on an absorber tube, and transferred to a fluid. In the case of the power tower, heat exchange takes place on the top of the tower where the central receiver is located. A Linear Fresnel System is similar to a parabolic trough. The main differences between the three types of technology are found in peak solar to conversion efficiencies, annual solar to electricity efficiency, the area of land use, and the geographical nature of the land used. The technologies have similar water consumption depending on whether they use wet or dry cooling systems. The development of the market for CSP technology is focused on solar towers because of the expectation that the higher efficiency of the systems will be cost-effective.

The difference between electric and thermal storage is explained as follows:

- Electric storage: A solar collector field provides heat to a power cycle. It provides about 2 000 hours of full-load heat per year in South Africa. Energy can be stored by pumped hydro but this adds costs to the service in terms of the construction and use of a hydro dam and the efficiency of the energy storage. In order to offset the losses of energy storage, it is necessary to create additional capacity.
- Thermal storage: Assuming that the solar collector field is doubled and a storage tank is integrated, it is possible to add a further 2 000 hours, or a total of 4 000 hours of full-load heat per year to the power cycle. The system produces twice the amount of electricity, but does not necessarily cost twice the money. It is possible to add a few hours of fossil fuel fire as the system is compatible, thereby replacing existing capacity without providing for shadow plant capacity in cases of limited sunshine or low storage capacity.

Efficient use of the solar field will improve cost-effectiveness of the system. Adding thermal storage to a CSP system and adapting the design of the CSP system to provide for a variety of requirements of the grid will increase the cost-effectiveness of the system. The design of the CSP systems would also depend on the relevant power purchase agreements and the demand.

The most mature technology available in many different power plants is parabolic troughs. In terms of the current market for the technology, power plants producing 2 GW are already in operation, power plants that will produce 3 GW are under construction, and further power plants to produce 3 GW are being developed. It is anticipated that by 2020, 20 GW of capacity would be installed, much less than the current capacity of PV installations. CSP technology is still in the early phases of development. Its actual levelised cost of electricity ranges between 15-20 €cents/kWh depending on technology, site and finance conditions. Three main drivers for cost reduction are scaling-up, volume production and technology innovations.

The EASAC report mentioned above investigated a couple of detailed studies that estimated the potential relative reduction of the levelised electricity cost (LEC) of trough plants of up 60%. Half of this potential can be exploited by technical innovations, the other half by scaling-up and mass production effects. If this potential is exploited, cost for dispatchable solar power from CSP plants will drop significantly below 9 €cents/kWh and can be considered competitive in many commercial markets.

The time to achieve this cost reduction is strongly coupled to the deployment rate of the technology. A total installed capacity between 10 and 100 GW is estimated as sufficient to achieve this target between 2020 and 2030. One of the options to reduce the costs of CSP systems is the use of the solar tower system, as higher concentration of solar energy provided by the tower systems leads to higher system efficiency, implying that fewer collectors are needed to provide the same amount of electricity.

CSP electricity is currently more expensive than PV electricity. However, the levelled cost of electricity is probably not the only measure of comparing costs of various technologies because electricity has different components of value, such as:
- kWs of electrical energy;
- contribution to meeting peak capacity needs;
- services provided to support grid operation.

It is necessary to compare the systems taking all aspects into consideration, not only the costs of various technologies. The CSP system has added value that incorporates fluctuating energy resources into the grid, achieving stability and security of supply.

CSP, PV and wind power can be applied as complementary technologies in order to generate a high percentage of renewables in an energy grid. It is estimated that cost reduction is dependent on mass production and scaling, and technology improvement.

The implementation of CSP technology in South Africa would be successful because of the following conditions in this country:
- The size and quality of the solar resource.
- A rapidly increasing indigenous demand.
- The high level of local supply share provided by CSP technology (potentially up to 60% by value by 2020).

The benefits of CSP technology are:
- It has potential to become a zero-carbon, low-cost electricity supplier.
- It can reduce the need for expensive storage capacity.
- It has a high local supply share creating local value and jobs.

Challenges related to CSP technology are:
- Parity with fossil fuel energy would have to be achieved in the next 10 to 15 years.
- Grid infrastructure and market mechanisms are required to integrate a

large proportion of CSP.

- Appropriate political and economic conditions would be essential in order to support long-term investments in low carbon technologies.
- Subsidy schemes, continuity of initiatives and a financing framework would be necessary for the technology to be installed in this country.

Recommendations are that South Africa should:

- Develop technical CSP assessment competence by gaining access to CSP plants of international bidders, creating and validating modelling capabilities, and testing infrastructure.
- Decide on the best CSP technology option for South Africa.
- Create a sustainable market opportunity for CSP technology in South Africa.
- Enforce local supply share in future bids.
- Support local industry to become part of the local supply chain.
- Integrate academic and industrial research in a new programme.

Synergies and Differences between Fossil and Solar Power, Prof Sigmar Wittig, Leopoldina, Karlsruhe Institute of Technology

Approximately three years ago, the German National Academy of Sciences, Leopoldina, in cooperation with "acatech", the German Academy of Technical Sciences and the Berlin-Brandenburgische Academy for the Union of the German Academies of Sciences published a report entitled *Konzept für ein integriertes Energieforschungsprogramm für Deutschland* (*A Concept for an Integrated Energy Research Programme for Germany*). Various research fields were defined, specifically stating that research in solar thermal power has to be primarily directed towards application.

In defining a suitable and appropriate solar power system, it is necessary to consider aspects of performance, design, reliability, efficiency and cost from a detailed engineering point of view. Much experience has been gained with respect to the long-ranging performance analysis of classical thermal power systems, such as steam power plants, gas turbines and combined cycle plants, as well as from jet engine operation.

In terms of thermodynamics, such as the simple Clausius-Rankine Cycle and the Joule-Brayton Cycle, efficiency is primarily dependent on the fluid properties, i.e. pressure and temperature levels, as well as on component performance. Typical examples are shown in Figure 12.

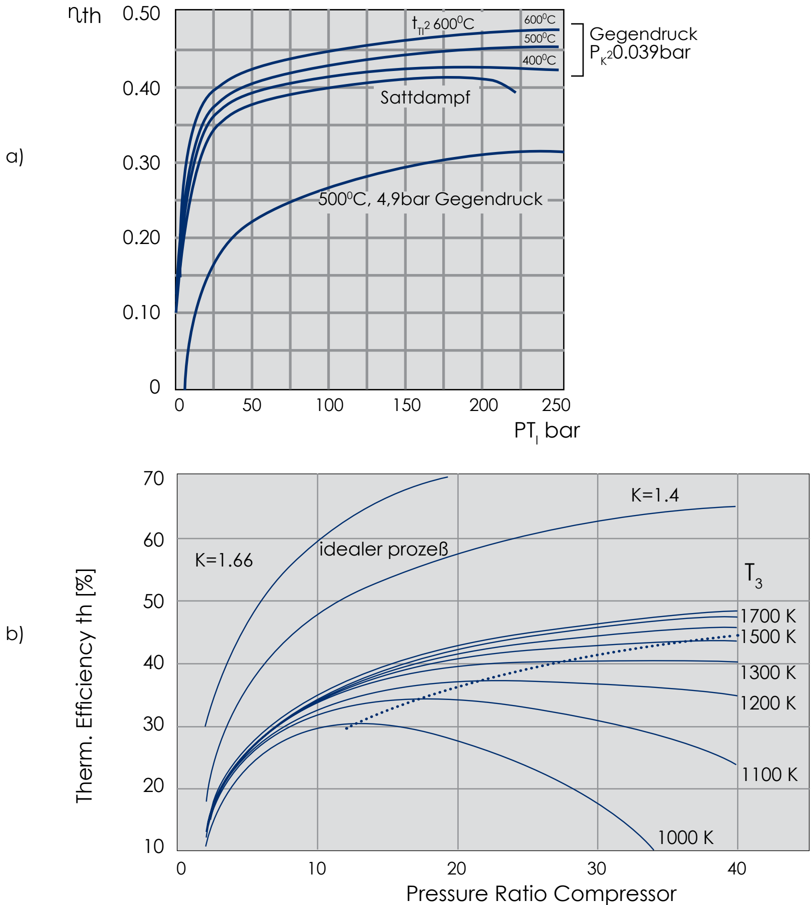


Figure 12: Thermal efficiencies
a) Clausius-Rankine (Steam) Cycle
b) Joule-Brayton (Gas Turbine) Cycle
(Source: KIT, Institute for Thermal Turbomachinery)

It is obvious, that the long-ranging experience with conventional plant operation is an excellent base for the design of solar thermic power systems. On the other hand, the specific conditions of solar power require major modifications. Especially, lower temperature levels and unsteady power availability lead to new design criteria. In the present context, primary emphasis is directed towards the power train.

An excellent example is the vapour solar-thermic power station Andasol III (See Figure 13). The relatively low-temperature level at the inlet to the high-pressure turbine requires special attention to the steam quality in the low-pressure turbine, i.e. to avoid major erosion and corrosion of the turbine blades. Furthermore, transient stress loads on shafts, blades etc. due to unsteady operation lead to modified design requirements.

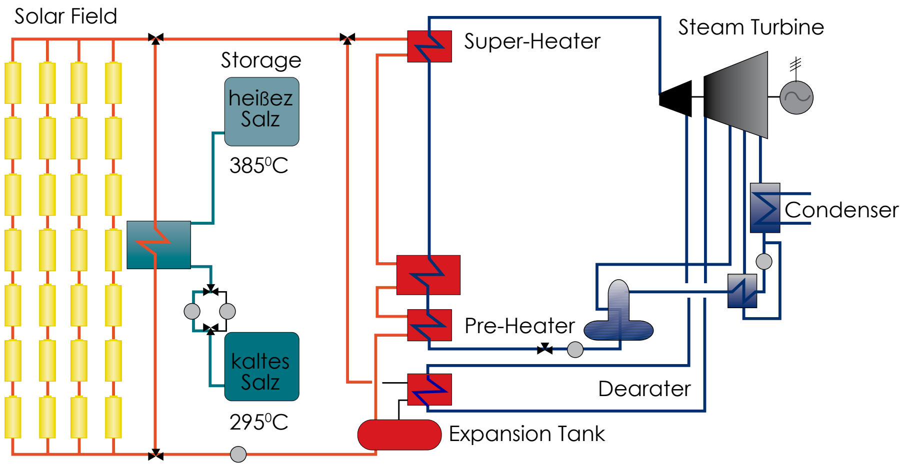


Figure 13: Vapour solar-thermic power system: Andasol III
(Source: Dr Reuß, MAN Diesel & Turbo: ISROMAC, 2012)

In considering other plant layouts, such as the Linear Fresnel Solar Thermal Power Plant, Puerto Errado (PE2) for example, saturated steam enters the turbine and as such, the design challenges mentioned above are of even higher importance. In addition, frequent start-ups lead to vibrational excitations primarily of the turbine rotor components with major effects on reliability and lifetime.

