CCS in Southern Africa

An assessment of the rationale, possibilities and capacity needs to enable CO_2 capture and storage in Botswana, Mozambique and Namibia

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Abstract

In April 2010, a series of workshops on CO_2 capture and storage were held in Botswana, Mozambique and Namibia, attended by a total of about 100 participants. The objectives of the workshops were to provide a thorough introduction to CCS to participants from relevant public, private and academic organizations and to explore the potential rationale, possibilities and capacity needs in each of the three countries. For the project, the Energy research Centre of the Netherlands (ECN) partnered with EECG Consultants (Botswana), the Eduardo Mondlane University (Mozambique) and the Desert Research Foundation of Namibia. This report reports on the workshops, provides information on the situation with regard to CCS in Botswana, Mozambique and Namibia, and gives recommendations for follow-up work.

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Summary

With climate change becoming a more urgent problem, many studies indicate that all mitigation options will need to be used to globally reduce emissions sufficiently to stabilise atmospheric greenhouse gas concentrations. This includes the option of the capture and geological storage of CO_2 (CCS), a relatively new technology that captures CO_2 from large point sources, such as power plants and large industrial installations, transports it, and stores it permanently in a geological reservoir. CCS is most likely first deployed in countries with high industrial emissions, but the most cost-effective opportunities are not necessarily in the developed world. In particular, the region of Southern Africa is mentioned as a potential place for CCS deployment, because of high-purity CO_2 sources in South Africa, abundant coal reserves all over the region, and a desire to be pro-active on climate change.

The aim of this report is threefold: to report on three workshops on CCS in Botswana, Mozambique and Namibia, to discuss the energy and industry situation in the countries and the potential role of CCS, and to provide recommendations for potential next steps on CCS in the Southern African region. Botswana, Mozambique and Namibia all border South Africa. Also, their power supplies are integrated through the Southern African Power Pool and both Botswana and Namibia currently import more than half of their electricity from South Africa.

Any efforts on CCS in the target countries should be aimed at the longer term, and would necessarily involve an initial period of awareness raising and basic capacity building. There is a clear rationale for informing stakeholders in Botswana, Mozambique and Namibia about CCS. First, building general awareness and engineering knowledge on a mitigation option with global relevance is a no-regret activity. Least-developed countries should have access to similar quality of information on CCS as developed and emerging economies.

Second, South Africa is taking an active role to advance CCS as an important national mitigation option. In 2009, the South African Centre for CCS was established. The first activities of the new centre include the development of a CO_2 geological storage atlas and a roadmap for CCS in South Africa, with a vision of achieving an initial demonstration project by 2020. For understanding the activities in neighbouring South Africa, it is important to raise awareness of and provide information on CCS in Botswana, Mozambique and Namibia.

A third reason for capacity building on CCS in developing countries stems from the debate of allowing CCS into international climate finance mechanisms. One potential barrier for allowing CCS into such mechanisms, such as the UNFCCC Clean Development Mechanism, is a general lack of awareness, deep understanding and regulatory capacity within developing countries of the costs, risks and impacts related to CCS.

The situations in Botswana, Mozambique and Namibia with regard to electricity generation, electricity demand, industrial development plans, CO_2 emissions and CCS have similarities and distinctions. All countries face an electricity deficit, energy access challenges and a need to industrialise for economic development. Also, the three countries share the desire to industrialise in a sustainable way. But the way in which this may be done differs. Botswana has two energy resources in abundance: solar energy and coal. While solar energy on a large scale is a technology with high costs and deployment challenges and more suitable for the long term, coal could be used in the short term. Mozambique has great hydropower, biomass and solar resources, as well as gas and coal reserves. Namibia's energy resources include primarily solar and biomass, and are limited in terms of fossil fuels.

All three countries have plans to increase their electricity generation capacities. In addition to renewable energy, in Mozambique and Botswana, coal-fired power is a likely option, as both countries have large reserves of coal. Botswana is also investigating the potential use of Underground Coal Gasification (UCG), a technology which if combined with CCS and if regulated appropriately, could represent a low-cost, low-carbon energy solution. In terms of geological CO_2 storage potential, there is understood to be significant potential in both Mozambique and Botswana, however the data required to provide reliable information is fragmented and dispersed across a number of different parties.

The workshops resulted in a debate about the general energy situation in the countries, and in identification of the potential capture sources, suitability for geological CO_2 storage, and policy and regulatory needs to enable CCS in the different countries. In addition, an open debate took place on whether CCS would be a good idea in the country in the first place, which often led to a lively debate regarding the possible conflicts between climate concerns and development needs.

It can be concluded that especially for Botswana and Mozambique, further knowledge building on CCS is useful, as realistic possibilities for CCS may exist. For Namibia, this is less obvious. It is clear that CCS can only function in a broader, integrated energy strategy for the countries but also for the region. Further work may include conducting geological storage assessments (quick scans) for the countries, providing regulatory capacity building with the relevant government bodies, and fostering continued interaction regarding CCS between European institutions, Southern African stakeholders, and South African institutions active on CCS.

1. Introduction

The capture and storage of CO_2 (CCS) is considered as a climate change mitigation option with a large global potential. CCS is particularly important for those nations that have shown the intention to make deep reductions in carbon emissions, but rely to a large extent on coal for their electricity supply, or have intensive industrial activities. In addition to the large potential in the power sector, which is unlikely to be implemented before 2020, there are early opportunities for CCS in large point sources that emit relatively pure CO_2, have low capture costs and storage sites close by.

South Africa is a country with a large reliance on coal, a political will to address climate change, and many large point sources of CO_2. There are also a number of point sources with a relatively high concentration of CO_2, given that a number of coal/gas to liquid (C/GTL) plants operate in the country. This CO_2 could be captured and stored at relatively low costs, if storage options are available. Currently, a geological storage atlas for South Africa is under development, but early results indicate that the geological storage capacity is limited, and at considerable distance from the point sources that are most amenable to capture. This would make transport and storage of CO_2 an expensive matter. Most of the early capture opportunities are located in the northeast and northwest of the country. Still, South Africa is investing in CCS by building up knowledge, developing a storage atlas, and being an active participant in international political discussions on CCS.

While South Africa is active in CCS, activities in other countries in Southern Africa are limited. There are however indications that storage capacity in Botswana, Mozambique and Namibia is more abundant. Mozambique is currently exploiting a number of gas fields, and negotiations regarding the development of a large gas field off the coast of Namibia are ongoing, if slow. Botswana is abundant in coal and might have considerable potential for Enhanced Coal Bed Methane recovery (ECBM). It is worthwhile investigating whether these countries would implement CCS themselves, but even when not, storage of South African CO_2 in those countries could provide economic benefits as well as benefits in climate change mitigation, if implemented in a safe and sound way.

The gaps and barriers to implementing CCS in South Africa and its neighbouring countries are diverse, but can be summarised in three points (Bakker et al., 2007):
1. Lack of awareness and knowledge of CCS in Botswana, Mozambique, and Namibia across stakeholders: academia, research institutions, government and the private sector do not have access to the latest insights and developments.
2. The geological storage capacity in Botswana, Mozambique and Namibia is unknown.
3. There is no regulatory framework for CO_2 transport across borders, and CO_2 storage in Botswana, Mozambique and Namibia, making project development in those countries unattractive.

The CCS-Africa programme, started in 2007 with two regional workshops on CCS and CDM in Dakar and Gaborone, and continued in 2010 with three workshops on CCS in Botswana, Mozambique and Namibia, aims to raise awareness and provide access to the most up to date knowledge on CCS for local stakeholders. This report provides information about the three countries, reports on the workshops, and provides recommendations for potential next steps on CCS in the Southern African region.

2. Botswana: the question of coal in the future energy system

2.1 Country assessment

2.1.1 Introduction to the country

Botswana is a large, sparsely populated country with an area of 582,000 km^2. The last Census was done in 2001 when the population was 1.68 million, split between 45.8% and 54.2% for rural and urban, respectively. Currently the population is estimated to have reached 1.9 million. Of this population, 80% are confined to 20% of the area in the South-east of the country creating a localized population density of 10 persons/km^2, in a country that otherwise has an overall population density of 2 person/km^2.

Economically, Botswana is an Upper Middle Income country with a total Gross Domestic Product (GDP) of US$12.5 billion , and per capita GDP of US$7,530[1]. The country has had an impressive economic performance over the past four decades, enjoying a high economic growth rate of 9% mainly driven by the diamond mining sector. On average the mining sector contributes 40% to GDP, followed by government services and development projects at 15%. In support of that development, Botswana can be considered a politically stable democracy, with a steady economy. Botswana also maintains foreign exchange reserves equivalent to over 20 months of import cover.

Botswana's development objectives are guided by the goals and objectives contained in the Vision 2016, on which National Development Plans (NDPs) are based. The current NDP10 and its predecessor NDPs emphasize economic diversification from a predominantly diamond dominated economy, global competitiveness and poverty reduction strategies. Despite its economic success, Botswana is still stalked by insufficient diversification and the challenges of poverty (>28% living on less than 1US$/day)[2], income inequality[3], unemployment (persistently above 20%) and high incidence of HIV/AIDS[4]. The global financial crisis has also significantly affected Botswana's diamond industry. The industry fell by 73% and is only expected to return to 2008 pre-crisis level by 2012.

In its quest to diversify the economy, Botswana has identified a number of engines of growth, among them to attain the capacity to supply the SADC region with coal and coal bed methane based electricity/energy and to create a range of support industries and activities from these resources.

2.1.2 Electricity demand, supply and industrial production

A potential upturn of the global economy, and the expected various mining operations (e.g. upgrade of diamond plants and new copper mines); the high electrification targets and the desired diversification to non mining sectors will increase electricity demand. Electricity demand in Botswana is expected to increase from ~517MW (peak) in 2008/09 to 613 MW (peak) by 2013; 850 MW (peak) by 2017 and 1130 MW (peak) by 2026. The measured deficit is 18% in 2009 and can increase to 83% in 2013 before new generation capacity is built.

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1 Data from 2008.
2 Effort has also been made to reduce individuals living below the Poverty Datum line from 59% in 1985/86 to 47% in 1993/94 and 30% by 2002/03.
3 Botswana ranks the 5th most unequal country in the world.
4 Although significant effort has been made to contain the scourge.

The sectoral electricity consumption for 2009 (summarized in Figure 3.1) is, expectedly, dominated by mining (39%)[5] followed by the domestic sector (26%), the commercial sector (25%) and government (10%). The national electrification programme reached an access/connectivity to electricity of 57.9% at the end of December 2009; split between 82.9% and 52.7% for urban and rural subsectors, respectively. The target is to reach 80% national connectivity by 2016.

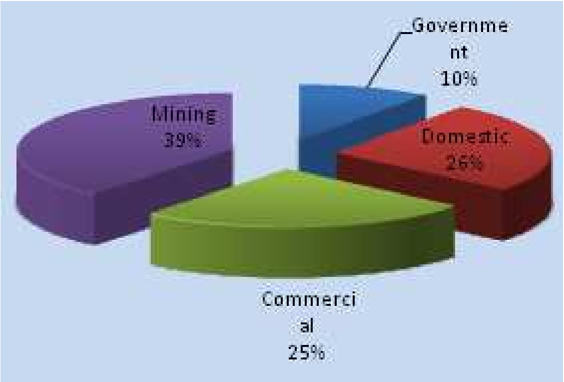

Figure 2.1 *Botswana electricity sales by sector - 2009 [kWh]*

Currently Botswana imports 80% of its electricity supply from Eskom of South Africa and other Southern African Power Pool (SAPP) countries (mainly Mozambique), and only generates 20% from its only coal-fired power station at Morupule (called the Morupule A Power Station) with an installed capacity of 132MW[6]. The supply from Eskom is being steadily reduced and there will be no supply under current agreement by 2013 (Table 2.1).

Table 2.1 *Botswana Electricity Generation Capacity and Imports*

Source	Quantum	Remarks
Morupule Power Station	120 MW	Normally operating at 90 MW
Eskom (South Africa)	410 MW - 2007 350 MW - 2008 350 MW - 2009 250 MW - 2010 150 MW - 2011 150 MW - 2012	5 Year Stepped Reduction Mandatory 10% reduction on 2007 profile. (Maximum Import limited to 315 MW)
HCB Mozambique	Up to 50 MW/75 MW	1 Year renewable agreement (Not firm)
EDM Mozambique	Up to 40 MW	1 Year renewable agreement (Not firm). Not available at peak (17:00-22:00hrs)

The electricity supply from Mozambique only becomes available when not needed in Mozambique itself. There is also no excess power in the region for further imports. Electricity imports are getting increasingly costly, from US$2 cents/kWh in 2007 to US$5 cents/kWh by 2010. Imports are also uncertain as electricity exporting countries give priority to national demand[7], and there are transmission constraints in some SAPP countries.

Botswana is resorting to various power generation options to meet its growing demand (Table 2.2). The Botswana Power Corporation (BPC) has contracted an Independent Power Producer to install 70MW of portable diesel generators in Matsiloje, near Francistown. Another 90MW diesel plant is planned supported by the Government and Debswana[8]. A Concentrated Solar Power (CSP) installation of 50MW is expected to be developed by 2016, with the target to reach

5 Diamond mining however declined in 2009 affected by the global economic crisis
6 With a firm power of 90MW up to 2012.
7 South Africa had an unexpected shortfall of 700MW in 2007
8 A diamond mining company owned by DeBeers of South Africa and Government of Botswana.

200 MW by 2020. Similarly gas turbine capacity of 50MW based on coal bed methane is expected on stream by 2016 also reaching 200MW by 2020. According to the SAPP Plan, up to 3000 MW of new coal power station capacity is to be built in Botswana. A 600 MW capacity expansion at Morupule (Morupule 'B') has already started and is due for completion by 2013[9]. Two Independent Power Producers (IPPs) are in the process of planning and designing coal power stations, one a 1200 MW[10] coal power station at Mmamabula Coalfield and the other a 1000MW at Mmamatswe Coalfield.

Table 2.2 *Botswana Power Generation Options*

Generation Option	Power Availability	Remarks
EXISTING COAL- Morupule A	90 MW net out of installed capacity of 132MW	The power station is to be retired in 2020
Diesel units	160 MW (70 MW by Government through BPC and 90MW by Government and Debswana)	Short term gap fill only
Concentrated Solar Power (CSP)	Up to 200 MW by 2020 (50 MW targeted by 2016)	Will need donor support
Coal Bed Methane (CBM)	200 MW by 2020 (50 MW likely by 2015/16)	Tapping of CBM is still to start
New Coal Power plants	Up to 3000 MW- as per SAPP Plan Morupule B 600 MW 2013 Mmamabula IPP 1200 MW 2015/6	Need 4 year lead time

Considering the cost implications of these electricity generation options, Table 2.3 shows that coal is the least cost option for Botswana at the moment, followed by the use of coal bed methane (CBM), CSP and then diesel. Diesel for power generation is significantly more expensive than coal, as all petroleum products are imported through South Africa as there are no oil refineries in the country.

Table 2.3 *Botswana power generation alternatives, costs, and feasibility*

Option	Cost [US¢/kWh]	Availability*	Remarks
Existing Coal (Morupule A)14	5+	90 MW net	To be retired by 2020
Diesel units	50+	160 MW	Short-term gap fill only
Concentrating solar power (CSP)	~20	Up to 200 MW by 2020	50 MW targeted by 2016; needs donor support (*e.g.* Clean Technology Fund).
CBM	7 to 22	200 MW by 2020; 50 MW likely by 2015/16	Exploration yet to commence; costs, timing and capacity would be based on availability of CBM.
New coal plants	5+	Up to 3000 MW as per SAPP	4 year construction feasible for small and standard unit size

*Availability means capacity size [MW] anticipated in the cost analysis.
Source: Project Appraisal Document Republic of Botswana for A Morupule B Generation and Transmission Project October 2, 2009, World Bank.

Whilst Botswana has abundant sunshine, exploitation to substitute the base load will be in the distant future due to the high costs of generation. Solar energy is currently only being exploited

9 BPC may add another 600 MW by 2016.

10 Developing of this power station will largely depend on Eskom's power purchase agreement as Eskom is expected to import 900MW while BPC will is expected to purchase 300MW.

for off-grid systems. The country has no hydro potential and has very limited wind and biomass resources for power generation.

On the other hand, Botswana has abundant coal reserves estimated at 212 billion tonnes and to date there is only one operating coal mine, Morupule, which has 5 billion tonnes economically mineable resources and a production of less than 1 million tonnes per year. With such large resources, Botswana is likely to depend on coal for power generation in the foreseeable future, making it necessary to explore clean coal technologies including CCS, if attempts are to be made to reduce CO_2 emissions in that same timeframe.

There is some CBM exploration taking place and there are plans to include the CBM in the energy mix once commercial viability has been verified. Recent studies put indicative estimates of large CBM resources at over 190 trillion cubic feet (TCF). Even if 10-15% of this estimate can be realized, this will be the largest gas find in the Southern African region. Combining coal and CBM potential for energy supply and creation of related industries in the region, would contribute to Botswana's economic diversification significantly.

2.1.3 CO_2 emissions

The official GHG inventory for Botswana is the one in its Initial National Communication of 2001, which is based on 1994 data. In CO_2-eq terms, the national greenhouse gas emissions were 9,315 GgCO_2-eq dominated by agriculture (55%) followed by power generation (19%), mining and industry (11%), transport (9%), households (4%) and government (1%). Including land use change and forestry, Botswana was a significant net sink. However the country is in the process of updating its GHG inventory basing on 2003 data.

Going beyond 2009, Botswana will generate more GHG emissions initially from the 1800MW coal based electricity generation that is expected to be installed by 2015/16. This should increase the power generation GHG emissions by 15-fold compared to the 1750Gg estimated for 1994 for its 132MW capacity. Coal generation for Botswana under the Southern African Power Pool power development schedule of 3000MW, together with CBM based capacity of 200MW will further increase GHG emissions by greater than 30-fold.

Botswana ratified the UNFCCC Convention in January 1994, and ratified the Kyoto Protocol in November 2003. The Designated National Authority (DNA) is established under the Ministry of Environment Wildlife and Tourism (MEWT) in the Department of Meteorological Services (DMS). The National Committee on Climate Change, consisting of members from Government, Private sector/business community, academia and Civil society, provide the necessary technical support that the DNA may require in executing its functions. The Inter-ministerial Committee is also a resource that can play an advisory role. There is currently no technical committee dedicated to Clean Development Mechanism activities, but there are plans to form a high level technical committee that can support the private sector to develop low-carbon and CDM projects.

Botswana has notified its intention to be part of the Copenhagen Accord and is going ahead to participate in the negotiations related to the Accord. Among the National Appropriate Mitigation Actions (NAMAs), Botswana has put forward efficiency and conservation; shift from coal to gas, nuclear, renewable technologies, and biomass for power generation; and carbon capture and storage for continued use of coal. Under energy conservation and efficiency projects/programmes, Botswana will target the mining/industry sector, transport sector, buildings sector and efficient energy appliances.

2.1.4 Activities relating to CCS

Botswana has been exposed to some initiatives on carbon capture and storage. Many stakeholders participated in the CCS-Africa Southern African regional workshop held in September 2007 where various facets of CCS and the link to CDM were presented and discussed. The CCS in Southern Africa project is a follow up of the recommendations made at that CCS-Africa regional workshop.

There is a growing number of projects that are testing the applicability and usefulness of CCS components including for example the practical feasibility and financial implications of CCS. SASOL of South Africa has also been engaging with Botswana Government stakeholders on the possibility of storing CO_2 from its operations in South Africa, and at the same time contributing to enhanced CBM recovery process. Agreement on this arrangement has not yet been reached (see Box 2.1). CIC Energy, which plans to build a coal mine and power station at Mmamabula, in Botswana, has been considering a 'capture ready' Power Station[11]. Preliminary considerations of using CCS were thus made as part of the Environmental Impact Assessment. The World Bank has also indicated its willingness to support Botswana through the Botswana Power Corporation to explore the possibility of piloting CCS in the country.

In the global studies regarding the geological suitability of parts of Southern Africa for CCS, Botswana is classified by the Intergovernmental Panel on Climate Change (IPCC) to fall within areas that have prospective sedimentary basins. Detailed investigations will however need to be undertaken to expose where the potential is.

It is through such further geological investigations and a wide consultative process that stakeholders can be informed about how best to proceed with CCS in Botswana. In addition, given the current lack of regulation and limited human capacity in government to regulate CCS, the regulatory capacity will have to be enhanced.

Box 2.1 *Botswana media on CCS*

> BALI - (Botswana) Government is reluctant to allow Sasol, a South African petroleum company, to construct a carbon capture storage (CCS) plant in Botswana, In an interview at the ongoing United Nations climate change conference in Indonesia, senior officials, Steven Monna and Phetolo Phage said government is monitoring global developments regarding such storage plants. Mr Monna is director of Environmental Affairs while Mr Phage heads the Meteorological Services department.
>
> So far t would be too risky to embark on such a project before we know its pros and cons, what if the gas eventually leaks from underground, and what happens to our water? Mr Monna asked rhetorically.

Source: Botswana Daily News article: 'carbon capture too risky' (Dated 12 December 2007).

2.2 Workshop proceedings

The workshop held in Gaborone on 8th and 9th of April 2010, was intended to explore with national stakeholders whether CCS should be considered in Botswana, and what the potential might be. The participant list and the workshop programme can be found in Annex I and Annex II respectively.

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[11] "A CO_2 capture ready power plant is a plant that will be able to include CO_2 capture when the necessary regulatory and/or economic drivers are in place, thereby avoiding the risk of 'stranded' assets and consequent 'carbon lock-in'" Capture Ready Study. July 2007. The Institution of Chemical Engineers. Prepared by Andrew Minchener, The Energy Conversion Group.

2.2.1 Programme and participation

The workshop was opened by the Deputy Permanent Secretary in the Ministry of Environment Wild Life and Tourism, Mr Mmopi, who welcomed the delegates, acknowledged the sponsors, the project team and workshop organizers. He also highlighted the importance of the occasion as a means to assess the opportunities for CCS in Botswana, and to support the decision making processes on CCS. He indicated that Botswana was honoured to have hosted the previous workshop on CCS in 2007 and to be part of the CCS-Africa 2 project now.

The workshop was attended by 57 participants consisting of 13 project team members and 44 national stakeholders. Figure 3.3 shows the breakdown of national stakeholders that attended the workshop. It is clear that the workshop attendance was dominated by government stakeholders and their parastatal organizations. The majority of the government and parastatal stakeholders came from the key departments of Meteorological Services, Geological Survey, Mines, Environment, Energy, Waste Management and Pollution Control; as well as the Botswana Power Corporation and research and technology organizations. Key private sector companies also attended, including Debswana that plans to install a 90 MW CBM plant, the Kalahari Gas Corporation/Energy that is exploring CBM, the Future Fuels organization and an underground coal gasification consultant. The academia (University of Botswana), NGO's and media communities were also represented.

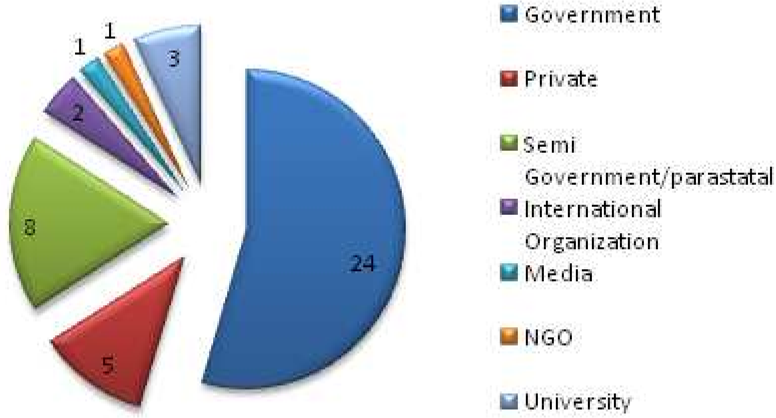

Figure 2.2 *Breakdown of participants*

The workshop objectives were mainly to:

- Provide information about CCS directly from international and regional experts.
- Provide a platform for Botswana stakeholders to deliberate on the issue.
- Explore the potential relevance of CCS for Botswana.
- Identify potential further steps in terms of knowledge, capacity and regulatory development.

The workshop programme was also tailored in a similar sequence, where after the introduction of the project background and objectives, international and regional speakers made a series of presentations on:

- Climate change, energy and development.
- Overview of CCS.
- Geological storage.
- Capture technology for power and industry.
- Assessment of geological potential in South Africa.
- Cost and economics of CCS.
- Risk and impacts of CCS.
- Policy and legal Issues for CCS.
- Public perception as seen by a national stakeholder.