Although primary attention has been directed in this context towards the rotating machinery, i.e. the steam turbine, major challenges are found in the design of the heat-exchanging equipment, i.e. condensers, superheaters, separators, as well as in the associated high-pressure feedwater pumps. Here, traditional power plant design provides an excellent base for the new systems. Specifically, impressive expertise exists in South Africa concerning cooling tower technology.

In general, it can be stated that the advantages of vapour power cycles include:
- Relatively high cycle efficiencies.
- A broad range of power levels.
- The incorporation of different energy sources.
- Operation over extended periods of time and high reliability.
- Relatively low material masses per power and energy output.

On the other hand the disadvantages of vapour power cycles are:
- They are two-phase systems with condensation.
- Heat transfer takes place at low densities.
- Cycle operation is strongly dependent on fluid properties such as:
  - Wetness
  - High-expansion ratios
  - Speed of sound, i.e. Mach number.

In considering various cycles, one-phase systems in general offer major advantages. As such, gas turbines have been shown in modern power plant development to be of increasing interest, especially in combined cycle applications (See Figure 14). High-temperature levels, short start-up times and relatively small plants, i.e. high specific power lead, in addition to excellent performance and reliability, to relatively low-investment costs.

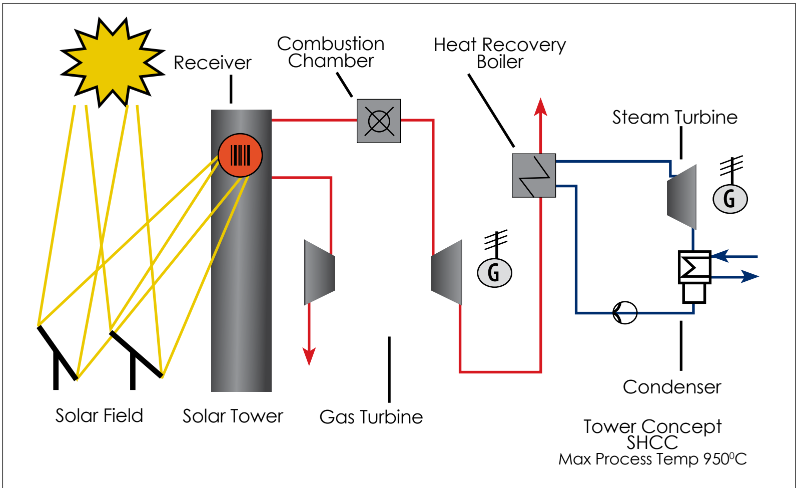


Figure 14: Solar Hybrid Combined Cycle (SHCC)
(Source: Dr Reuß, MAN Diesel & Turbo: ISROMAC, 2012)

The problem, however, with using modern gas-driven equipment in solar applications is the indirect heat transfer, for example, within the solar power receiver. Maximum temperatures are limited by the materials of the external receiver and associated hot gas-carrying ducts. The addition of an (internal) conventional combustor will support a continuous operation even at elevated temperatures. In general, it can be stated, that the future development of gas turbine-based solar thermal power plants can depend on many years of experience with successfully tested high-performance gas turbines and jet engines with extremely high power density. A wide range of possible alternative cycle options and combinations, as well as systems designs remains to be tested. For example, the efficient use of gases other than air with higher specific heat ratios would lead to improved efficiencies (See Figure 14) requiring, however, closed-loop designs.

In conclusion it can be stated that:

- Development of solar thermal power generation can be based on long-ranging experience from fossil-fired power plants.
- Specific difficulties arise from solar energy transfer and collector technology, such as

  - temperature levels and steam quality;
  - demands for highest efficiency;
  - operational requirements, i.e. start up frequency, temperature variations, etc.
- Modified cycles offer promising improvements.
- Specific designs are necessary in rising efficiencies and reducing investment costs.

Operational Aspects and Environmental Profile of Solar Thermal Technologies, Dr Christoph Richter, German Aerospace Centre: Institute of Solar Research

Currently, three Andasol power plants are in operation in Spain, each producing 50 MW, with 7.5 hours of storage (Plate 1). Each plant covers about 2 km^2 and provides about 500 jobs during the two years of construction and about 50 permanent jobs during operation. Storage tanks, 36 m in diameter and 14 m high, are filled with 30 000 tons of molten salt that can be pumped through the solar field to heat it up and stored in two tanks. The tanks are designed to provide a nominal capacity of about seven hours of electricity. This means that the plant with a nominal capacity of 50 MW to the grid is able to run from the thermal storage without sun for seven hours.

Plate 1: Two thermal storage tanks and field at Andasol Plant *(Source: Solar Millennium)*

The most advanced solar thermal tower plant is the Gemasolar (Plate 2), which produces 20 MW nominal power and is designed for 15 hours storage. PE2, a 30-MW CSP plant built by Novatec using Fresnel technology, started operation recently. It is the biggest Linear Fresnel solar thermal power plant to date. The plant's design includes a small steam-storage system that is integrated and allows for smooth operation parameters of the plant even during fluctuating solar irradiation.

Plate 2: Aerial view of Gemasolar plant in operation *(Source: www.torresolenergy.com, Image library)*

There are many modelling efforts underway producing a variety of options to integrate data to ensure system optimisation of solar power systems. A further aspect that supports the technology and rollout of the systems is the quality assurance of the parabolic troughs during manufacturing and operation of the thermal systems to guarantee precision and the expected performance and economic result.

Results of a business case analysis of the system in North Africa shows the modelling of the transition from a system that is based on heavy fuel oil and light fuel natural gas to a more renewable energy system-based on PV, using solar radiation when it is available and CSP with storage capacity to balance the other fluctuating energy sources. A business case study for Germany shows the role of variable and flexible renewable power sources in a 90% renewable electricity scenario for the year 2050, with a high proportion of PV in installed capacity, 50% of variable renewables, 40% flexible renewables and 10% natural gas, to accommodate electricity demand in summer and winter.

The greenhouse gas (GHG) emissions per kWh of solar thermal power plants are below 100g per kWh, similar to other forms of renewable energy and much lower than the conventional fossil fuels, contributing to a high saving in GHG emissions when replacing fossil fuel power plants. The lifecycle land use of solar thermal power plants is minimal and water consumption is dependent on the overall efficiency of the system, the combination of technologies and whether a wet, dry or hybrid cooling system is used.

A niche market exists for applications of solar technologies in treating toxic components in the water to make it easier to clean further in urban treatment plants. Long-term developments include the use of CSP to drive thermo-chemical cycles of water to generate hydrogen as a solar fuel and produce liquid fuels.

In summary:
- The broad experience in commercial CSP technology contributes to the fast-growing area of green technology.
- There is a large amount of R&D to monitor and improve performance of CSP technology.
- CSP technologies have a good environmental profile, which is continuously improving.
- CSP can contribute a significant share of clean energy to the power sector.

Facilitated Group Discussions, Panel: Prof Van Niekerk, Prof Werner, Prof Pitz-Paal, Prof Wittig and Dr Richter

Questions and Comments
Saliem Fakir: Based on the Panel's knowledge on renewable technologies, is the goal of reaching 100% renewable electricity achievable in the next 50 years, and what would it take to achieve this goal? What would be the strategic opportunity for South Africa to participate in CSP, or would it be better to delay our participation?

Thomas Roos: Prof Pitz-Paal made an important statement about the integration of academic and industrial research in new programmes. A point was raised earlier about the need to focus research. A study, funded by the DST and subsequently taken up by the DoE's Centre for Solar Energy Competence pointed towards dry cooling and solar gas turbines as being important for South Africa. Independent of this study, SASOL, CSIR and Stellenbosch University were undertaking work on solar gas turbines. It was surprising that German Aerospace Centre (DLR) representatives made no comment on the smelting of secondary aluminium as a possible energy-intensive material. Most of our secondary aluminium is not processed in this country, but exported to Japan where it is processed. It was as a result of the DLR analysis that the CSIR is investigating secondary aluminium and a proposal in this regard will be submitted to the Federal Ministry of Education and Research (BMBF). What is the Panel's comment on this aspect of energy-intensive materials and the other aspects of solar fuels, such as the solar upgrade of carbonaceous feedstocks, which we believe is the more cost-effective route to introduce renewables into our very energy-intensive processes?

Velaphi Msimang: In terms of the comments made about the suitability of South Africa participating in this whole range of technology options and partnering industrial with academic research, what would be the potential of leveraging this partnership to build the country's capabilities, in the context of the local content specification and given the skills and efficiency constraints of this country? Could there be missed opportunities if we procure of a variety of renewables as opposed to carefully selecting specific renewables that would enable a skills base to be built?

Responses from the Panel:

Robert Pitz-Paal: It should be easier for South Africa to achieve 100% renewable electricity than for Germany, although it remains a challenge. The availability of resources it not a problem for South Africa. The pace at which renewables are introduced will depend on the development of prices of solar and wind energy. If these costs continue to fall, these renewable energy sources will become the cheapest option. It is obvious that with the resource potential and the technology available to this country, the renewable energy goal should be achievable.

In terms of the benefits of CSP in South Africa, it is an opportunity to combine expertise in a sustainable technology that clearly has a future in this country because of the resource potential, and its potential to complement other technologies to secure supply. The technology can be supplied locally and will boost the local economy. Over time and as markets develop, more complex projects can be undertaken, such as building the mirrors or the absorber tubes, but it does not make sense to start with a commercial application because initially there will be failures due to competition with large, established international companies. Perhaps South Africa should start projects in cooperation with these companies in order to get access to the technology and then define the rules in the context of the South African market. There are companies that are ready to cooperate with South Africa in this way.