The late afternoon of the first day was then occupied by a panel discussion in which both national (government, private, parastatal, NGO, University) and regional (SANERI of South Africa) stakeholders were prompted to react to the following.

1. Whether Botswana could do a geological storage atlas like South Africa (panellists were Geological Survey, Mines and Kalahari Gas Corporation/Energy).
2. What could be the role of CCS in the Botswana future energy system? (Panellists: Botswana Power Corporation, Kalahari Energy, Future Fuels and Energy Affairs Division).
3. What are the capacity and knowledge needs in Botswana before CCS can be done? (Panellists: University of Botswana).
4. How could CCS be regulated in Botswana? (Panellists: Departments of Environmental Affairs & Water Affairs).
5. What could be the role of Underground Coal Gasification? (Panellist: Alan Golding (UCG consultant).

The beginning of the second day was the presentation of fact sheets of the countries involved in the project namely, Botswana, Mozambique and Namibia. South Africa shared their experiences on CCS and making a geological storage atlas in this session. After presentations participants were divided into three groups to deliberate on:

- Storage potential in Botswana.
- Capture Issues- sources and technology.
- Policy/legal issues- regulatory framework, is CCS legal?

These titles are discussed below, mainly drawing from key observations and comments from the panel and group discussions.

2.2.2 Geological storage potential

The key elements that were presented as crucial for carbon storage were whether Botswana would have sufficient underground porous reservoir space (capacity and injectivity) at sufficient depth (>800m) and with appropriate containment (cap rock to avoid leakage). It was also investigated if sufficient data to analyse those parameters existed, and/or was freely available.

CCS has been successfully implemented for enhanced oil recovery, and global assessments indicate that deep saline formations could have the greatest volumetric potential for CO_2 storage. Storage in other geological formations such as coal seams, basalts and shales is less certain (IPCC, 2005).

Botswana doesn't have oil reserves but is known to have huge amounts of coal, some seams are being mined and other seams are under exploration (shaded area in Figure 2.4). It is clear that Botswana must decide how best to utilize its coal resources, whereby coal mining, coal bed methane extraction and underground coal gasification are all options. There are also unmineable coal seams that could be potential storage sites for CO_2 if the depth, porosity and cap rock are suitable.

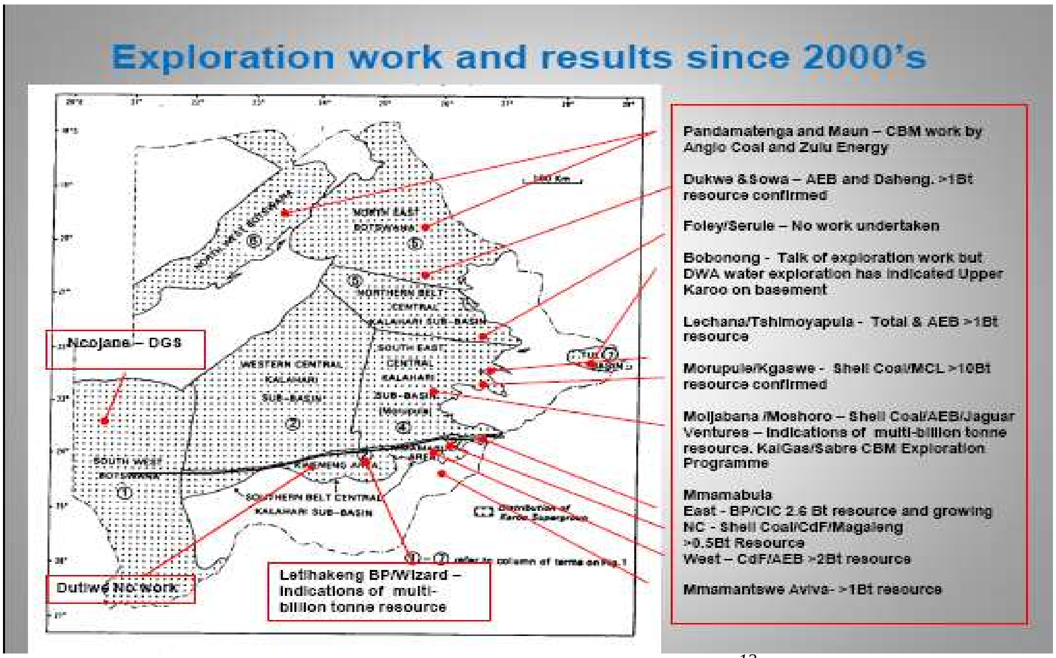

Figure 2.3 *Coal exploration activities in Botswana up to 2000*[12]

Due to its large coal deposits, Botswana also has large inferred coal bed methane reserves, and captured CO_2 could be used for enhanced coal bed methane recovery (ECBM), but the technology is not mature and is still under demonstration stage in the chain of technology development.

In the 1980's there was oil exploration of onshore basins, and some aeromagnetic data showed thick sediments (>3km) in the Nosop and Ncojane basin of Botswana. The state of these reservoirs for CO_2 storages is not known but would warrant investigations. Botswana is also known to have some basalts at depth, however information on depth and their state of porosity is not known.

Underground coal gasification (UCG) could be a good addition to Botswana's coal industry, and possibilities exist to couple UCG with CCS technologies. UCG involves igniting a coal seam underground and pumping out the partially burned gases that result, which can then be processed into useful products such as synthetic gas and synthetic fuels. After gasification, the remaining char (burnt coal), can absorb the CO_2 quite well, if CO_2 were to be captured from the gas processing facility at the surface and then re-injected. Another advantage of UCG, is that a very small surface footprint is needed to produce up to 1GW of energy. The experience shows that UCG allows use of coal resources in deep coal seams that normally would not be accessible. The cost associated with UCG can be lower than coal mining, as no coal has to be brought to the surface.

[12] Pers Comm. Alan Golding.

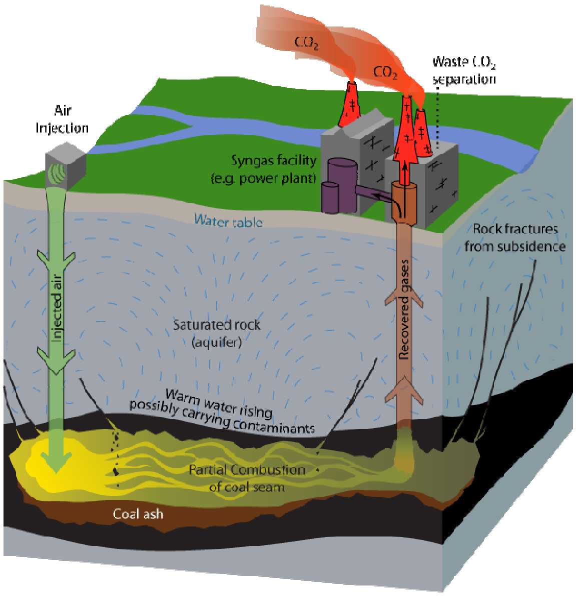

Figure 2.4 *Underground coal gasification without CCS*[13]

Whilst all these features could be explored for CCS, it would be important to ensure that CO_2 is stored at a depth that would not interfere with groundwater, since 70% of Botswanans use bore-hole water. The area around Pandamatenga is believed to have depths that are being recommended for CCS but that needs to be verified by data analysis.

There are a number of bore holes that have been drilled as part of mineral and water exploration[14], but the information is held by different parties. Most of the data are from the 1980s when Shell and Amex undertook coal exploration. The cores are in a library and would have to be reviewed and collated. This will require motivating the private companies that have the data to see the benefits of exploring CCS possibilities in Botswana, so that they can allow the use of their data.

The area that is to be assessed is huge, but stakeholders believed it would be good to make a start if resources can be made available. The initial action recommended was to produce a quick scan atlas that can be used to motivate a more detailed atlas that could show potential sites for CCS in Botswana. The action plan that was proposed is given in Table 2.3.

[13] http://groundtruthtrekking.org/WildResource/Issues/UndergroundCoalGasification.html.
[14] As much as 5000 boreholes may have been drilled in 1970s and 1980s. Pers comm. Kalahari Gas Exploration/Kalahari Energy.

Table 2.4 *Proposed Action Plan to determine storage potential for Botswana*

Action	Milestone	Actor	Timeframe
Awareness raising on CCS continues	Buy in from key stakeholders	MMEWR supported by Project Team	Continuous
Resource mobilisation.	Budgeted Funds for follow-up project	MMEWR supported by Project Team	At start of follow-up project
Context analysis • Stakeholder analysis • Create a task team	Task team for reviewing and collating storage potential data	MMEWR supported by Project Team	At start of follow-up project
Quick scan study based on existing data • Detailed study • Characterisation of storage formations on regional scale	Report with • Potential areas/sites • Information gaps • Further work • Proposal with budget • Promotional output	DGS, DWA of MMEWR and University supported by Project Team	6 months
	• Geological storage Map • Test results	UB DGS, DWA Private sector, RTOS	24 months
Site selection characterisation (towards demonstration)	Demonstration potential	Government, BIUST, task force, Local companies, International Companies	3 - 5 years

Note: MMWER- Ministry of Minerals, Energy and Water Resources; DGS- Department of Geological Survey; UB-University of Botswana; DWA- Department of Water Affairs; BIUST- Botswana International University of Science and Technology; RTO- Research and Technology Organization such as Rural Industries Innovation Centre and Botswana Technology Centre.

2.2.3 Current and future CO_2 sources

CO_2 capture is feasible from stationary point sources. Success so far has been registered particularly in the gas processing industry. Hydrogen production at oil refineries, fertilizer production, synthetic fuels production, such as biodiesel and underground coal gasification, involve waste gas streams of concentrated CO_2. The other sources such as furnaces and power station boilers produce diluted CO_2. A conventional pulverized coal power plant has approximately 12% of CO_2 in the flue gas while a natural gas plant has 4-8%. Cement production has 20% CO_2 in its flue gas (Pers. Comm. van den Brink).

Botswana stakeholders indicated the following as current and potential CO_2 sources which are significant future sources of CO_2:

- Morupule Coal-fired power generation A (132MW) & *planned* B (600MW) for 2013
- *Planned* Mmamabula coal fired power station (1200MW) (potentially by 2015/16)
- *Planned* Mmamatswe Coal Power Station (1000MW) (potentially by 2020)
- Underground coal gasification (timeframe not yet defined)

In addition, Botswana has or is planning a number of sources of CO_2 that are less significant in emissions:

- BCL Smelter Copper / Nickel mine at Selebi Phikwe.
- Makoro Bricks.
- BMC.
- Sua Pan (Botash).
- Lobatse Clayworks.
- Cement production.
- Diesel generators.
- Waste incinerators.

Potential capture sources that may emerge in the economy of Botswana include new coal-fired power stations and UCG. Stakeholders indicated that in the meantime while coal is the dominant source of electricity, employing CCS could take Botswana to a clean coal future. Botswana already has an energy deficit, and coal is already assuming an important role to meet existing and future energy demand. Exploring the use of CCS as a clean coal technology could put Botswana on a path to be one of the leaders in clean coal technology[15], and in particular CCS.

CCS could be viewed as a bridging gap while costs of renewable energy technologies are reduced, and become able to support base load electricity requirements. UCG like CCS can also be deployed as a bridging technology to continue utilizing coal resources en route to renewable energy options. Based on current progress in Botswana, a move to full solar seems a long-term prospect, and so in the meanwhile Botswana could use CBM and coal coupled with CCS (Pers. Comm. Dr Peter Zhou).

CCS comes with a price: higher material and service costs, and the fact that more energy is required for the capture process. This means that consumer prices will likely become higher. With regard to consumer prices, stakeholders also noted that in Southern Africa energy prices were already low, so consumers should learn to pay premium price[16] for electricity supply, accounting for the external costs of energy generation. It was noted that the government was introducing feed-in tariffs for renewable energy, but although a possible policy option, it is not expected to be extended to CCS as yet.

The Action Plan proposed by stakeholders for follow-up is given in Table 2.4 below.

Table 2.5 *Action Plan proposed for Capture Issues*

Action	Milestone	Actor	Time Frame [yr]
Skills Development/technology transfer: • Identify the gaps in skills set. Identify necessary technology transfer. • Specific training on CCS capture - either abroad/or nationally (depending on cost and project specifics). • Collaboration with international CCS organisations, universities	Skills capacity and Technology transfer requirements report Affiliation with a number of organisations, universities Report	CCS Project Team Ministry of Education, RIIC, BOTEC. Department of Energy Affairs, University of Botswana	1 2-3 2-3
Institutional arrangement • Identify barriers and needs in infrastructure, in organisation of government • Implementation of measures to remove barriers and satisfy needs for incorporation of CCS	Report	Project team consisting of various stakeholders, e.g. in workshop DMS/ project team	1-2 >3 1-2
Water/energy/infrastructure study • Feasibility study of CCS in specific site/project, technology selection; identify water and energy needs, and costs.	Report		
Funding for: • Inventory of current and potential point sources, potential for CCS.	Report	Project team	1-3

15 'Clean coal technology' describes a new generation of energy processes, some currently available and others being developed, which have the ability to sharply reduce air emissions and other pollutants. These new technological breakthroughs make it possible for new and older coal-burning power plants to produce power in an economical and environmentally responsible manner. http://www.engineerlive.com/Power-Engineer/Focus_on_Coal/New_technologies_reduce_environmental_impacts_of_coal-fired_plants/22603/

16 Tariffs are often politically pegged and sometimes below cost of supply.

2.2.4 Incentivising and regulating CCS

There a number of concerns that were identified by Botswana stakeholders as requiring regulation, among them, possible CO_2 leakage and related contamination of groundwater, specifications of the CO_2 to be stored and suitability of storage sites, the related energy penalties for CCS and licensing of the pore space. Resource diversion from renewable/cleaner energy options may also need to be regulated. All regulation is required at capture, transport and storage stages of CCS for completeness.

Stakeholders pointed out that a Needs Assessment is required on CCS regulation to guide establishment of a policy position on CCS, after a review of the alternatives (based on costs and environmental considerations)

If CCS is endorsed for implementation in Botswana, stakeholders thought it could be incentivised through tax incentives, financing subsidies, policy at a local level, and through trading carbon credits at the international level. Capacity building and technology transfer will also be necessary ingredients for CCS to succeed.

It was indicated that at the onset, existing planning laws e.g. Environmental Impact Assessment and Social Impact Assessments (EIA and SIA) would provide the basis to regulate CCS but these will need to be reviewed in the context of CCS specifics.

2.2.5 Rationale for CCS, capacity requirements and other salient points

Rationale for CCS in Botswana

Coal is an abundant resource in Botswana and it is imperative that the country must devise a sustainable manner to use coal as cleanly as possible. It is quite clear that coal will play a part in the nation's energy strategy.

Coal-fired power plants play an important role in providing a stable energy supply at a low cost. The reality is that coal is abundant, efficient, and less expensive than most other energy options and will remain an important part of the global energy mix. It will however be important to assess whether coal can be used to produce energy in an efficient manner. Botswana has the possibility of reducing GHGs while maintaining a strong economy, using energy at a reasonable cost, by deploying several options that include energy conservation, the increased use of renewables, as well as CO_2 emission controls including CO_2 capture and storage.

Botswana has an opportunity to tap its coal and CBM resources as a means to diversify its economy- if it can cleanly produce energy to sell to the Southern African region and create other chemical industries. Botswana also has the potential to become a leader, if it starts early, in clean coal technologies, among them CCS, UCG and deploying high energy efficient and low polluting coal power plant technology.

Botswana has already lined up power development projects up to 2026 that are based largely on coal, so coupling these projects with clean coal technologies is imperative in the light of global effort to reduce emissions of greenhouse gases into the atmosphere. It is possible that future lending for power projects by multilateral organizations may require recipients to prove that they will generate power responsibly.

Capacity requirements

To start exploring the potential of CCS, stakeholders proposed that a project team is required to gather the data from the oil/coal/water and other mineral investigations to explore storage potential, identify the gaps in knowledge, and then acquire funding to fill the gaps.

Institutional, technical and human capacity will be required for assessment of geological storage potential from existing data and any further work that may emanate from a possible quick scan of the Botswana geology. Similar capacity will be required for establishing a regulatory framework for CCS in Botswana. Training of CO_2 capture, transport and storage engineers could be realised both in local and overseas institutions.

Salient issues and proposed action plan

Stakeholders have recommended that it is important to get started on assessing the general CCS potential of Botswana through the following processes:

- Continued awareness will be important in the form of further workshops and stakeholder consultations on the issue. Creating a national and regional network of CCS interested professionals could maintain interest.
- Detailed studies will be important for assessing the geological storage potential using existing data. This could culminate into a quick scan atlas that can be used to lobby for more financial resources to undertake a more detailed assessment- leading to an atlas and selection of sites (if available).
- Skills assessment will also be required to identify requirements for building the necessary capacity for CCS in the country. This will lead to identification of necessary training and where it can be completed. Capture training involves technology transfer and is suggested that collaboration with international organizations be established.
- A detailed study is also required to evaluate requirements for carbon dioxide capture, and how feasible that would be for Botswana in terms of appropriate technology, energy and water requirements, and significance of the existing and future point sources.
- For regulatory framework, stakeholders proposed a Needs Assessment study to guide establishment of a policy position on CCS and also guide development of a regulatory framework.

3. Mozambique: economic opportunities

3.1 Country assessment

3.1.1 Introduction to the country

Mozambique covers an area of 799 380 km^2, with 786 380 km^2 of land and the remaining 13000 km^2 consisting of water bodies (Figure 3.1). The population of the country is approximately 20.2 million inhabitants, with 81% in the subsistence agricultural sector. In 2008 the per capita GDP in the country was estimated at U.S. $956, a significant increase over the mid-1980s level of U.S. $120. The annual economic (GDP) growth rate was 6.5% in 2008. The industry sector contributes with 41.2% for the GDP, followed by services with 34.6% and agriculture with 24.2%. The Agenda 2025 (Mozambique's long term vision)[17] and the Five Year Plan[18] are policy documents where development strategies and objectives in the country are defined. One of the main objectives is to reduce the levels of poverty and to promote a fast and sustainable economic growth. The country observes successive years of peace, stability, and economic growth, but remains dependent upon foreign assistance for much of its annual budget, and the majority of the population remains below the poverty line.

Figure 3.1 *Map of Mozambique*

3.1.2 Electricity generation and industrial production

The enormous existing energy potential includes hydropower and hydrocarbons, primarily gas and coal. The hydroelectric potential of Mozambique is estimated at 12500 MW. The largest portion of the hydropower potential is located on the Zambezi River. Here the only potential that has been developed is Cahora Bassa South Bank, commissioned in 1975, with an installed capacity of 2075 MW. Hidroeléctrica de Cahora Bassa (HCB) is the power producer company at Cahora Bassa dam.

17 Agenda 2025 'The Nations Visions and Strategies', Maputo, Mozambique, November 2003.
18 Mozambique Five Year Plan 2010-2014, Maputo, Mozambique, April 2010.

Mozambique has large sedimentary basins of natural gas. Accumulations of gas have been discovered in Pande and Temane, Province of Inhambane, and Buzi, Province of Sofala. Additional reserves are currently under investigation in the Cabo Delgado Province. Total gas reserves might be as high as 5 TCF. Pande gas is now being exported to South Africa through a pipeline linking the locality of Temane, in the Province of Inhambane, and Sekonda, in the Province of Gauteng, in South Africa. In 2005 a ramification of the pipeline from Ressano Garcia, border to South Africa, enabled the supply of natural gas to the industrial park of Maputo.

Concerning coal resources, Mozambique has three relatively large known deposits at Moatize-Minjova, Senangoe and Mucanha-Vuzi, all of them in the province of Tete. Total reserves are estimated at about six billion tonnes. Mining of coal is still to start.

The country's generating capacity as per 2010 totals some 2339.90 MW (Table 3.1), being HCB the main producer of that capacity, followed by the National Utility EDM. The total energy consumed in Mozambique is of about 500 MW. The rest is exported to South Africa, Zimbabwe, Malawi and Botswana.

Table 3.1 *Electricity sources in Mozambique in installed capacity in 2010*

	Capacity in 2010 [MW]
Hydro (Hidroeléctrica de Cahora Bassa (HCB))	2075
Hydro (Electricidade de Moçambique (ECM))	103
Gas turbine	128
Diesel engine	20
Others	13
Total	2340
Internal consumption:	500

Five large power generation projects are in the development process, as shown in Table 3.2 below. They are regional projects by nature, with the aim to meeting the growing power demand in Mozambique and contribute to minimize the impact of the current shortage of power in Southern Africa.

Table 3.2 *Projects in process of development*

Project Name	Developer	Capacity [MW]	Completion Date
Mpanda Nkuwa	Hidroelectrica de Mpanda Nkuwa	1500	2014
Moatize	EDM/AES Whatana Investments	2400	2015
Benga	ELGAS/Riversdale	2000	2015
Maputo Gas	EDM/SUEZ INTELEC	500-1000	2012
HCB North Bank	HCB	850	2012-2015
Total		**7250 - 7750**	

In parallel with the above mentioned power projects there is a need to develop a 765 kV backbone transmission line, from Tete to Maputo. That transmission line will guarantee that power is produced in Tete and most of it is then exported via Maputo

3.1.3 CO_2 emissions

The Mozambican First National Communication to the UNFCCC reported direct CO_2 emissions amount of 9,265 ktCO_2 per annum (with 2004 as the reference year). These emissions were released mainly from land use, land use change and forestry (LULUCF) (82.9%) and energy (16.5%) sectors. The remaining trace amounts were released by industrial processes.

Figure 3.2 *Burning of forests for agriculture*

The total amount of GHG emissions accounted for 15,905 ktCO_2-eq in 2004. From this amount, the larger contribution came from LULUCF (48.7%), agriculture (25.7%) and energy (11.6%) sectors (Figure 3.2). However, since then, the country has experienced substantial economic development as well as a growth in population which have contributed to a rise in GHG emissions. Additionally, there are a number of new projects in the energy sector which will take advantage of the existing potential (under partial exploitation) of natural gas (in the southern Province of Inhambane), as well as the main reservoirs of coal in the central Province of Tete.

Regarding the Mozambican commitment to global climate agreements, in general, it is to note that the country is a member of the UNFCCC and has ratified the Kyoto Protocol. In this regard, the country has been adopting and implementing different regulations aiming at engaging the global agenda under the Rio World Summit Convention. The country has established a Designated National Authority (DNA) which is due to take care of activities under the Kyoto Protocol's Clean Development Mechanism (CDM) within Mozambique. One CDM project has been proposed and submitted to the CDM's executive board on fuel switching from coal to natural gas in a cement plant in Matola. Some additional project activities are emerging from different sectors. However, as the National Power Grid is arguably based mainly on hydropower, there have been very few opportunities to identify CDM potential activities in the energy sector.

3.1.4 Activities relating to CCS

So far there are no carbon capture and storage (CCS) activities in Mozambique. To date, the only initiatives regarding CCS relate to participation of Mozambican stakeholders in seminars on CCS both in Botswana (2007) and in South Africa (2009). Nevertheless, as projects for installation of coal-fired power stations have started, the potential for CCS activities in Mozambique will increase, due to the large amounts of carbon dioxide emitted from such installations. Apart from that, some of the existing industries, like the cement industry, are potentially suited for CCS deployment. The geological storage potential for CO_2 in Mozambique has not yet been assessed, but the country has prospective sedimentary basins.

Figure 3.3 *Main sedimentary basins of Mozambique*

3.2 Workshop proceedings

3.2.1 Programme and participation

The CCS in Southern Africa workshop in Maputo, which took place on 12th and 13th April, was attended by professionals from different governmental and non-governmental organisations, the private sector and public institutions related to the fields of energy and environment, with incidence on representatives of the hydrocarbon sector and teaching/research institutions. The participants lists and final programme can be found in Annexes I and III respectively.

The Academic Deputy Vice-Chancellor of the Eduardo Mondlane University, the host institution, Orlando Quilambo conducted the welcome address to the participants, in representation of the Vice-Chancellor of the Eduardo Mondlane University, Filipe Couto. In his speech he mentioned that Mozambique has substantial resources of coal and gas, which together with the harnessing of the high hydroelectric potential, could contribute to minimize the energy crisis that the region is facing. Thus the technology of carbon dioxide capture and storage can help the country to explore its hydrocarbon potential without major impacts to the climate system. The technology can also help in other industrial activities. He ended his speech thanking ECN for having chosen the Eduardo Mondlane University as the major partner for the dissemination of information about this technology in Mozambique. He also thanked all the participants for having dedicated their time to participate in this event.