The choice of technology for South Africa should not be an academic choice, but should be a choice taken together with an industrial supplier, perhaps an international supplier at the onset. It is important to choose the appropriate industry partner for technology that is already in the market and where financing is possible, and try to develop further. There is a high risk of failure if South Africa undertakes a CSP project on its own.

Aluminium smelting and other applications are a potential option for using CSP technology. Our experience however, is that all these options are not yet competitive. It is necessary to develop a funding mechanism for aluminium smelting or solar fuel production as these options are more difficult to fund than electricity production. It is suggested that these options are researched to get more insight and know-how while working on the electricity sector, and wait until the cost reduction in this region comes to a point and other aspects are commercially viable. Once the technology gets cheaper, there will be a competitive option for aluminium smelting or solar fuel production, and it will not be necessary to find more funding to support projects.

Wikus van Niekerk: World markets in CSP have provided a window of opportunity for investment in CSP right now. South Africa has some constraints in this regard, such as the IRP 2010 that only calls for a very small proportion of energy to be supplied by CSP. The additional value that CSP electricity can provide in peak-demand times is significant.

I agree with the sentiment that the solar projects will be subsidised by South African tax payers who have every right to certain demands of the development partners.

Renewable energy in South African needs a champion in government to nurture the cause and ensure that aspects, such as localised requirements and sharing of knowledge are taken into account in the procurement processes, and that the country derives maximum benefit from new projects. The Minister of Energy is not receiving the best advice on different energy options for the country. Specialists who are knowledgeable in the field should be offering advice to government. I am however, optimistic about the future of renewable energy in this country.

CSP is important in the South African context because solar renewables in the Northern Cape will be placed where the grid is weak and where there is no generation. Not only do we need the CSP plants to assist the PV plants and produce electricity when the sun goes down, but they are also required in order to anchor our grid in the Northern Cape. This is a compelling argument for CSP in the South African context.

Sigmar Wittig: I am convinced that it is possible for South Africa to achieve the 100% goal, technologically. However, this country's socio-economic situation differs greatly from that of Germany. The point has been made at this conference that carbon should not be the dominant factor in the energy options for South Africa. I tend to agree with this and think that renewable energy should be introduced slowly, taking into consideration the economic and social realities of this country. In the current circumstances, it is important to keep the cost of electricity as low and as affordable as possible. In terms of research cooperation between academia and industry, I am of the view that the R&D expenditure in South Africa should be increased, and industry can assist in this regard. Good ideas from academic research cannot be imposed on industry. Industry must lead research and support the developmental process, based on an agreement between the parties.

Jürgen Werner: Germany received 3% of its electricity from hydropower 20 years ago and this has risen to 25% in 2012. The official goal of the German government is to have 35% of its electricity from renewable sources by 2020 and 80% by 2050. This will require storage of electricity. These plans are based solely on PV and wind energy and storage systems are mainly based on methane. CSP is not included in Germany's plan. If CSP is used in South Africa, South Africa will be able to achieve the 100% goal.

The current situation is that people from other countries want to sell products that are not necessarily suitable for South Africa. South Africa must build and invest in its own knowledge base in universities and industry where independent South African opinions must be grown and nurtured. Own hands-on experience in the technology is necessary in order to choose the right options that respond to the needs of this country. What is good for other countries may not be appropriate here. However, this would require investment.

Christoph Richter: Upgrading of carbonaceous feedstocks is another option of solar fuels that should be investigated. However, this is not necessarily the best option for South Africa in the short term.

Questions and Comments:

Unknown Person: Prof Werner has said that South Africa should use its own universities and science councils to develop technology for this country, and Prof Pitz-Paal has suggested that international collaborators should be involved. We cannot work in isolation. Collaborative partnerships are always business-oriented and confuse policymakers. However, development of new technologies requires assistance that will contribute to the development of the country.

Unknown Person: A recent article in a local engineering journal indicated that Germany is moving into another coal-fired power station incentive, developing 23 coal-fired power stations, with one under construction. How does this affect Germany's long-term plan for renewable energy?

Peter Lukey: Prof Van Niekerk made a point about the dialogue between industry and government and the regulators. Although policy and plans are in place, there does not appear to be a conversation between developers and government about implementation. A developer who has a system has to obtain authorisation from numerous government departments in order to implement such a system. There does not seem to be any platform for this dialogue. Does a similar situation exist in Germany and was there a continuous dialogue between industry and the regulators in terms of removing barriers to achieving goals?

Richard Worthington: The discussion on the value proposition of the different conditions is interesting. Is there more work being done, particularly concerning the contribution of CSP, around the value proposition of the different technology offerings from the point of view of where the energy supply should be in the future? So much of the value is difficult to prove under current market conditions. If we look at the situation where we need to be in future, the value proposition for the current technologies seems to be more compelling than the incumbent system we have.

Louis Roux: CSP electricity at R2.50 per kWh is expensive. Even nuclear power is cheaper than that. PVs present an opportunity to provide electricity to smaller users. I believe that South Africa should focus R&D and investment in the ocean as a resource of renewable energy as it clean and constant. We have excellent resources but are constantly bullied by those who propagate solar energy and the industry across the world that is dominated by solar. What is the status of research into energy from the ocean's waves and currents?

Responses from the Panel:
Jürgen Werner: The point raised by Mr Roux formed the centre of discussions in Germany 20 years ago. The people of Germany made the decision to no longer use nuclear or coal power whatever the cost advantage might be. Germany uses all available resources to produce renewable energy. Although nuclear might be less expensive to the consumer, it has other problems. Research into generating renewable energy from the ocean could be difficult to apply. Technologies such as wind, CSP and PVs can be applied now, on an industrial level. What prevents us from using the technologies that are already available? Research will not bring down the cost of the product. It is mass production that brings down the cost. This was the case with PVs. About 20 years ago the efficiency of PV modules was 10% and it is currently 17%, and the cost has decreased substantially.

Sigmar Wittig: In Germany the gross domestic product (GDP) *per capita* is much higher than in South Africa. Electricity costs have increased in the last few years and continue to increase in Germany. Germany shut down seven nuclear power plants immediately. Germans did not realise how close they came to a catastrophe concerning power supply earlier this year. Every effort was made to import power. Germany does not have a decentralised supply. It was necessary to build a centralised station as fast as possible. I cannot offer advice because I do not have sufficient knowledge, but I can explain the experiences of Germany. It is better to have a slow movement towards technological developments and not a sudden change as this will bring a catastrophe.

Wikus van Niekerk: The point made about collaborative partnerships being business-oriented is true. The problem is that business has very short horizons, whereas strategically, the country needs longer horizons. It is difficult to reach synergy between short-term financial goals and long-term strategic goals. A strategic and not a business decision was taken to establish Sasol.

Most of the renewable energy project developers are small entrepreneurs with small budgets who have until recently been somewhat disorganised. In future there will be a better dialogue between government and industry. It should be remembered that nuclear and fossil fuel energy have been substantially subsidised in the past, whereas renewable energy has to be cost-effective from the onset. Huge coal and nuclear companies come to this country and spend millions lobbying funding organisations, running short courses and being involved in other activities, while the renewable energy group does not have the same gravitas behind it. The renewable energy group is faced with an unfair situation.

In terms of cost, Eskom is running open cycle gas turbines at R5 or R6 per kWh, yet CSP at R2.50 per kWh is too expensive for Eskom. When the CSP industry is started, energy production of a CSP plant should be compared with an open cycle gas turbine. As we become more experienced with CSP plants and the prices decrease, CSP will become more cost-effective. Eskom should compare CSP with their most expensive energy generation.

I support research into ocean current energy, but even the Agulhas Current will not produce baseload because of certain reversals that take place in the current.

A symphony of renewables, all of them working together to supply energy and job security, and economic development to the country, is what is required for South Africa.

Robert Pitz-Paal: In terms of the value proposition of CSP, this subject is very relevant and has been addressed by many countries. One of several reports on this issue, a report from the Desertec Industrial Initiative was based on a complex study of the energy supply in North Africa and Europe in 2050 and an evaluation of the role of the different technologies and energy mixes. The report, as well as other information to this effect can be downloaded from the internet. This is a possible topic for R&D.

NEW AND EMERGING TECHNOLOGIES

FACILITATOR: DR VELAPHI MSIMANG, MAPUNGUBWE INSTITUTE

***The Beauti-Fuel Project:* A Biomass to Fuels Concept, Prof Diane Hildebrandt, Centre for Material and Process Synthesis, Wits**

The challenge facing South Africa (and the rest of the African continent) is how to use our expertise and skills to benefit the country and its people, particularly in terms of improving quality of life. Postgraduate chemical engineering students at the University of the Witwatersrand discussed possible ways to address this challenge in the following context.

In order to improve quality of life it is necessary to increase access to energy. Electricity and fuel, particularly diesel, are the two sources of energy that are in short supply in Africa. However, efforts to increase access to energy in Africa will have to take cognisance of the worldwide pressure to reduce CO_2 emissions while supplying affordable energy. Cooperation, new processes, different resources that pollute less, and improved energy efficiency are essential in order to limit the impact of carbon emissions, provide cheaper energy to more people and provide employment opportunities.

The problem faced in South Africa is not unique as in almost all countries the cost of electricity is below replacement cost. Attempts to reduce the cost of electricity by installing new equipment are not politically, economically or socially feasible. Technology should not be imported from abroad, or care should be taken in doing so as the drivers elsewhere often differ from those in South Africa. Technologies should provide employment to both skilled and unskilled people in South Africa.

In addition to the mix of energy discussed in previous presentations, other potential energy resources that could be used to address the problem that are often regarded as environmental problems are:

- agricultural waste and/or excess from the sugar industry, paper industry and farming activities;
- old tyres;
- municipal wastes (sewage and garbage).

The Centre for Material and Process Synthesis (COMPS) based at the University of the Witwatersrand provides multidisciplinary project solutions to industry using resources from across academia and industry. COMPS is regarded as a world leader in a number of areas:

- reactor design;
- separation design;
- process design for improved process efficiency.