The official opening address of the workshop was made by the Deputy Minister of Energy, His Excellency Jaime Himede, in representation of His Excellency the Minister of Energy, Salvador Namburete, who although had planned to address the workshop participants, he had a urgent duty to integrate the delegation of the Head of State in the province of Tete. This province has the highest coal reserves and hydroelectric potential in Mozambique. In his speech, Jaime Himede introduced CCS and its potential applications. He also highlighted the fact that the full integration of CCS is still at an early stage of development, and thus investment and capacity building was necessary. It was also stressed that the involvement of Mozambique in the development of the technology, through the Eduardo Mondlane University, was of national importance (The full translated speech can be found in Annex VI of this report). With these opening remarks, His Excellency the Deputy Minister of Energy declared the workshop open, reiterating the votes for profitable discussions.

The workshop was attended by 45 participants consisting of 9 project team members and 36 national stakeholders. The national participants represented organizations such as the National Petroleum Institute (INP), the National Enterprise of Hydrocarbons (ENH), the National Power Utility (EDM), the National Enterprise of Petroleum Products (PETROMOC), the consultancy company KPMG, the Geological Survey (DNG), the National Institute of Meteorology (INAM), the Academy of Sciences of Mozambique (ACM), the Association for Scientific Research of Mozambique (AICIMO), the Technical University of Mozambique (UDM), the Pedagogical University (UP), the Eduardo Mondlane University (UEM), the Ministry of Transport and Communications (MTC), the Ministry of Science and Technology (MCT) and the Ministry of Energy (ME).

The press was also well represented through the National Television (TVM), the National Radio (RM), the Portuguese broadcasting company (RTP), the Mozambican private television (STV) and the newspaper producer Notícias.

The number of participants was below what had been expected. The visit to the province of Tete by the Head of State in the same week, taking with him a delegation of companies investing in the energy sector in that province, significantly influenced the participation. In fact none of the coal companies, namely Vale and Riversdale, for which the issue of CCS is interesting were represented in the workshop, as they had to be in Tete province. Nonetheless the discussions were very fruitful, and the aims of the workshop have been attained.

The workshop objectives, which were the same in the three target countries, were mainly to
- Provide information about CCS directly from international and regional experts.
- Provide a platform for Mozambique stakeholders to deliberate on the issue.
- Explore potential relevance of CCS for Mozambique.
- Identify potential further steps in terms of knowledge, capacity and regulatory development.

The workshop programme was also tailored in a similar sequence, where after the introducing the project background and objectives, international and regional speakers made a series of presentations on:
- Climate change, energy and development.
- Overview of CCS.
- Geological storage.
- Capture technology for power and industry.
- Assessment of geological potential in South Africa.
- Cost and economics of CCS.
- Risk and impacts of CCS.
- Policy and Legal Issues for CCS.
- Public perception of CCS.

The afternoon of the first day was then occupied by a panel discussion in which national stakeholders were prompted to react to issues related with the presentations made. The idea was to consolidate the issues presented and try to ask some critical questions, as a preparation for the breakout groups the following day. The beginning of the second day was the presentation of fact sheets of the countries involved in the project namely, Botswana, Mozambique and Namibia. South Africa shared their experiences on CCS in this session. After the presentations, participants were divided into two groups to deliberate on:
- Storage potential in Mozambique.
- Capture sources, present and future.

These titles are dealt with below and mainly derive from the panel and group discussions. The presentations from both groups can be found online[19].

3.2.2 Geological storage potential

The breakout groups were structured based on the relevant experience of each individual. During the breakout groups, a number of questions were given to each group to discuss, and then complete a small presentation to communicate the answers to all the participants. In relation to geological storage potential in Mozambique, the questions asked and the answers were:

What are potential CO_2 storage reservoirs in Mozambique?

- Roughly 50% of the country's geology consists of sedimentary basins.
- 3 types of potential CO_2 storage reservoirs can be found:
  - future depleted gas fields
  - coal seams
  - cap rocks.
- Big basalt flows underneath the sedimentary cover in central-south Mozambique.

Is there sufficient-quality information?

- Insufficient quality information.
- Detailed geological work needed to characterize potential sites.
- Oil companies have plenty of info that is not public.
- Need to involve oil companies in the process so that they can make some of this information available.

Why (if at all) would Mozambique consider CO_2 storage

Mozambique would consider CO_2 storage in the following cases:

- Existence of a clear development roadmap: if Mozambique will be a carbon-intensive country, CCS needs to be considered. If Mozambique will be a green economy, this might not be needed.
- Incentives to the companies/investors.
- Certainty in climate change agreements (internationally).
- South Africa could consider Mozambique as a potential CO_2 importer and storage location.

What would be needed for CO_2 storage to take place in Mozambique in terms of human capacity, investors and companies?

- Money to invest in training and national regulation implementation.
- Global cooperation framework on policies and regulations.
- Knowledge, companies and resources need to be developed so that risks of investments are reduced.

3.2.3 Current and future CO_2 sources

The second breakout group was asked to outline the potential deployment of CCS, based on current and envisioned CO_2 sources, based on plans from within industry.

- Current: Cement and aluminium production (BHP Billiton Mozal plant - Maputo (250kt product output per year)).
- Planned: Coal-fired power (Riversdale/Tata - 500MW plant, Benga, Tete Province, planned completion for 2013; Companhia Vale do Rio Doce (CVRD) - 1500MW plant - planned completion (Moatize, Tete) and gas-fired power (to be realised to utilise national resources).

[19] See, http://www.ccs-africa.org/projects/ccs-in-southern-africa/mozambique/workshop-programmes-and-presentations/

- Potential: Refineries, fertilizer production, biomass conversion.

Figure 3.4 *Gas processing plant (no CO_2 separation), Mozambique*[20]

3.2.4 Incentivising and regulating CCS

If CCS is to be incentivised in Mozambique, the discussions concluded that CCS should play some part in the international agreements on climate change, namely the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. There were extensive discussions about the issue of the possibility of integrating CCS into the Clean Development Mechanism (CDM) for developing countries, since currently the only potential mechanism that could stimulate deployment of CCS in Mozambique are national interests.

3.2.5 Rationale for CCS, capacity requirements and other salient points

The workshop results were generally in favour of the involvement of Mozambique with ongoing developments regarding CCS. The main rationale for continued and perhaps increased involvement were due to the fact that the country is gradually increasing its production of CO_2, through its cement production, aluminium smelting industries and natural gas processing. It was also taken into consideration that the country is planning to start producing electricity through the use of coal and to expand its natural gas fired power production, as a contribution to minimize the regional energy crisis and to increase national income. Other industries with potential to produce carbon dioxide are those of refineries, production of fertilizers and biomass conversion, however plans involving such industries currently unclear.

According to the discussions of the workshop, Mozambique may have a reasonable geological capacity for carbon storage, as half of the country is made of sedimentary basins. The fact that the country is exploring natural gas already is an additional advantage. The depleted gas fields may be used in the future as storage sites. Apart from the CCS for national purposes, it was also considered that the storage of South African CO_2 could be an option if this is considered under the international agreements on climate protection.

[20] Mobote, A. Natural Gas in Developing Countries: Investment Needs and Opportunities for International Cooperation. Natural Gas Development in Mozambique. Available online: http://www.un.org/esa/sustdev/sdissues/energy/op/qatarSymposium/20Presentation_Mozambique_Mabote.pdf

Mozambique is part of the UNFCCC and of the Kyoto protocol and thus it has moral obligation to contribute for these instruments. Regarding the way of implementation of CCS in Mozambique, the workshop concluded that it should start with capacity building at different levels, involving researchers, with focus on institutions dealing with potential of geological storage and analysis of implications of CCS on ecosystems, ground water resources and other issues. This capacity building process would provide a background for regulating CCS activities in Mozambique, and for the decision making process regarding future CCS implementation activities.

4. Namibia: balancing supply and demand

4.1 Country assessment

4.1.1 Introduction to the country

Namibia covers a land area of about 824,000 km^2, with a population of about 2.1 million. Namibia’s economy is heavily dependent, both directly and indirectly, on the primary sectors such as mining, agriculture and fisheries. In 2007, mining alone contributed more than 12% to GDP, and to some 50% of export earnings. GDP growth from 2001 to 2009 has been an average 4% per annum, and stands at US$ 8.5 billion in 2009. Through its key policy document, Vision 2030, and its 5-year National Development Plans, the Namibian government seeks to transform Namibia into an industrialized nation by 2030. However substantial challenges, such as unemployment, income dependence from the Southern African Customs Union, income disparities, a fledgling manufacturing sector and high import dependence, need to be addressed.

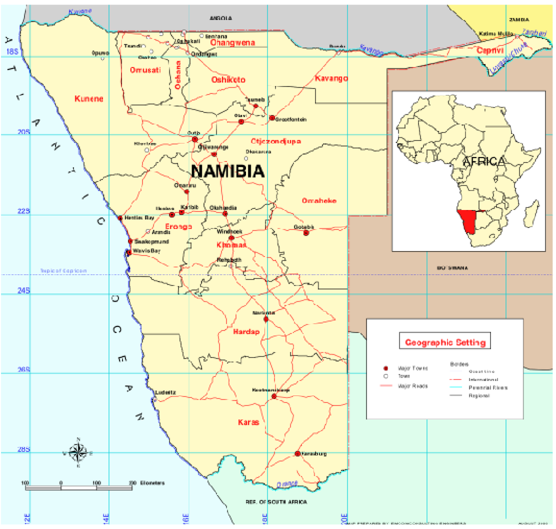

Figure 4.1 *Map of Namibia*

4.1.2 Electricity generation and industrial production

Namibia’s current electricity mix, which accounts for about 25% of total energy demand, is heavily dependent on imports, mainly from South Africa and Zimbabwe. Generation through local coal and diesel generation is reserved for periods of import shortages. Average annual electricity imports exceed 50% of total consumption. Only about 30% of Namibia’s population has access to electricity. Continued grid expansion and off-grid electrification thus are a key challenges. Investigations for new electricity generation capacity in the country are underway, and include assessments for a coal-fired power station of up to 800 MW, 50 MW diesel, 800 MW natural gas, 80 MW wind, up to 600 MW from hydro, and a nuclear power station.

Table 4.1 *Electricity sources in Namibia. The imported capacity depends on the hydropower production in a given year.*

	Estimated capacity in 2008 [MW]
Hydro	249
Coal	120
Diesel	24
Annual Imports (equivalent capacity)	~ 100 to 300 MW
Maximum demand in 2008 was 533 MW	

Namibia does not offer easily exploitable fossil fuel reserves, apart from its natural gas resources at the Kudu gas field. The country's dependence on fuel imports remains a concern. Although Namibia's utility NamPower currently generates all electricity in Namibia, and is the country's electricity trading entity, various initiatives are under way to establish Independent Power Producers (IPP). The low cost of electricity imports are however a disincentive, and Namibia's existing IPP framework therefore remains untested.

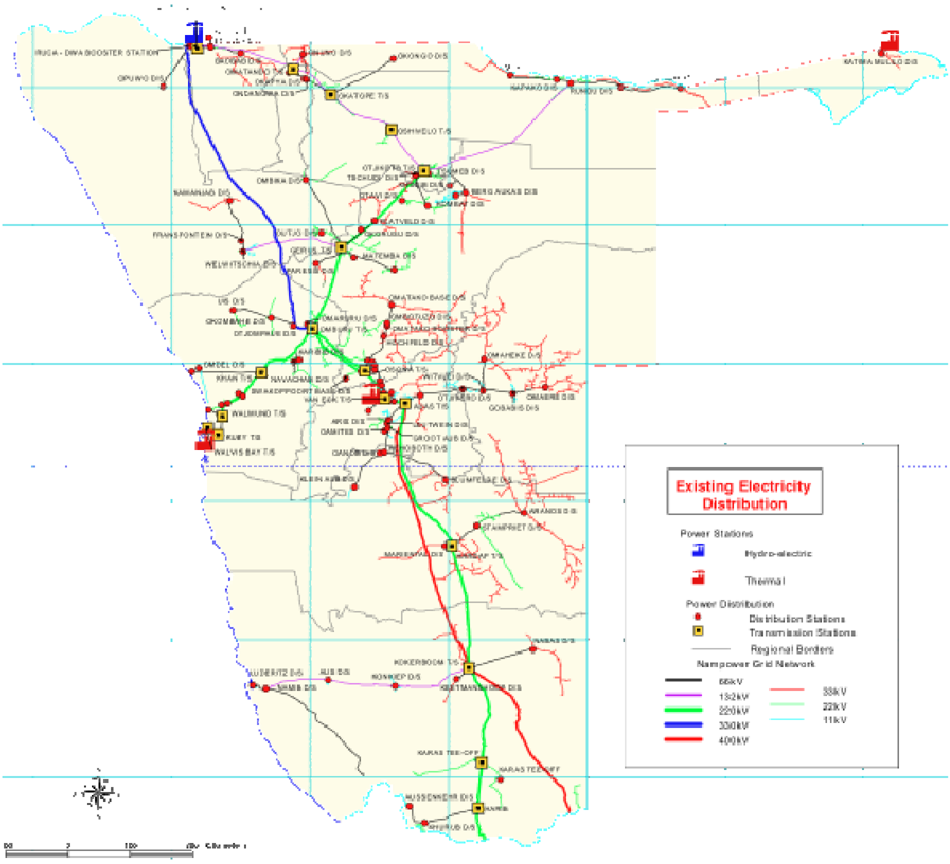

Figure 4.2 *Electricity distribution grid of Namibia*

4.1.3 CO_2 emissions

Namibia's greenhouse gas emissions in 2000 were mainly from the agriculture (6,700 Gg) and energy (2,200 Gg) sectors. At the time, Namibia was a net carbon sink, sequestering a total carbon dioxide (CO_2) equivalent of some 1,400 Gg per annum. Some major developments are underway, which would influence this status, such as:

1. Harvesting of about 80,000 tonnes of biomass from invader bush species per annum, to be used for wood gasification power plants, coal-fuel replacement for cement production and export of wood pellets.
2. Commissioning of a cement factory towards the end of 2010 with an annual coal consumption of 120,000 tonnes.

In 1995, Namibia ratified the United Nations Framework Convention on Climate Change and established the country's Designated National Authority (DNA) at the Ministry of Environment and Tourism. By March 2010, the DNA had issued several 'Letters of No Objection' to project developers wishing to initiate activities relevant to the Clean Development Mechanism (CDM). The DNA provides guidance on CDM procedures relating to projects and programmatic activities that seek to reduce emissions and/or sequester carbon in Namibia.

As yet, Namibia does not have a registered CDM project, although several Project Idea Notes have been developed. In 2009, Namibia has compiled its first climate change policy, which is now available in draft form for further stakeholder input. Namibia has also signalled its agreement with the Copenhagen Accord, and has a multi-sector stakeholder group - the Namibia Climate Change Committee - which advises government on strategies and policies relating to climate change.

Project developers wishing to tap into international carbon markets remain cognizant that the country offers some CDM and voluntary carbon sequestering opportunities. However, as a sparsely populated country with very limited industrial activities generating greenhouse gases, the scope and scale of such projects remains limited.

4.1.4 Activities relating to CCS

To date, the only initiatives regarding CCS relate to desktop research into carbon sequestration in soils using biochar. No assessment of geological formations in Namibia, which can be used to store CO_2, have been undertaken yet, partially because there are few significant and permanent point source emitters of CO_2. As a consequence, the understanding of CCS potentials in Namibia remains very limited, both at government institutions and the private sector. There is only a very limited understanding where geological formations of relevance to CCS exist, and the associated regulatory requirements remain undeveloped.

4.2 Workshop proceedings

4.2.1 Programme and participation

The CCS in Southern Africa workshop in Windhoek took place on April 15th and 16th at the Habitat Research and Development Centre. The participants lists and the final programme can be found in Annex I and IV respectively.

The workshop attracted an initial participation of 21 people and was officially opened by the Director for Environmental Affairs at the Ministry of Environment and Tourism. The participants comprised the governors for the Kavango and Omusati Regions and representatives from the Ministry of Mines and Energy, the Ministry of Environment and Tourism, the national water utility, the Ohorongo cement factory and NGO’s and private consultancy firms.

The workshop objectives, which were the same in the three target countries, were mainly to:

- Provide information about CCS directly from international and regional experts.
- Provide a platform for Namibian stakeholders to deliberate on the issue.
- Explore potential relevance of CCS for Namibia.
- Identify potential further steps in terms of knowledge, capacity and regulatory development.

The workshop programme was also tailored in a similar sequence, where after the introducing the project background and objectives, international and regional speakers made a series of presentations on:

- Climate change, energy and development.
- Overview of CCS.
- Geological storage.
- Capture technology for power and industry.
- Assessment of geological potential in South Africa.
- Cost and economics of CCS.
- Risk and impacts of CCS.
- Policy and legal Issues for CCS.
- Public perceptions about CCS.

The invitation to the workshop was distributed twice to over 100 public and private stakeholders with subsequent follow-ups. Feedback received from invitees was that there is a general perception that CCS is not applicable to Namibia. This resulted in lower than anticipated participation (see Annex I).

4.2.2 Geological storage potential

It is currently difficult for Namibia to provide an estimate of geological CO_2 storage potential as very little is known about the geology at depths below 800 meters. Boreholes have been drilled in search of oil and minerals, however none at depths relevant for CO_2 storage. There may be data, however, this will not have been scrutinized for potential CO_2 storage locations, and such information may not be available in the public domain. In addition to this, seismic data is scarce.

In general, much of Namibia is based on metamorphic rocks and sedimentary rocks. Although sedimentary rocks are normally considered as having suitable porosity for the geological storage of CO_2, the sedimentary formations are considered to be highly cemented and thus have a low porosity.

There is a large gas reservoir, the Kudu reservoir, off the coast of Namibia. First discovered in 1974, the field has 1.3 trillion cubic feet of proven reserves. The license for the field has passed between a number of large energy companies, but has yet to be drilled. In early 2010, Gazprom and Namcor established a special purpose company to accelerate the extraction of gas, with first production expected to take place in 2014[21]. The Kudu reservoir is 180 km from the coast, and at a depth of 4.5 km.

Due to the distance from the coast, and the ferocity of the ocean in the area, an idea has circulated that LNG may be produced on the rig, so that a pipeline is not needed. However, the original idea was to build a pipeline to provide gas to a planned (dependant on gas extraction) 800 MW power plant near Oranjemund. Whether this plan goes ahead is partly dependant on a power purchase deal with South African utility company Eskom, who would ideally purchase 50% of the electricity generated[22]. The potential of involving CCS at any point of the gas refining process is unattractive as the gas for the Kudu reservoir has a very low content CO_2 of less than 5% (Pers. Comm. Swart)

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[21] Upstreamonline. 2010. Gazprom signs up for Kudo. Available online (21/04/2010): http://www.upstreamonline.com/live/article208127.ece.

[22] Salgado, I. 2007. Tullow in partnership talks for Kudo gas field. Published in Business Report on 27th March 2007. Available online (21/04/2010): http://www.busrep.co.za/index.php?fArticleId=3754456&fSectionId=610&fSetId=662.

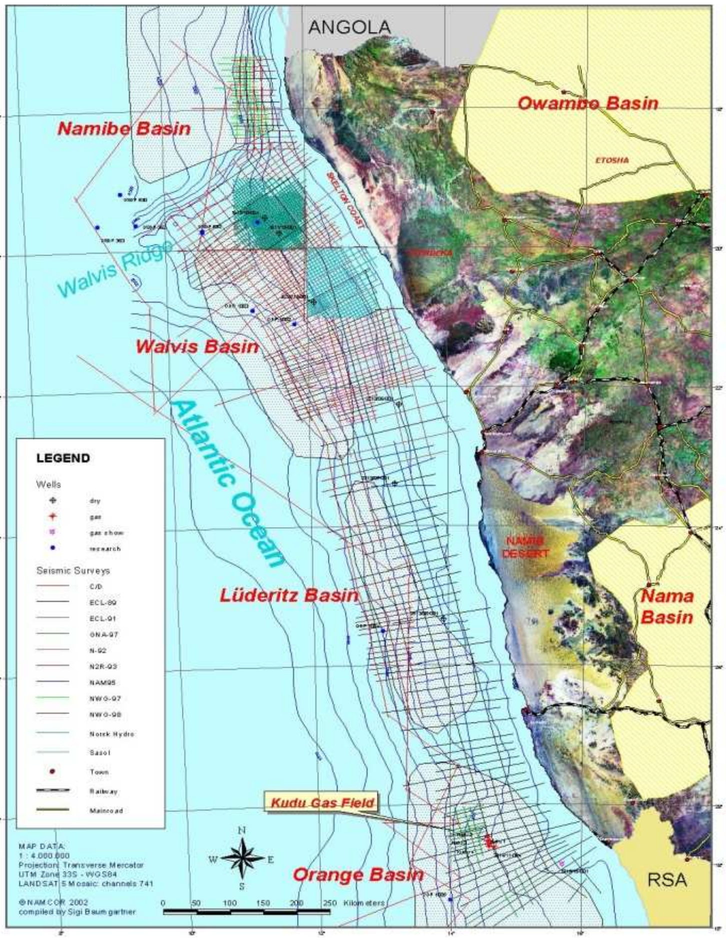


Figure 4.3 *Geological map of Namibia*

There are limited coal reserves in Namibia. Although the Aranos Basin has coal reserves amounting to about 350 million tonnes, the reserves are located at a depth of about 200 to 300 meters. The feasibility of exploiting this resource remains unknown.

In the Owambo Basin in Northern Namibia has also been explored to some extent and shows some potential CO_2 storage. At depths of about 800 meters, the basin contains several 'mounds' with a capacity of 500 million barrels each. Although 40% of the mounds are reservoir rock, they have not been drilled yet.

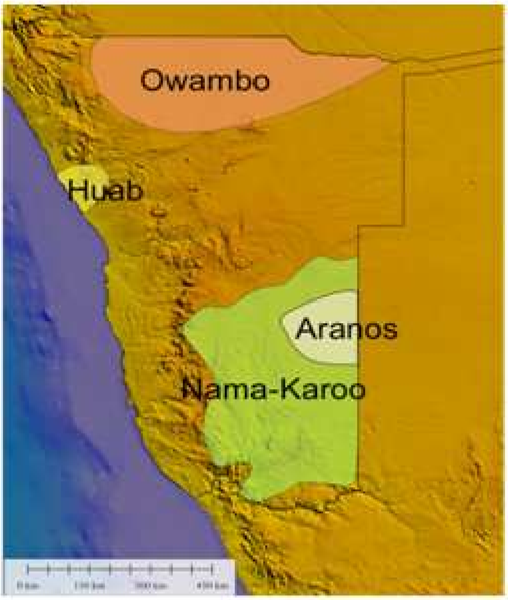


Figure 4.4 *Geological basins in Namibia*

4.2.3 Current and future CO_2 sources

Namibia depends on imports to meet approximately 50% of its electricity needs from South Africa. In 2009, due to downtime of South African power plants, NamPower had said that load-shedding would have to be introduced to prevent a total shutdown of the entire network. The situation was stabilized after 150MW of capacity was purchased from Zimbabwe.

In Windhoek, the aging and inefficient 120MW Van Eck coal-fired power plant is used during certain parts of the year, dependent on consumer demand and hydropower power provisions from Raucana (240MW) in the Northern part of the country. When operational, the Van Eck power station is understood to operate at a loss, with operational costs of about 1 N$ per kWh, which the utility then sells on at a price of about 0.4 N$ per kWh to Regional Electricity Distributors and other larger clients. (Pers. Comm. Schultz).

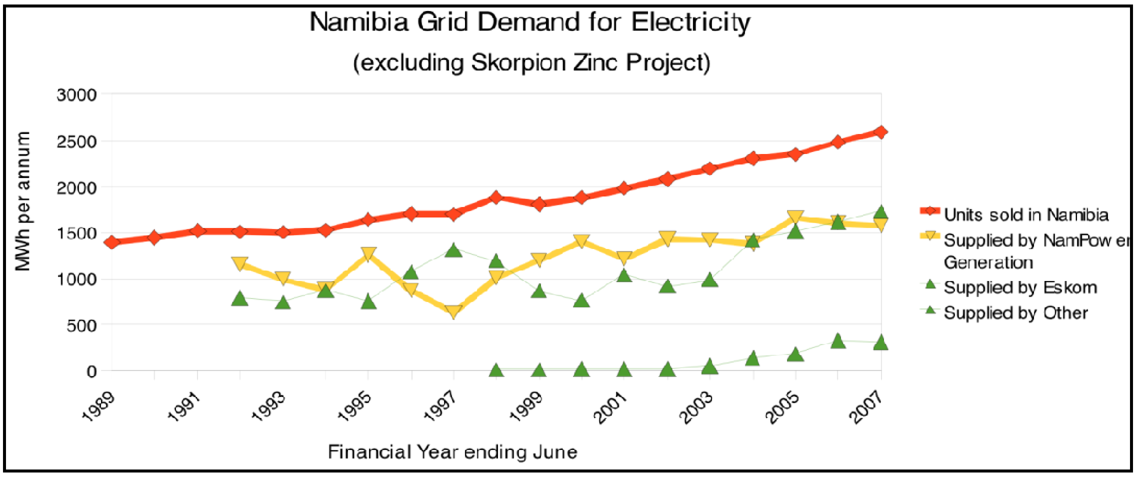


Figure 4.5 *Namibia grid demand for electricity*

Demand for electricity is however growing steadily, with a surge in demand expected by 2011. This increase in demand can be largely attributed to the establishment and/or expansion of several Uranium mines.