COMPS has worked in Fischer-Tropsch (FT) technology for the last 20 years because this technology is important in the chemical industry in South Africa. This experience was used to develop a novel technology process that has lower CO_2 emissions, that is more scalable and more flexible, reduces water requirements, and is small, yet economically competitive. The technology is fairly simple and is a downscaled version of technology used by the Germans during World War II. The process involves gasification using air or enriched air, gas clean-up to remove sulphur and other substances that could cause a problem with the catalyst, FT synthesis, and the removal of liquid products. The remaining light hydrocarbons and unconverted syngas are used for electricity generation. The process produces both liquid products and electricity and makes a very good quality diesel. Furthermore, the process can respond at short notice to fluctuating electricity demands while in operation.

Research done at COMPS was used to look at how to reduce efficiencies in the process. Individual units used in the process are all conventional, interconnections between the units are novel and the technology is simpler than current commercial technology, and is therefore low risk. The concept has been tested in other projects such as:

- Golden Nest and clean coal technology (CCT): A pilot plant located at BaoDan in China was commissioned in 2008 and operated for 18 months to get data for the full- scale implementation of the technology. COMPS was involved in the conceptual design, the feasibility study and in the basic engineering. The detailed engineering was done in China under the supervision of the COMPS team, and the commissioning, collecting and analysing of data was led by Masters and PhD students. The process proved to be simple and robust.
- Linc Energy: Underground coal gasification was combined with FT for the first time at a demonstration plant in Australia. The plant was successfully commissioned and will possibly be implemented.
- Floor-scale demonstration plant in China: The project is based at the University of Herbei, the gasifier is a commercial unit and the plant uses wood chips as a feed.

T*he BeauTi-fueL* concept, in partnership with the South African Nuclear Energy Corporation (Necsa), is looking at using agricultural waste as a feed to the process, which will produce synthetic crude and electricity. The idea is to uplift and make small communities self-sufficient in energy and for the plant to be simple and robust to operate. The scale of the plant is of the order of 1 ton of dry biomass per day that will be converted to 1 barrel of synthetic crude per day and 0.5 MWh of electricity per day. The plant will be designed to fit into a shipping container so that it can be transported on a truck. A prototype will demonstrate the concept, to optimise and get more reliable data for implementation.

A mock-up plant, placed inside a shipping container and transported on the back of a truck was built for COP17 in 2011. The concept is one of economy-of-scale by making many small plants that fit into shipping containers rather than a single, large plant. This modular approach has the advantage of being less capital intensive and more flexible, and will have a faster time-to-market. New ideas will be able to be incorporated in later modules to enhance efficiency of the technology.

The business case is as follows:
- Capital cost per container is expected to be in the region of R4.5 million. If *BeauTi-fueL* containers are built in bulk, this cost could be reduced considerably.
- Operating expenses are estimated at R0.5 million per annum. This cost would be reduced considerably if the catalysts are manufactured in bulk.
- The cost of fuel produced will be considerably reduced if government provides tax breaks and/or allows fuel to be sold at a taxed rate.

In terms of the project cycle of technology, the perceived financial risk is low during the research phase, increases during development, peaks during demonstration, and begins decreasing through the deployment and maturity phases of the cycle. The challenge is to cross the barrier between the research and maturity phases, as investment from overseas is often the only available option. The research phase of *The BeauTi-fueL Project* received funding of about R1 million, and a further R50 million investment is required in order to reach the deployment and mature phases of the project. IP has the highest value at the mature phase. Universities are placed in a very weak position to negotiate IP as they are forced to sell their IP at the research phase when it at its lowest value and when overseas and not local companies are interested in the IP. This results in IP for technology that is researched and developed in this country being lost to other countries.

In conclusion:
- In order to improve the lives of Africans, it is necessary to supply cheap and renewable electricity and fuel. New feedstocks will have to be considered in order to do this.
- New technologies to utilise these feedstocks will have to be developed.
- Universities, government and industry will have to work together to make this possible.
- There is a gap in funding between universities, government and industry, and this means that universities are forced to sell IP and future IP rights to accommodate the perceived risk.
- A model should be developed that ensures that new technologies are funded through to the mature phase so that the IP is not sold too early and it can make a difference to lives of South Africans.

Carbon Capture and Storage in South Africa. Dr Tony Surridge, South African Centre for Carbon Capture and Storage, SANEDI

Carbon capture and storage (CCS) is regarded as a transition between the three types of energy available: fossil fuel, nuclear and renewable energy. Fossil fuels are part of the history of this country as they are relatively inexpensive and the technologies are well developed. However, fossil fuels are finite and irrespective of climate change, it has become necessary to incorporate renewables into the energy mix.

South Africa's energy economy is coal dominated, with 95% of electricity coming from coal. Half of the hydropower goes into pump storage, which is a net energy loss, and there is a small percentage of electricity from nuclear. Biomass, although it is renewable energy, is to a large extent not being renewed in the rural areas.

A projection of South Africa's CO_2 emissions, presented at the Department of Environmental Affairs (DEA's) Climate Change Summit in March 2009, showed an increase in emissions until 2020 to 2025 followed by a ten-year plateau and a decrease in emissions towards 2050.

The relationship between energy and the environment began at the beginning of the 20th century. Smoke pouring out of chimneys was a sign of prosperity through technological development, until there was an awareness of the negative impact of smoke on health. Several technologies were developed at a cost to mitigate the impact of excessive sulphur dioxide released into the atmosphere. Similarly, lowering carbon emissions will only be possible at a cost. One of the options to lower carbon emissions is CCS.

The principle of CCS is simple (Figure 15). Consider a gas field that has stored natural gas for ~100 million years. We drill a hole through the cap rock and release the gas. When the gas field is depleted, CO_2 is injected and the hole resealed, thus preventing the CO_2 from being released into the atmosphere. The most suitable places to store CO_2 are depleted oil and gas fields and deep saline aquifers. The CO_2 must be captured from the source. Electricity generation stations chimney emissions contain about 12% concentration of CO_2 and synthetic fuel plants produce 95% concentration CO_2.

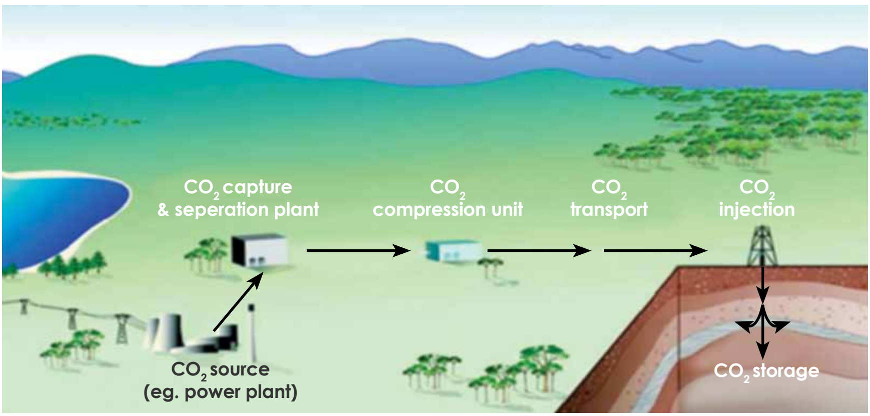


Figure 15: CCS Process *(Source: CO2CRC/IEAGHG)*

In the CCS process, CO_2 is captured, compressed, transported and injected into a storage site where the rock is porous at least 800 m below the surface and sealed by caprock. This is followed by ongoing monitoring and verification of the site and the trapped CO_2. CO_2 is not stored in a cavern or depleted mines. The risk of CO_2 rising to the surface is decreased as the permanency stages advance. It is essential to ensure the integrity of the sites.

The permanency stages of trapped CO_2 involve:
- Structural trapping
- Residual trapping
- Solubility trapping
- Dissolving in saline water
- Mineral trapping (When the CO_2 reacts chemically with surrounding rocks to become part of the rock over a long period of time.)

There are a number of CCS projects throughout the world, where the technology has been used successfully for several decades. An investigation in 2004, showed that there was potential for CCS in South Africa. The South African Centre for Carbon Capture and Storage (SACCCS) was established in March 2009. It is funded by a number of core parties and participants and aims to scale-up CCS technology in South Africa. The *Atlas on Geological Storage of Carbon Dioxide in South Africa*, published in 2010, shows potential sites for CO_2 storage, most of which are offshore. Preparations are underway for a Pilot CO_2 Storage Project and the first test injection is expected to take place in 2017. A timeline showing progress in CCS is depicted in Figure 16.

Figure 16: Timeline showing progress in CCS in South Africa

CCS is a flagship programme of the National Climate Change Response White Paper, which was released by the DEA in November 2011. The Carbon Capture and Storage Road Map was endorsed by Cabinet in May 2012. A CCS regulatory regime for South Africa is currently being developed by the DoE and the technical aspects of CCS are being addressed by the SANEDI/SACCCS.

Clean Coal Technologies in a Low Carbon Economy: South African Scenarios, Prof Rosemary Falcon, Wits

Coal has a limited lifespan and it is essential to prepare the way for nuclear and renewable energy. CCS is one of the options to make coal more efficient. South Africa and its neighbouring countries have huge coal reserves. The problems relating to carbon emissions from coal in this country are unique and much needs to be done to ensure that the coal is used in an environmentally friendly and efficient manner.

The International Energy Agency (IEA) and the World Energy Council plan to reduce global warming, which implies that coal's share of the total energy demand will be substantially reduced from 30% to 16% by 2035. In order to achieve this goal the following factors will come into play:

- Efficiency (of use as well as process technology)
- Renewables
- Biofuels
- Nuclear
- CCS

Efficiency gains using today's technology can cut CO_2 emissions by 33% and make significant changes in fuel use and emissions. Technology is capable of bringing down the CO_2 emissions by a maximum of 50%, beyond which CCS will be required.