Uranium mining in the West of Namibia constitutes significant industrial growth for the country, however it may be constrained by access to energy. Apart from mine-based consumption, water desalination facilities along the coast to satisfy industrial water demands will also contribute substantially to electricity demand. The Trekkoppje mine's desalination plant inaugurated in 2009, has a demand of 20 MW and further desalination plants are in planning. Hence, in 2008 NamPower proposed that a coal-fired power station would be built near the port town of Walvis Bay. The capacity of the power plant would be 800 MW[23]. As Namibia has few exploitable coal reserves, the coal would have to be supplied by Botswana, South Africa or Indonesia. A decision to move forward on this project has yet to be made, since exact site selection is a key element in economic feasibility.

The Ohorongo Cement production plant roughly 450 km North of Windhoek is currently under construction. Ohorongo Cement is fully owned by German Group Schwenk Zement KG, and is expected to produce 700,000 tonnes of cement per year. Once operational, the plant will represent a major source of CO_2 in Namibia through the combustion of about 120,000 tonnes of coal per annum. About half of the annual coal consumption would ideally be replaced by about 85,000 tonnes of biomass from encroaching bush species. The owners of the plant have submitted a proposal to the Clean Development Mechanism Executive Board and an Environmental Impact Assessment to the Directorate of Environmental Affairs in order to pursue the large-scale utilisation of the available bush resources. It is estimated that about 26 million hectares of prime Namibian agricultural lands are subjected to bush encroachment (termed a symptom of environmental degradation), with an approximate total biomass tonnage of 520 million tonnes. The Ohorongo cement plant could access the Owambo Basin, but the pipeline would traverse areas of high population density.

4.2.4 Incentivising and regulating CCS

At present there are no incentive schemes in place regarding CCS in particular or large-scale clean energy technology deployment in general. In fact Namibia does not have an official energy strategy in place through which CCS could be accommodated. Current market conditions actually act as disincentives to clean energy technologies, since Namibia still has exceptionally low electricity tariffs and has no official targets on implementing clean energy technologies and/or greenhouse gas mitigation.

4.2.5 Rationale for CCS, capacity requirements and other salient points

Although CCS specifically offers very little scope in Namibia at present, there are a number of key issues in CCS that would be of relevance to Namibia especially in regards to the development of clean energy technologies.

Devising a national energy strategy that would encourage greater deployment of clean energy technologies would provide vital policy support. Such a strategy may address issues such as clean energy targets in the national energy mix, inventive mechanisms such as feed-in tariffs, penalties for industrial emissions of greenhouse gasses and levies on electricity tariffs and energy prices to support clean energy initiatives.

A national strategy would also prompt the need to build human resource capacities. Although facilities in tertiary education can cater for training in geology, mining and engineering, they are as yet not harmonised to cater for the specific skill needs of CCS or other clean energy technologies.

[23] Johnstone, A. 2008. Proposed 200/400/800 MW coal-fired power station and additional black start generation facility at Walvis Bay, Namibia. Site selection - geology, hydrology, soil and hydrology. Version - 5, 17 November 2008.

Investigations on geological formations as part of mining exploration activities should be expanded to consider CO_2 storage. Although much exploration data is available, it is either not in the public domain, or does not contain information relevant to CO_2 storage (because it was not considered important for mineral extraction). Making CO_2 storage assessment obligatory in the exploration license application requirements through Directorate of Mines may bridge the information gap.

A study to identify what information is available at present could be the pre-cursor to producing high-level geological maps on suitable CO_2 storage sites. This would be indicative of the potential and pending the results, may merit further targeted in-depth evaluations.

Greater cooperation with South Africa, Botswana and Mozambique CCS initiatives are advisable, to facilitate the capacity building process in Namibia. Especially collaboration with SANERI in South Africa, The Botswana Innovation Hub, The University of Botswana and the Eduardo Mondlane University in Maputo, Mozambique, could be pursued.

5. Cross-cutting issues

Drawing from the information obtained though the country assessments, and the views and comments expressed by participants of the workshops, three common issues that are relevant for CCS and specific to the Southern African region can identified: power demand, sustainable economic diversification and industrialisation, and the human and institutional capacity to address the challenges associated with those developments.

First, Mozambique, Botswana and Namibia all experience difficulties in meeting demand for electricity. Although currently demand is met, the countries rely on South Africa for a large share of their electricity use. South Africa is cutting exports drastically over the next years due to shortages in South Africa itself, necessitating in particular Botswana and Namibia to add to their own generating capacity. This is a challenge that may turn into an opportunity, though, if managed well. The region, especially Mozambique and Botswana, is endowed with large coal resources, so the use of coal for power capacity seems an obvious choice. Mozambique already is exporting clean hydropower to the region. But generation capacity is not the only issue; grid quality and access, combined with barriers to independent power producers, inhibit the utilisation of often abundantly present resources for renewable energy, in particular solar energy and biomass. If coal-fired power is to be developed in Botswana and Mozambique, the dynamic of power supply in the region may change drastically. CCS can be part of the consideration, but it would be better if integrated regional and national plans for power production also make use of other assets in the countries.

Second, Botswana, Mozambique and Namibia all have ambitions to develop and diversify their economies and industrialise. Botswana is endowed with natural resources such as diamonds, uranium, coal, gold and copper, and its economy has benefited from exploiting those. However, reliance on minerals alone has proven to be an economic risk. The country is therefore actively pursuing possibilities to diversifying its economy towards more competitive and less economically vulnerable sectors, including energy. Combinations with CCS are thinkable in unconventional coal applications, such as Enhanced Coal Bed Methane recovery or underground coal gasification, even though these technologies are still in an early stage and their environmental impacts will need to be evaluated. Mozambique is experiencing growth in both its cement and aluminium industries, as well as gas and coal extraction (soon to commence), and continues to attract foreign investment from other developing countries such as South Africa, Brazil and China. Namibia has a growing mining sector, particularly uranium, but also diamonds, zinc, lead, tin and tungsten. Such industrial expansion across the Southern Africa region will exacerbate the power deficit and increase greenhouse gas emissions.

Third, the level of institutional and human capacity in the field of energy in general and CCS in specific is insufficient for safe and efficient deployment of CCS. There is a general shortage of skilled, aware and well-informed entrepreneurs, government employees and academics. Hence, skills need to be imported, which is relatively costly and would limit the contribution clean energy would make to domestic economic diversification and employment. And the risk is greater that the economic and environmental goals of the government will not be met.

Additional issues in the region are issues that are common to CCS all over the world: the question of significant potential for geological CO_2 storage, the absence and challenges of a sound regulatory framework, and the lack of financial incentives for national or foreign investment in CCS.

6. Conclusion and further work

The workshops on CCS in Botswana, Mozambique and Namibia have unveiled an array of information about the reality of exploring CCS opportunities in developing countries. It is clear that CCS cannot be seen in isolation: it can only play a role if there is a broader energy and power strategy, preferably with a regional component as power grids and trade markets are integrated in the Southern Africa region. However, as both Botswana and Mozambique are explicitly looking into coal as a source of power, and there are some sources of CO_2 in the region with relatively low capture costs, it is recommended that an awareness level is maintained in the region, that further knowledge and capacity is developed in particularly Botswana and Mozambique, and that data collection on CCS is commenced.

From the workshops, the project team has distilled four concrete region-wide recommendations:
1. Regional power and industrialisation plans: Countries in the Southern African region face power shortages that inhibit economic development and industrialisation. The region is therefore in need of national power and industrialisation strategies that could also be aligned on the regional level. Such a strategy could outline the ways to enable sustainable expansion of capacity and possibly include a role for CCS.
2. Data and storage assessment: Both data on current and future CO_2 sources (including industry) and information on geological storage capacity is needed to inform a strategy for CCS in Southern African regions. A geological storage assessment could comprise of a quick scan of existing geological data to examine suitability for CO_2 injection. Associated activities are to organise funding and build capacity for assessments of storage capacity and emission sources within universities and in the geological survey.
3. Regulatory framework: In order to develop a sound regulatory framework for CO_2 storage and for regulating unconventional mining activities for coal, capacity building is needed. Support and government-to-government knowledge sharing and capacity building is recommended.
4. Southern African CCS knowledge network: The participants in the workshops greatly appreciated the information provided and the exchange of information with participants from neighbouring countries. In order to keep this newly raised awareness in place, it is recommended that a regional CCS network is organised in the region, with the aim of keeping the participants up to date and involved. The network could involve webportal providing up-to-date information and possibly yearly meetings. It is recommended that such a network is hosted in the region with one of the three countries.

In addition to these broader recommendations, it is suggested that in Botswana in particular, research, development and demonstration programmes are started to investigate cleaner and more benign technologies for unconventional coal mining and use.

Appendix A Workshops participant lists

Workshop	First Name	Last Name	Organisation	Country
Botswana	Alan	Golding	Analytika Holdings	Botswana
Botswana	Daniel	Mahupela	BCL	Botswana
Botswana	Ari	Kalmari	Botswana Innovation Hub	Botswana
Botswana	Othusitse	Kgangyapelo	Botswana Power Corporation	Botswana
Botswana	Caiphus Live	Makombo	Botswana Power Corporation	Botswana
Botswana	Mothusi	Lebala	Botswana Power Corporation	Botswana
Botswana	Engelinah	Sephatla	Botswana Power Corporation	Botswana
Botswana	Timothy	Ramontshonyana	Botswana Power Corporation	Botswana
Botswana	Bernard	Busani	Debswana	Botswana
Botswana	Mareledi	Wright	Department of Energy	Botswana
Botswana	Edwin	Pule	Department of Energy	Botswana
Botswana	Thabo	Kentse	Department of Energy	Botswana
Botswana	Kamogelo	Modimo	Department of Energy	Botswana
Botswana	Gomolemo	Oganne	Department of Energy	Botswana
Botswana	Steve	Monna	Department of Environment	Botswana
Botswana	Rudd	Jansen	Department of Environment / Environmental Support Programme	Botswana
Botswana	Peter	Olekantse	Department of Forestry and Rangeland Resource	Botswana
Botswana	Ngonidzashe	Tobani	Department of Geological Services	Botswana
Botswana	Tebogo	Segwabe	Department of Geological Services	Botswana
Botswana	Phetolo	Phage	Department of Metrological Services	Botswana
Botswana	Gopolang	Balisi	Department of Metrological Services	Botswana
Botswana	Russel	Mothupi	Department of Metrological Services	Botswana
Botswana	Kgomotso	Abi	Department of Mines	Botswana
Botswana	Barulaganyi	Ace	Department of Mines	Botswana
Botswana	Shadrack	Masilompane	Department of Mines	Botswana
Botswana	Kesegofetse	Mokoma	Department of Waste Management and Pollution Control	Botswana
Botswana	Tshimologo	Matladi	Department of Waste Management and Pollution Control	Botswana
Botswana	Audrey	Kgomotso	Department of Waste Management and Pollution Control	Botswana
Botswana	Obolokile Thothi	Obakeng	Department of Water	Botswana
Botswana	B	Morake	Department of Water	Botswana
Botswana	Charles	Nkile	Department of Water	Botswana
Botswana	Peter	Kettle	Future Fuels	Botswana
Botswana	Julian	Scales	Kalahari Energy	Botswana
Botswana	Mpho	Mmopi	Ministry of Environment and Tourism	Botswana
Botswana	David	Lesolle	Ministry of Environment and Tourism	Botswana