South Africa is the highest coal-dependent country in the world according to IEA standards and is the seventh largest producer of coal in the world and the sixth largest exporter of coal, even though it has less that 10% of global coal reserves. Coal in South Africa accounts for:

- the second largest foreign exchange earnings in the country;
- 95% of the energy production, 81% of the region's energy;
- 90% of carbon reductants in the metallurgical industry;
- 40% of petrol and diesel requirements;
- 200 major chemicals for thousands of carbon-based products, many of which are exported.

In terms of growing demand for coal in South Africa, it is predicted that the total requirements of coal will increase from 250 million tons in 2010 to 350 million tons by 2020, representing a 40% increase. New mines for expansion and replacement will be necessary and export potential will be driven by China and India. However, this growth is constrained by transportation infrastructure.

The value of coal is only slightly less than the value of the platinum group metals to South Africa, and coal is therefore vital to the South African economy. It has been shown that if South Africa did not use any coal at all, the cost to the country would be R260 to R422 billion per year, excluding the benefits of investment, employment, taxation, economic stimulation and more. It would be necessary to import 230 GW of electricity or coal and crude oil.

According to the IRP 2010, government intends to reduce coal as an energy resource from almost 100% to 56% between 2010 and 2030, substituting it with co-generation, renewables, gas, wind, hydro and nuclear energy. However, the projected rise in energy requirements of this country will require a proportion of coal (in terms of its MW production) in the energy mix that is similar to the proportion predicted for 2015. This accentuates the necessity to find clean coal technologies.

Coal is a natural dirty carbonaceous 'rock' and a complex fuel, and it has many pros and cons. It is necessary to minimise the adverse effects (air and water pollutants and GHG emissions) and maximise the social and economic benefits, including its reliability, affordability, abundance and the fact that it is easily transported and that markets for coal function well.

Technologies for cleaner coal generation involve:
- reducing the coal consumption by increasing the efficiency of coal into the boiler to generate power;
- reducing non-GHG emissions by capturing the pollutants;
- CCS.

South Africa produced 303 million tons of coal in 2011 of which 24 million tons were used locally by 6 000 industrial users, and 64 million tons were exported. Local coal products are graded according to calorific value: special grade and grades A to D. It is important to note that coal is used not only to produce electricity. South Africa used to export 88% of its coal production, the high-grade, clean, low-ash coal, to Europe. This left middle-quality coal for local industry. More recently, the Asian demand is stimulating the export of coal to the East. Currently, South Africa exports 60% to 70% of its coal to India and China, with huge implications for this country. The Far East countries require a lower grade, poorer coal, leaving the poorest coal for local use and making it difficult to provide efficiency. As a result of the changing and reducing grades, Eskom's grid emission factor has increased CO_2 emissions in terms of electricity over a period of ten years. Combustion problems from using poor-grade coal cause reduced combustion efficiency.

The challenges in the coal industry are that:
- coal qualities are generally poor;
- beneficiation of coal is essential, although difficult;
- the bulk of the best-quality coals have been mined out in conventional areas;
- remaining coal resources lie in relatively remote coalfields where there is a lack of infrastructure and it is often difficult to mine conventionally.

These challenges have several consequences. Increasing export tonnages to the East leaves the poorer grades for local markets and better, more consistent qualities of coal is obtained at a higher cost. It is very unlikely that South Africa will be able to meet the European standards for carbon emissions given the nature of the coals used in this country. Variable combustion efficiencies due to poor feedstocks will have to be addressed in the face of increasingly stringent environmental constraints and a pending carbon tax. New process technologies will be required to increase combustion efficiencies. These are being considered by Eskom and are expensive and new, and the technology has to be compatible with local coal qualities.

Clean coal technology options take into account the South African coal value chain: coal mining, coal preparation, coal usage and ultimately high-value uses of coal. Areas of current and ongoing clean coal technologies R&D in South Africa include:

- Beneficiation
- Combustion
- Polluting emissions
- Carbon dioxide capture, transport and storage

New and emerging technologies for clean coal include:

- Carbon reductants in the metallurgical industry
- High-value coal-based carbon products
- Carbon dioxide utilisation.
- Algal-based technology
- Co-firing biomass waste
- Underground coal gasification

Coal provides about 45% of the world's energy requirements and is likely to do so for some decades to come. However, this must be done responsibly as a source of industrialisation and human development during the transition to alternative clean energy sources.

Advanced Lignocellulose Conversion Technologies for Sustainable Bioenergy Production in South(ern) Africa, Prof Emile van Zyl, Senior Chair of Energy Research: Biofuels, SU

Renewable energy can make up to 50% of the share of total energy supply to countries north of South Africa, although not in an efficient and sustainable way. Charcoal is the energy currency in most of Africa.

The primary energy needs of Africa are currently so low that the biomass growing on underutilised land can provide the primary energy source and bioenergy can play a specific role in the African context.

The Chair of Energy Research (CoER): Biofuels focuses on biomass conversion technologies, but acknowledges the importance of establishing the whole value chain. The CoER interacts with different departments of Stellenbosch University (SU), as well as other universities.

There are various lignocellulosic biomass conversion options:
- the biological route to cellulosic ethanol;
- basic combustion;
- pyrolysis;
- gasification.

The CoER has put most of its efforts into biological conversion of biomass, and has partnered with Sasol to work on gasification. Research objectives in this regard include:
- development of second-generation technologies for biofuels
  - microbial hydrolysis and fermentation
  - pyrolysis and gasification of lignocelluloses;
- process modelling and development of bio-refinery concepts;
- scenario building, techno-economic and lifecycle analysis of these technologies.

Microbial conversion of cellulose to ethanol has been investigated for some time, together with colleagues in the US. The process for producing ethanol from sugar is classic, and ethanol production from cellulosics using polysaccharides is a more costly and complex process.

The CoER focus is on Consolidated Bio-processing (CBP), which consolidates the enzyme step with the fermentation step of the process. Technology was developed together with an American company, Mascoma. A demonstration plant was built close to New York where the technology was demonstrated in enzyme reduction on paper sludge, a by-product of the paper industry. In addition, the CoER has developed in-house expertise on steamgun pre-treatment of lignocellulose.

In terms of thermochemical technologies for biofuel production, the CoER has been looking at:
- Optimisation of fast, slow and vacuum pyrolysis with sugarcane bagasse, corn stover and eucalyptus for the production of charcoal, bio-oil, activated carbon and biochar.
- Co-gasification of biomass with coal in a Sasol-type process addressed in terms of differences in reactivity between biomass and coal, and how this affects the overall process performance.
- Helping Sasol to make biomass and technology choices towards utilising up to 10% biomass as a feedstock for the FT process.

The CoER has developed valuable expertise to assist industry in evaluating different technology combinations in pre-feasibility desktop studies in terms of lifecycle analysis and modelling. Some examples are:
- Process (bio-refinery) modelling of both biological and thermochemical processes for optimisation of energy efficiency and as basis for economic assessments for second generation biofuels production in South Africa.

- Quantification of the economic risk associated with second generation biofuels production. This demonstrated that second generation bio-ethanol production may be viable in South Africa.
- Lifecycle assessment to compare biological and thermochemical processes for conversion of lignocellulose to biofuels. This demonstrated that energy efficiency was critically important to maximise environmental benefits.

Integrating first and second-generation technologies could create opportunities for sub-Saharan Africa, as energy plays a key role in the development of nations, provides vital services and improves quality of lives. Renewable energy has a key role to play in improving the quality and magnitude of energy services to sub-Saharan Africa's population of about 800 million people (which is expected to grow to 1.2 billion by 2020), most of whom live in poverty and do not have access to electricity. In developed countries, the main thrust for producing bioenergy is the replacement of fossil fuels, whereas in Africa there is a unique need to address socio-economic issues, such as chronic food and energy insecurity, extreme poverty, high unemployment and the degradation of the natural environment.

Africa has huge potential in biofuel production using available and existing technology, although the constraints of the continent need to be recognised. Green fuel and second-generation plants would be capital intensive and too costly. However, integration with first-generation plants in the paper or sugarcane industries would be possible solutions. An example is the production of fuel from sugarcane. Currently, ethanol production in Africa is very low and sugar production in southern Africa is concentrated on only 325 000 hectares of land in South Africa. A recent study (Watson, 2011) estimated that about 6 million hectares of arable land in SADC countries (primarily Mozambique, Angola, Tanzania, Zambia, Zimbabwe and Malawi) are suitable for sugarcane production and will yield an average of at least 65 tons per hectare. This implies that the South African sugar industry can be replicated every year for at least 15 -20 years in southern Africa. Theoretically, Africa is producing only 1% of its potential and can, together with Brazil, be a major biofuel producer in the future.

As the world considers paths to a sustainable future and the role of bioenergy in this context, Africa can contribute important assets and wants to be an active partner. However, it is essential to ensure that bioenergy development is implemented in a way that contributes to critical human needs. To this end, the CoER participates in the Global Sustainable Bioenergy Project (GSB). A draft resolution was developed at the African Convention of the GSB in 2010, accentuating Africa's role in bioenergy production and indicating the actions that need to be taken to ensure that Africa benefits along the full value chain of bioenergy supply and utilisation, and includes the development of:

- More analysis, understanding, and consensus on the potential of bioenergy to realise a sustainable Africa.
- African scalable demonstration projects using latest state-of-the-art

technologies and African raw materials for learning perspectives.
- Required human capacity and career opportunities, including creating an African intellectual base, reducing the brain-drain and engaging existing African traditional knowledge systems.
- The institutional resources to foster coordination across Africa for stakeholder interaction, and suitable strategies, policies and initiatives.
- Pilot projects to show best practices in energy efficiency and resource protection in transport, electricity supply, cooking and other household needs.

In addition to the above, international, regional and local policies on trade, aid, land tenure, and development have to be aligned to develop integrated value chains of agriculture and forestry for food and bioenergy in Africa.

The CoER has developed a strategic partnership with New Partnership for Africa's Development (NEPAD) and is working closely with the organisation in terms of the implementation of bioenergy and agriculture programmes in Africa.

A sustainable world needs a sustainable Africa.

Clean Electrification for the World, Mr Hulisani Nemaxwi, Corporate Communications Manager, Energy: Siemens

Siemens is committed to innovating green energy technologies for the future.

Research has shown that:
- agricultural production in Africa is expected to drop by 50% by 2020;
- about 70 to 200 million Africans may be at risk because of increased water stress levels due to climate change;
- a 2°C rise in temperatures may expose an additional 40 to 60 million Africans to malaria;
- rising sea levels may cause increased risk of flooding and severely affect mangrove forests, as well as coastal fisheries.

There are about 550 million people in Africa who do not have access to electricity. Siemens faces the challenge of how to supply low carbon electricity to Africa, in collaboration with government, the public sector and business, using all available resources to achieve energy security in a sustainable manner while supporting local economies.

Siemens aims to enhance the quality of lives through innovation, is involved in the entire energy value chain and has been present in Africa for over 150 years. The company is committed to R&D, particularly in green technologies for a variety of sectors, and has invested €4 billion in R&D during the 2012 fiscal year, exceeding the previous year's investment in R&D by €500 million. In 2011, the quality of Siemens' inventions helped its customers to reduce CO_2 emissions by 317 million tons and revenue from the company's environmental portfolio increased to almost €30 billion.

In 1889, Siemens built its first renewable energy project in Cape Town, the Molteno Reservoir, the city's first power plant and the first hydropower station in South Africa. Siemens was a key partner in the construction of the Cahora Bassa hydropower plant in Mozambique that was built in 1977 and supplied bipolar high-voltage direct current (HVDC) lines that transmit electricity from Mozambique to Johannesburg. Siemens is currently involved in Eskom's Ingula pump storage plant in partnership with Voith-Hydro.

Siemens is the current market leader in various technologies in the energy sector. In terms of wind energy, Siemens recently introduced the world's longest rotor blades, using special technologies, for installation on a prototype 6 MW offshore wind-power system in Denmark. DONG Energy has signed an agreement with Siemens for a total of 300 wind turbines using these new rotor blades.

In terms of clean fossil power generation, Siemens has been successful in achieving higher efficiency of fossil power plants and power transmission, and has introduced a new gas turbine, which decreases carbon emissions by 60.75% and is suitable for European, as well as African, markets. Siemens has also produced energy-efficient concentrated PV modules and wind turbines and is developing two technologies for CCS for new and existing power plants.

Siemens invests in local talent and innovation, and has partnered with the University of Johannesburg for the Sasol South Africa Solar Challenge 2012, which aimed to promote the development of sustainable engineering design, efficient energy use, environmental awareness and innovation.

The Local University Ambassadors programme is aimed at strengthening Siemens' long-term, strategically important, collaboration with academic institutions. The selected ambassadors help identify research that requires collaboration and promote Siemens as an innovative technology leader. The programme also aims to position Siemens as an employer of choice and to attract young talent.

Siemens is committed to helping South Africa develop a skilled human resource capacity and to this end, has invested in an artisan training centre and a further education and training (FET) college. NXAir Switchgears that were previously imported from Europe and are now built in South Africa as a result of Siemens' partnership with Voith-Hydro. The project is one of several localisation initiatives.

Renewable energy in South Africa is booming. By 2030, the government intends adding about 17 800 MW of renewable energy to the grid. Siemens has already established the Centre of Wind Power Competence in South Africa to service Africa and the Middle East, and is well positioned as a technology leader and a local company to help supply carbon-free energy to the people.

Faciltated Group Discussion Panel: Prof Hildebrandt, Dr Surridge, Prof Falcon, Prof Van Zyl and Mr Nemaxwi

Questions and Comments:
Wikus van Niekerk: Eskom and Siemens representatives should note that pump storage schemes are not renewable energy power plants. Is Prof Falcon aware of the Hubbert curve that has been used to predict the oil peak in the USA and coal production in various countries? The CoER has been running some of these models using the difference between the past and current coal production in this country. The curves predict that coal peak will be reached in South Africa within about five years. Perhaps we have an obligation to leave some of the coal in the ground for future generations and to be careful how we exploit our current resources because coal is not only used for the production of energy, but it also has other uses that are important to society.

Saliem Fakir: Dr Surridge avoided some of the economics of CCS with regard to transporting the gas to offshore sites and the provision of guarantees for the risk. Is CCS really a viable option for South Africa? Prof Falcon mentioned that the coal calorific value of coal is decreasing. I am curious about the type of calorific value that was used in the IRP 2010 modelling. It appears that the IRP 2010 assumed that the emissions will remain unchanged. Should the figures in the IRP 2010 be adjusted?

Hans Hahn: Could Prof Hildebrandt indicate the throughput capacity of the reactor and more about the innovation aspect of the technology, which has been used for 40 years?

Louis Roux: In 2003, I started trying to produce diesel fuel from tyres using technology from Germany, but was faced with numerous obstacles. Trading fuel in South Africa is an extremely complicated process as policies and procedures do not make provision for biofuels. Has Prof Hildebrandt's research come across technology other than Fischer-Tropsch (FT) technology?

Responses from the Panel:
Rosemary Falcon: The Hubbert curve does not work on coal. The reserves and the resources of this country are in the process of being republished and I am one of the reviewers of the document. The problem is that when coal reserves are defined, it is necessary to define what coal is. People define coal as having 50% or less ash, as a seam which is more than 1,2 meters and a depth less than 200 meters. A great deal of coal is found outside of these parameters, which are defined because of economic reasons. We are using coal that is up to 70% ash in some of our power stations.

In terms of leaving coal in the ground for future generations, from a metallurgic point of view there is clever work being done at the moment that looks at splitting CO_2 to remove the carbon to be used is various ways. From the biomass material from which carbon is naturally obtained, diesel could be produced and re-enhance carbon solid materials. However, these technologies are currently very costly and if the development of these technologies is left for too long and the coal is left in the ground the expertise will disappear. There needs to be continuity.

The carbon emission figures will increase as the quality of the coal decreases, but there is not enough understanding of that scenario. Everybody is assuming that there is only one type of coal all over the world or in the country, and the effect of lower grade coal on carbon emission is not incorporated in the models, such as those used in the IRP 2010. More coal will be needed to reach the heat required to make electricity.

Tony Surridge: Work that I have done based on a certain scenario shows that the coal peak will be 2050. I think the coal in the ground should be used. In terms of CCS, we are relying on international economics that may or may not be directly applicable to South Africa. The DoE, the World Bank and SACCCS are in the process of doing a techno-economic study on the CCS in South Africa, to look at the costs, the various technical options, and other issues, such as carbon tax and trade-offs. Risk is being addressed through the regulatory environment. One of the options could be a state-owned entity that buys or sells in the CO_2 and then stores it, implying that the liability will be on the state and not on commercial operators.

Diane Hildebrandt: Plasmic gasifiers, using electricity to supply some of the energy and the rest through oxygen, are used for biomass or small-scale use. The advantage is that they are very high-intensity reactors that operate with the press of a button and are very robust as the feed can be changed easily and quickly, and the reactors produce a very clean gas.

In terms of FT, we are using fixed-bed reactors because they are robust, simple, easy to design and to scale-up or scale-down. The energy window in FT when working with biomass and other feeds, requires a fairly dry feed and is not efficient when the moisture content is high. Combining feeds can produce the right moisture content to do gasification that can be controlled to some degree. FT was chosen because of the marketing of the fuel as synthetic crude is a known commodity even though there are legislation issues, particularly when referring to biofuels or synthetic crude oil. A farmer who uses the technology on a farm can avoid these problems. It is hoped that refining can be minimised initially and that the crude can be used directly. Marketing, logistics and legislation must be resolved in order to make the technology work for the country.

ROUNDTABLE DISCUSSION: IS A LOW CARBON SOCIETY POSSIBLE IN SOUTH AFRICA?

FACILITATOR: MR SALIEM FAKIR, WWF, SOUTH AFRICA

Panel: Prof Annegarn, Mr Isaac Maredi, Ms Cecilia Kinuthis-Njenga, Prof Pitz-Paal, Mr Peter Lukey

Saliem Fakir: There are numerous approaches to dealing with a low carbon future and changing the systemic way in which we are used to thinking about this issue. In South Africa, despite the fact that we have peak coal and that there is a potential for shale and other gas, what is the compelling reason for striving towards a low carbon future? Will it affect jobs, can we afford it, and is there an international agenda behind it?

Isaac Maredi: The South African economy is dependent on fossil fuels and mineral resources. The DST's policy perspective is that it makes sense to invest in a low carbon future, particularly in terms of the innovation mix and spin-offs from these efforts. However, there are issues concerning readiness, sustainability and capacity in respect of green technologies. The DST is addressing these issues with other stakeholders in the National System of Innovation.

Harold Annegarn: Until recently, I was a firm proponent of peak oil. I had an opportunity to visit with a former student working in research laboratories in the USA on the topic of enhanced oil recovery. He says that there are vast reserves of unrecovered oil in the wells, which could be recovered with suitable technology. In addition, fracking has proved successful and the problems related to fracking are to do with bad engineering. I believe that there is an international agenda behind the concept of a low carbon future. I strongly resent the foreign-driven agenda that is totally distorting our energy market. The cost of the current disasters from domestic coal burning is at least 20 times the value of the climate change cost. Adding the carbon tax onto our economy will further distort the economy of this country to the detriment of the poor and complicate our tax structure by adding yet another bureaucratic expense that has no net benefit to our national economy and precious little in contributing the overall carbon to the atmosphere.

Robert Pitz-Paal: Climate change is a reality and is not an international agenda that is being imposed on Africa. One response to climate change is carbon-free, renewable energy. However, I cannot ascertain whether this is an option for South Africa, even though many other developing countries are depending on this option. Renewable energy presents early opportunities for innovation and for countries, such as Germany, to benefit, possibly economically, from green technologies and a carbon-free society. It is definitely worthwhile considering exploring the technology options that are appropriate for South Africa, particularly as this country is rich in renewable resources.

Saliem Fakir: The DEA is involved in climate change negotiations and has released the National Climate Change Response Policy, which addresses the need to decrease South Africa's carbon emissions. If we follow the path supported by Prof Annegarn, the emissions will not decline in the proposed parameters.

Peter Lukey: I do not believe that pegging our future to a 'no future' is sustainable. In all these aspects, there has to be a transition to renewable energy, the only source of sustainable energy for all life on the planet. This is where the real future lies. We cannot cling to the past and bank on planetary destruction as those who are engaged in very specific, focused areas of research tend to do. We need to start looking at a new future and accept that the game plan is changing.

Cecilia Kinuthia-Njenga: A few months ago the world community assembled in Rio to relook at the models that we have tried to apply in the last 20 years to ensure a sustainable future. One of the clear messages that came out, not only from Rio+20, the United Nations Conference on Sustainable Development in 2012, but also from other major arenas around the world, is that we cannot continue on this unsustainable path. We should debate how we reach a sustainable future and not what technology should be used. A business as usual model is not acceptable at this stage. UNEP has in the last few years been debating with scientists, policymakers and practitioners around the world on the issues of how to transition to a green economy. Reports on the matter inform us that 2% transfer of the GDP into ten key sectors would see economies transitioning themselves to a green pathway. We need to see how to focus on making little changes and how to move to a sustainable future. The notion against decoupling economic growth towards resource efficiency is a very significant discussion. The discussion in South Africa should focus on what kinds of technology are being proposed, what steps should be taken to move towards a sustainable future and whether all, or only some countries should be involved in innovation and technology transfer. The argument that South Africa has enough coal for 100 years and does not have to participate in world efforts to decrease carbon emissions is the wrong approach.

Saliem Fakir: What is the vision for the long term and the elements of affordability of a low carbon future?

Harold Annegarn: I am in favour of a low carbon future, but the disagreement is on how we achieve this. Germany concentrated efforts on energy efficiency before they introduced the variety of renewables. My major concern in the South African context is that the blocks in moving towards the transition are primarily administrative and legal. For example, the hundreds of thousands of low-cost houses are not energy efficient. Energy efficient models, at no additional cost, have not yet been able to be rolled out after four years of struggling to get approval for and funding from the government. There is a lack of coordination between the DEA, DoE and DST to change the administrative structures to allow for energy efficient low-cost houses to be built. Government has chosen to improve the lives of the poor by placing expensive solar heaters on the roofs of low-cost houses and refuses to orientate the houses to face north and use insulation. Why is there no operational independent power producer feeding into the grid after so many years? This is an administrative problem. Why after five years of Johannesburg being a declared partner in the clean cities initiative, has the city not yet been comprehensively retro-fitted? It is not because we lack the technology or the know-how, but merely because of administrative blocks and political leadership. The South African green economy is headed for a crash.

Robert Pitz-Paal: Energy efficiency and renewable energy are on parallel paths. I agree that in many cases energy efficiency is the first and the cheapest step to a low carbon future. What is required, besides removing administrative hurdles, is capital to invest in efficiency. This is part of the solution. Renewable energy, however, is a longer-term solution. It is possible to wait until others develop the technology and buy the cheapest technology, but this creates limited opportunities for local supply. It is necessary to ensure that there is a strategy for South Africa's choice of energy efficient or renewable energy technology that takes into account investment in renewables, combats carbon emissions and addresses longer-term employment and economic development.

Saliem Fakir: There appears to be agreement that there needs to be flexibility in terms of how we manage a low carbon future. What steps are necessary in order to achieve this low carbon future? The bureaucratic system talks about an ideal future but does not create the space for this to happen rapidly. How can this be remedied?

Peter Lukey: I agree with Prof Annegarn's comments. In terms of reducing our demand for energy, in the South African situation there are numerous examples of energy wastage while there is also immense energy poverty. Poor people have no access to energy. The lack of inter-governmental co-ordination in respect of the rollout of the green economy, with renewable energy as a component, is a fundamental issue that is not facilitating the process. While our policies provide a strong basis for R&D in green technologies, implementation is not facilitated through actions. This is a massive challenge in the transition to a low carbon future in South Africa.

Isaac Maredi: Mr Lukey is correct about the administrative challenges at different levels of government. Another element that must be addressed is South Africa's capacity to implement the policies. The soft issues, such as awareness of human behaviour in terms of the environment, tend to be overlooked and should be addressed through effective communication.

Saliem Fakirr: Mrs Kinuthia-Njenga, would you share some of the findings of the modelling work done to stimulate the green economy?

Cecilia Kinuthia-Njenga: One of the key lessons learnt by UNEP is the need for a comprehensive and integrated approach to address the green economy. Based on UNEP's global practice, pillars to drive transition at a national level have been identified. Some of these pillars are: finance, institutional framework (including a regulatory framework that allows for IP protection and innovation – a current problem in South Africa), capacity (human and institutional), and access to energy by vulnerable communities.

General Discussion

Emile van Zyl: We should be asking whether we really need these renewable energies, not only to reduce carbon emissions or energy needs, but actually to contribute towards a sustainable future for South Africa and the continent. This brings in job creation, health issues and other aspects which have not been addressed and that can be addressed by modern technologies.

Velaphi Msimang: There are many sides to this debate. The discussion about the paradigm shift was alluded to by one of the presenters. A low carbon future can be viewed as a threat or an opportunity. If it is an opportunity, we do not know what will drive the revival of the economy. It may be low carbon technologies. It is also possible to ignore all the other options because we have a lot of coal. The discussion of the options can also be limited and become a trend. Price sensitivity will make it difficult for awareness campaigns to have any impact on human behaviour. Price is a lever that can be used to make people aware of demand-side options. Institutional instruments are necessary to enable the application of green technologies. Unless this issue is resolved, South Africa will not be able to begin transition towards a green economy.

Diane Hildebrandt: At least one hundred mistakes will be made in research before making a single contribution to knowledge. This also applies to new technologies. We should expect to make mistakes. As long as we learn from them we will eventually make progress. My impression is that the bureaucrats are afraid of making a mistake. We will be faced with blockages until there is an understanding from those that provide funding and the bureaucrats that some mistakes will have to be made in the transition to a low carbon economy.

Hans Hahn: Coal should not be burnt in a most wasteful manner, but should be preserved for the future because it is more precious as a raw material than as a source of energy. Replacements for coal as a source of energy are imminent, as South Africa is heading towards becoming a gas-based energy economy, which will be less carbon intensive than a coal-based energy economy. Fracking should not be condemned at this early phase of exploration. Alternative gases such as biogas should also be investigated further. We should focus on small-scale production and consumption of energy where feedstocks are available. Renewable energy does not have to be so expensive.

Jürgen Werner: We are discussing electricity for Africa where most people do not live in large cities and want to have electricity available in rural areas. This would require either installing power lines or generating electricity on-site. Every small village could have a constant supply of diesel to run generators. In my view there is no way to supply electricity to the majority of Africa if it is based on fossil energy because nobody will pay for it. This means it is necessary to generate electricity on-site either using biomass, which has a low efficiency, or PVs.

Markus Bollmohr: There are challenges in South Africa with regard to the effective and large-scale rollout of renewable energy to replace coal and the environmental consequences of new technologies, such as fracking. From the regional perspective it appears that the enormous potential of renewable or other alternative energy sources in the neighbouring countries remain largely untapped at this stage. South Africa is the power house of the region and even though its neighbours are developing they still lag behind in terms of development and energy demand. It is possible for 100% of the energy needs of some of these countries to be renewable energy, and for them to export some of the energy? How can this aspect be brought into the discussion?

Saliem Fakir: What about shale gas being the wild card and what are the other options in the region?

Harold Annegarn: If we are going to have fracking, then it must be done according to high standards to ensure and enforce environmental, personal and economic safety. Contamination of water bodies in fracking efforts is due to poor engineering and not inherent in the technology.

Peter Lukey: Shale gas is indeed a wild card. The political decision about whether or not to look for shale gas will be difficult to make. In terms of what shale gas will do to investments in a low carbon future, there is a chance that shale gas could undermine renewables unless there is strong government intervention. There is no level playing field in respect of access to the resource and the players themselves. The other aspect is that there needs to be a market for shale gas. If the downstream life of shale gas is another major source of carbon emissions, then shale gas is not a good option. We have to start revaluing our renewable resources and our coal in terms of sustainability. One of the most important aspects of climate change is that the theoretical discussion of sustainable development has become a real and practical discussion in the future of the planet. It does not have to do with comparisons between resources but a 'symphony' of resources that looks at a sustainable pathway.

Robert Pitz-Paal: Shale gas is a wild card and should be explored. However, there is always the concern that if cheap, CO_2 emitting options are created then the carbon targets will not be achieved.

Isaac Maredi: The aspect of competing priorities or trade-offs is important. Are the demand issues being addressed and are we seriously considering environmental issues, or are we merely exploring possibilities for renewable energy? It is important to consider which opportunities are worthwhile pursuing in terms of the economic imperatives of the country. If shale gas exploration is to be approved by government it would have to address the economic challenges of the country.

Saliem Fakir: Ms Kinuthia-Njenga, how do you view the future of low carbon in Africa in terms of distributed generation outside of diesel?

Cecilia Kinuthia-Njenga: There have been ongoing discussions in the SADC region in this regard. I do believe that a regional perspective in Africa is inevitable in order to move Africa towards being a low carbon society. At least 80% of people in Africa are not connected to the grid, yet there is not a single response to this need. As Mr Lukey said, it is a 'symphony' of responses that is necessary. There will be certain factors that will determine how this regional discussion and regional action will take place in terms of implementation. The whole issue of governance in Africa in relation to the new scramble for our resources will determine whether we are able to tap into the resources and whether these resources can improve the lives of the 80% rural and poor population of Africa. Governance and leadership, both national and regional, are fundamental issues in this debate. South Africa is regarded as a leader and is expected to provide the leadership in terms of not only showing best practices of the energy mix, but also in supporting and building capacities in the rest of Africa to light up the continent. Governance and leadership are crucial, even more important than enhancing capacity building and raising awareness.

Harold Annegarn: We have an excellent example of energy distribution in the way that cell phone technology has spread through Africa without a fixed line system being necessary. Gas discoveries off the Mozambican coast are significant and gas will be a game changer even without fracking. Gas is twice as efficient as coal in generating electricity. If we are serious about moving rapidly to low carbon, even though gas is a carbon-based fuel, the maximum should be done to support the development of the Mozambique gas fields. Compressed natural gas can be used as a vehicle propellant and is more efficient that current fuel. This aspect should be investigated further.

Jannie Pretorius: I would like to explain the scientific basis of fracking. Fracking removes carbon hydrants that are bonded to structures that are reasonably weak, and nature will replace the carbon hydrants with an extremely strong hydrogen bond that keeps all life forms together. The water table will fill up the cavities created. This has been tested and it has been proved that it will cause damage. PetroSA creates about 2 000 metric tons per day of super pure CO_2 and Sasol creates about 6 000 metric tons of super pure CO_2 that is required to create hydrogen for the hydro carbon process. This presents an opportunity to convert CO_2 to a fuel or a chemical. We have developed software with collaborators to model materials to act as catalysts to enable this process. British and German experts will join the research group at UP in January 2013 for a period of six months, to work on this principle. South Africa has approximately 240 years of high-quality coal left in the seam running from Delmas to Ellisras at the rate coal is currently used. UP is also working on a process to combust that coal into a very high-quality CO_2 that will be recycled.

Robert Pitz-Paal: CO_2 is a very stable molecule and requires energy to split it. Where will the energy come from?

Jannie Pretorius: The thermal energy of cracking CO_2 takes place at about 200°C. The process is economically better than CCS.

Thomas Roos: Gas does not replace renewables, it replaces coal. Renewables are introduced as a result of various policy instruments. The fact that there is gas does not threaten renewables unless the policy instrument changes. I support Prof Annegarn's view of how gas should be used to lower carbon emissions, increase efficiency and limit water usage. Gas is already being turned into fuel and this is not a green technology. Whether coal or gas is used to make liquid fuel is of no consequence to renewables.

Emile van Zyl: It is annoying to hear Africans consistently referring to 'all the poor people in Africa' in discussions with the African Union, NEPAD and other similar bodies. It appears to be convenient to continue talking in this way. I believe that it is time for us to work towards a sustainable Africa, and for Africa to become an international partner in renewable energy and in creating a sustainable continent. South Africa has a role to play in this regard.

Richard Worthington: We should approach the debate by asking whether a high carbon future is possible. There are those who look at the science and tell us that it is not possible and that society will collapse if we do not turn to renewable energy. There is no choice between a high carbon future and a low carbon future with a bit of inconvenience. There is only a choice between a functional society that is low carbon or a crash. If we think that a high carbon society is possible, who is articulating and demonstrating what the future will look like? We do not have a real vision of a high or a low carbon society. If we assume that human decision-making will become rational and that we start to act cooperatively, is there anyone who thinks that we could be prevented from achieving a low carbon society?

Saliem Fakir: There are different views of what a low carbon future is: using only renewables, low carbon intense fossil fuels with a mix of renewables, and other options. Is there any consensus about what a low carbon future is?

Isaac Maredi: It is important to consider energy efficiency at the same level as suitable renewable energy sources for South Africa. It will be necessary to consolidate all innovation efforts towards a low carbon future, taking into account the socio-economic, as well as the technological aspects. The underlying issue is to have policy instruments in place that will promote and encourage a low carbon future, and build competencies at all levels that are necessary in order to achieve this goal.

Cecilia Kinuthia-Njenga: South Africa is leading Africa in terms of GHG emissions and, on the other hand, there are strong policy statements from South Africa indicating that this country is prepared to take on the sustainable path to a low carbon society. It is necessary for South Africa to take serious steps, particularly with regard to institutional reforms, technological innovations and financial innovations that facilitate the transition towards a green economy. South Africa should set best practices for this transition. I believe that it is possible for South Africa to become a low carbon society if the necessary mechanisms are put in place, followed through and monitored.

Harold Annegarn: I do not accept that anyone is advocating for a high carbon future. What is distressing is that we do not take the low cost or no cost options that are currently available to transition towards a low carbon society. As an academic, I see my responsibilities in the larger debate as:

- the human resource capacity needs across Africa;
- measuring in order to manage;
- ensuring a common lexicon concerning low carbon matters;
- technology development.

Robert Pitz-Paal: In terms of how Europe, particularly Germany, could contribute to the development of a low carbon society in South Africa, two aspects have been noted:

- Building the necessary capacity for implementation of green technologies.
- Germany's policy with respect to energy and renewables could be used as an example of how the energy transition may work in South Africa and would prevent South Africa from making the same mistakes as Germany and Europe, as a low carbon society is the only option for the future.

Peter Lukey: We need to be allowed to make some mistakes in innovation. The South African circumstances are completely different, and with that we have an opportunity to do great things. South Africa has not lacked innovation in the past. We have an immense wealth of resources and raw materials. However, we sometimes ignore our natural and renewable resources. Although governments prepare their own energy plans and draft their own policies, more such debates are necessary, particularly concerning renewable energy and the involvement of the nation in the rollout of renewable energy in the interest of the country.

Wrap-Up: Key Points and Way Forward

PROF SIGMAR WITTIG AND PROF ROSEANNE DIAB

Prof Wittig gave his impressions of the proceedings and highlighted some of the key points raised in the presentations and during the discussions.

When listening to the keynote speakers, it became evident that the technological aspects were not necessarily the driving points of this conference. Mr Patel stated that there is too much focus on technology and not enough focus on social developmental and human behavioural aspects and the management of transition to a green society. He later referred to technological development. It was surprising, yet fascinating, to hear that the dominant factors in the South African context differed from those in the German context.

Ms Yawitch posed the realistic question relating to job opportunities and a low carbon society and the need to define priorities. The Panel also raised this matter.

Mr Lukey spoke of priorities in the developmental context and then added the term 'innovation'. He stated that South Africa tends to ignore its real wealth (people, resources and space). The question is how can and should the real wealth be used.

Prof Hildebrandt asked her students what can be done to make a difference to and improve the quality of life. This question is posed to technologists in general. There are sociological, as well as the technological paths to change. Technological change occurs more rapidly than societal changes.

Prof Falcon said that South Africa is currently coal-dependent. Fifty years ago Germany was driven by coal and steel. Today there is no coal and almost no steel and wealth has to a large extent been transferred from the north to the southern parts of Germany. Elsewhere in the world, previously industrial cities, such as Pittsburgh, Pennsylvania in the USA, have been transformed to clean cities. This is an indication that technological innovation has been supported by sociological developments.

Prof Annegarn expressed the opinion that the low carbon targets were driven by a foreign agenda. It is difficult to accept that South Africa would follow a foreign agenda blindly. South Africans themselves will make the decision about whether or not to move towards a low carbon future. Observations indicate that there will probably be a smooth change to a lower carbon society in South Africa. It is important for the transition to be organised and that people are made aware of the need to move to a low carbon society, and appropriately educated in order to support a green future. The definition of priorities for the country was unclear from the discussions and this is a concern.

The proceedings on the first day of the conference initially appeared slightly pessimistic and a series of analyses of the problem areas, and no solutions were offered. However, speakers on the second day presented technological innovations to address the problems. They also expressed determination to pursue a low carbon future and acknowledged the availability of a broad range of resources in South Africa, which presented many opportunities for exploitation for purposes of sustainable energy.

Leopoldina had published a report titled, *Concept for an Integrated Energy Research Programme in Germany* and offered to share their experiences with South Africa.

Germany can offer continued cooperation (on a 'win-win' basis) with South Africa towards achieving the targets set for carbon emissions and a low carbon future.

Prof Diab thanked Prof Wittig for sharing his impressions and providing a summary of the highlights. She expressed her gratitude to the Leopoldina representatives and German scientists for their significant contributions to the discussion.

This conference was a good example of the role that science academies can play in providing a forum to debate issues of national importance. Through their convening power, science academies are able to create a platform that brings together people from different sectors and with varying perspectives. This diversity had contributed to enriching the discussions during this conference. It was apparent during the conference that there was a sense of frustration at the lack of leadership from government and a lack of strategic direction in terms of identification of priorities for low carbon development. Different discipline groupings appear to drive their own agendas with no overall goal in mind. Science academies, as neutral bodies with no vested interest in the outcome of a specific scientific debate, can act to address this problem by bringing people with diverse backgrounds together to discuss matters of common interest and to provide strategic direction.

Some of the key messages that emerged from the conference emphasised the fundamental principles required for a low carbon future and provided pointers in terms of the way forward. These were:

- The availability of resources in South Africa.
- The importance of partnerships.
- The need for communication and debate among people from difference disciplines.
- The importance of human capital development and education.
- The need to focus on and gain clarity on how the transition to a low carbon future should take place.
- The need to emphasise the value of a systems perspective on low carbon technologies.
- The need to emphasise the role of the green economy.
- The importance of social innovation in low carbon technological solutions.

Although social innovation had not been identified as a specific topic for this conference, the programme had been structured to allow the relevance of social issues in finding technological solutions to emerge as a key theme. Certainly, in the South African context, social issues are of paramount importance in the transition towards a low carbon future.

Prof Diab acknowledged the following contributors to the conference, on behalf of ASSAf:

- Funders of the conference: NRF, DST, Nedbank, Leopoldina and WWF
- Speakers, particularly the keynote speakers and the visitors from Germany
- Facilitators of the various sessions
- All delegates for their interaction and participation in the discussions
- Ms Zarina Moolla, Programme Officer at ASSAf, for compiling the conference programme and for organising the conference

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APPENDIX A:

ATTENDANCE LIST

SURNAME	NAME	INSTITUTION
Annegarn	Harold	University of Johannesburg
Aye	Sylvester	University of Pretoria
Badenhorst	Heinrich	University of Pretoria
Balmer	Marlett	South African German Energy Programme (SAGEN), GIZ
Bollmohr	Markus	German Embassy
Bowen	Justin	Equity Estates
Brent	Alan	Stellenbosch University
Buckley	Chris	University of KwaZulu-Natal
De Kock	Charl	Nedbank
Diab	Roseanne	ASSAf
Du Plessis	Chrisna	University of Pretoria
Erasmus	Heather	Write Connection (Scribe)
Fakir	Saliem	WWF South Africa
Falcon	Lionel	University of the Witwatersrand
Falcon	Rosemary	University of the Witwatersrand
Govender	Niveshen	The Innovation Hub Management Company
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Hahn	Hans Helmut	Intellectual Property and Technical Consultant
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