Workshop	First Name	Last Name	Organisation	Country
Botswana	Gamu	Mpofu	Ministry of Minerals Water and Energy Resources	Botswana
Botswana	Mothusi	Odireng	RIIC	Botswana
Botswana	Thuso	Mogaetsho	RIIC	Botswana
Botswana	Boris	Sesanyane	Somarelang Tikologo	Botswana
Botswana	Keabile	Tlhalewa	UB Department of ES	Botswana
Botswana	Leonard	Dikgobe	UNDP	Botswana
Botswana	Tunde	Oladiran	University of Botswana	Botswana
Botswana	Ovid	Plumb	University pf Botswana	Botswana
Botswana	Florah	Mmereki	Wena Magazine	Botswana
Botswana	Mathinus	Cloete	Council for Geoscience	South Africa
Botswana	Tony	Surridge	SANERI	South Africa
Botswana	Boaventura	Cuamba	EMU	Mozambique
Botswana	Helen	de Coninck	Energy Research Centre of the Netherlands	Netherlands
Botswana	Tom	Mikunda	Energy Research Centre of the Netherlands	Netherlands
Botswana	Rudd	van den Brink	Energy Research Centre of the Netherlands	Netherlands
Botswana	Neil	Wildgust	IEA-GHG	United Kingdom
Botswana	Harald	Shuett	DRFN	Namibia
Botswana	Chris	Hendriks	Ecofys	Netherlands
Botswana	Peter	Zhou	EECG	Botswana
Botswana	Wanano	Kenneth	EECG	Botswana
Botswana	Tich	Simbini	EECG	Botswana
Botswana	Gift	Sibanda	EECG	Botswana
Mozambique	Inocente	Mutimucuio	Academy of Sciences of Mozambique	Mozambique
Mozambique	Patrício	Sande	AICIMO	Mozambique
Mozambique	Harald	Schutt	Amusha	Namibia
Mozambique	Paul	Zakkour	Carbon Counts	United Kingdom
Mozambique	Mussa	Usman	CPI	Mozambique
Mozambique	Dino	Milisse	National Directoracte of Geology	Mozambique
Mozambique	Rui	Gonzalez	DNA	Mozambique
Mozambique	Heleen	de Coninck	ECN	Netherlands
Mozambique	Ruud	van den Brink	ECN	Netherlands
Mozambique	Thomas	Mikunda	ECN	Netherlands
Mozambique	Chris	Hendriks	Ecofys	Netherlands
Mozambique	Carlos	Yum	EDM	Mozambique
Mozambique	Peter	ZHOU	EECG Consultants Pty Ltd	Botswana
Mozambique	Alexandre	Muianga	ENH	Mozambique
Mozambique	António	Matola	ENH	Mozambique
Mozambique	Neil	Wildgust	IEA GHG	United Kingdom
Mozambique	Aristides	Neves	INAM	Mozambique
Mozambique	Júlio	Mirapeix	KPMG	Mozambique
Mozambique	António	Saíde	Ministry of Energy	Mozambique
Mozambique	Laura	Nhancale	Ministry of Energy	Mozambique
Mozambique	Liliana	Rebelo	Ministry of Energy	Mozambique
Mozambique	Pascoal	Bacela	Ministry of Energy	Mozambique

Workshop	First Name	Last Name	Organisation	Country
Mozambique	Sérgio	Elísio	Ministry of Energy	Mozambique
Mozambique	Eduardo	Ventura	Ministry of Transports and Communications	Mozambique
Mozambique	Baltazar	Nhanzilo	National Petroleum Institute	Mozambique
Mozambique	Atália Bernardete	Tembe	Petromoc	Mozambique
Mozambique	Eugénio	Silva	Petromoc	Mozambique
Mozambique	Herman	van der Walt	Sasol	South Africa
Mozambique	Mevace Muhai	Tembe	Sasol	Mozambique
Mozambique	Rui	Maia	UDM	Mozambique
Mozambique	Alberto	Tsamba	UEM	Mozambique
Mozambique	Amalia	Uamusse	UEM	Mozambique
Mozambique	António	Leão	UEM	Mozambique
Mozambique	Boaventura	Cuamba	UEM	Mozambique
Mozambique	Carlos	Lucas	UEM	Mozambique
Mozambique	Carvalho	Madivate	UEM	Mozambique
Mozambique	Daúde	Jamal	UEM	Mozambique
Mozambique	Genito	Maúre	UEM	Mozambique
Mozambique	Lazáro	Chissico	UEM	Mozambique
Mozambique	Lopo	Vasconcelos	UEM	Mozambique
Mozambique	Manuel	Chenene	UEM	Mozambique
Mozambique	Silene	Bila	UEM	Mozambique
Mozambique	Lolita	Hilário	UNDP	Mozambique
Mozambique	Julião	Cumbane	Universidade Pedagógica	Mozambique
Mozambique	Agostinho	Magaia	Universidade Tecnica de Moçambique	Mozambique
Namibia	Vincent	Louw	Min of Agriculture , Water and forestry	Namibia
Namibia	Teofilus	Nghitila	Ministry of Environment and Tourism	Namibia
Namibia	Fransina	Shihepo	NAMREP; Ministry of Environment and Tourism	Namibia
Namibia	Nilson	Kisaka	Ministry of Environment and Tourism	Namibia
Namibia	J.H	Thighuru	Kavango Regional council	Namibia
Namibia	S.U	Kayone	Omusati Regional council	Namibia
Namibia	NP	Du Plessis	Namwater	Namibia
Namibia	Rual	Alfaro	UNDP	Namibia
Namibia	Marika	Matengu	Embassy of Finland	Namibia
Namibia	Helvi	Ileka	Renewable Energy and energy efficiently	Namibia
Namibia	Kirsten	Gunzel	Ohorongo Cement	Namibia
Namibia	Roger	Swartz	Blackgold Geoscience	Namibia
Namibia	Andreas	Wienecke,	Habitat Research & Development Centre	Namibia
Namibia	Gerhardt	Boois	National Botanical Research Institute ; Ministry of Agriculture Water & Forestry	Namibia
Namibia	GL Jonas	Capoco	Asca Investments	Namibia
Namibia	Axel	Rothauge	Agra	Namibia
Namibia	Harald	Schutt	Amusha	Namibia
Namibia	Goffey	Dzinomwa	Polythenic of Namibia	Namibia
Namibia	Benhard	Haak	DRFN /Sen.export Service Bonn, Germany	Namibia

Workshop	First Name	Last Name	Organisation	Country
Namibia	Robert	Schultz	Desert Research Foundation	Namibia
Namibia	Viviane	Kinyaga	Desert Research Foundation	Namibia
Namibia	Caroline	Coulson	Desert Research Foundation	Namibia
Namibia	Heleen	de Coninck	ECN	Netherlands
Namibia	Tom	Mikunda	ECN	Netherlands
Namibia	Paul	Zakkour	ECN	United Kingdom
Namibia	Boaventura	Cuamba	ECN	Mozambique
Namibia	Neil	Wildgust	ECN / IEAGH	United Kingdom
Namibia	Mary	Gagen	Swansea University	United Kingdom
Namibia	Peter	Zhou	EECG	Botswana
Namibia	Chris	Hendriks	ECOFYS	Netherlands

Appendix B Workshop programme Botswana

Thursday, 8th April 2010

WORKSHOP DAY 1 Venue: Boipuso Hall, Fairgrounds		
Times:	**Speakers:**	**Content/ Themes**
ARRIVAL AND REGISTRATION		
8h:00 - 9h:00	**Participants arrive and register**	**All participants in workshop venue and seated by 9h:00**
INTRODUCTION AND CONTEXT (Chair: Mr P. Phage- Director Department of Meteorological Services-DMS)		
09h00 - 09h15	Morning Session Chair	Prayer & Welcome
09h15 - 09h30	Mr Mmopi - Deputy Permanent Secretary Ministry of Environment, Wildlife and Tourism (MEWT)- Botswana Government	Opening address
09h30 - 10h00	Heleen de Coninck (ECN) and Peter Zhou (EECG)	Project Background and Objectives
10h00 - 10h20	**TEA**	
TECHNICAL SESSION (Chair: Mr P. Phage-DMS)		
10h20 - 10h40	David Lesolle (National Climate Change Coordinator)	Context Climate Change and Energy and Development
10h40 - 10h50	Heleen de Coninck (ECN)	Overview on CCS
10h50 - 11h15	Ruud van der Brink (ECN)	Capture Technology (Power and other Industry)
11h15 - 11h40	Neil Wildgust (IEA GHG)	Geological Storage
11h40 - 12h05	Martinus Cloete (Council of Geoscience South Africa)	Geological Potential Assessment/Atlas
12h05 - 12h30	Questions and General Discussion	
12h30 - 13h45	**LUNCH**	
ECONOMICS, POLICY, LEGAL FRAMEWORK (Chair: Mr. Abi- Department of Mines)		
13h45 - 14h05	Chris Hendriks (Ecofys)	Costs and Economic Potential of CCS
14h05 - 14h25	Neil Wildgust (IEA GHG)	Risk and Impacts
14h25 - 14h45	Heleen de Coninck (ECN)	Policy and legal issues/Licensing
14h45 - 15h05	Mr Steve Monna-Department of Environmental Affairs	Public Perception (waste dumping, water reservoirs, etc)
15h05 - 15h15	Questions	
15h15 - 15h30	**TEA**	

PANEL DISCUSSION: (Chair. Mr D Lesolle Climate Change Coordinator MEWT & G. Balisi Principal DMS)		
15h30 - 17h00	Analytika Holdings Alan Golding Kalahari Energy Future Fuels Africa Department of Environmental Affairs Department of Water Affairs Department of Mines Energy Affairs Division Botswana Power Corporation Department of Geological Services University of Botswana SANERI	Views on CCS for Botswana
17h00	**CLOSE**	
19h00	**COCKTAIL - CRESTA LODGE**	

Friday, 9th April 2010

WORKSHOP DAY 2 **Venue: Boipuso Hall**		
Times:	**Speakers:**	**Content/ Themes**
CCS IN SOUTHERN AFRICA: Country Overviews (Chair: G. Balisi-DMS)		
09h00 - 09h10		Welcome
09h10 - 09h30	Tony Surridge (SANERI)	South Africa Roadmap
09h30 - 09h50	Peter Zhou (EECG)	Botswana
09h50 - 10h10	Boaventura Cuamba - UEM	Mozambique
10h10 - 10h30	Harald Schutt - AMUSHA	Namibia
10h30 - 10h45	Discussion on Country Situation	
10h45 - 11h00	**TEA**	
BREAK OUT GROUPS (Chair: Heleen de Coninck/P Zhou) **To identify the capacity gaps and needs in the country/the Southern African Region**		
11h00 - 13h00	**Break out into three groups to identify the potential and capacity gaps and needs in the Botswana**	Geological Storage
		Capture Issues
		Policy/Legal
13h00 - 14h00	**LUNCH**	
REPORTING AND DISCUSSION ON GROUP RESULTS (Chair: Dr Peter Zhou-EECG)		
14h00 - 14h20	Kalahari Energy, DGS, DoM, Analytika Holdings, Debswana, EECG, Media, Council for Geoscience, ECN	Geological Storage
14h20 - 14h40	BPC, BCL, EAD,ECN	Capture Issues
14h40 - 15h00	DEA, DMS, DWA, UB, EAD, DWMPC, RIIC, Somarelang Tokilogo, SANERI, ECN, AMUSHA,	Policy/Legal
15h00 - 15h30	**TEA**	
WORKSHOP REVIEW / CONCLUSION (Chair: P. Zhou-EECG)		
15h30 - 15h45	Heleen de Coninck	Next Step for CCS in Botswana
15h45 - 16h00	Heleen de Coninck	Closing Remarks
CLOSE		

Appendix C Workshop programme Mozambique

Monday, 12th April 2010

WORKSHOP DAY 1 Venue: Hotel VIP Grand, Maputo		
Times:	**Speakers:**	**Content:**
INTRODUCTION AND CONTEXT (Chair: Gopolang Balisi)		
09h00 - 09h15	Morning Session Chair	Prayer & Welcome
09h15 - 10h30	Ministry of Energy/Eduardo Mondlane University	Opening address
10h30 - 11h00	**TEA**	
TECHNICAL SESSION (Nazário Meguigi)		
11h00 - 11h30	Telma Manjate (UNFCCC Focal Point)	Context Climate Change and Energy and Development
11h30 - 12h00	Ruud van den Brink (ECN)	Capture Technology (Power and other Industry)
12h00 - 12h30	Neil Wildgust (IEA GHG)	Geological Storage (Overview + Reservoirs)
12h30 - 13h00	Questions and general discussion	
13h00 - 14h00	**LUNCH**	
ECONOMICS, POLICY, LEGAL FRAMEWORK (Pascoal Bacela)		
14h00 - 14h20	Chris Hendriks (Ecofys)	Costs of CCS
14h20 - 14h40	Neil Wildgust (IEA GHG)	Risk and Impacts
14h40 - 15h00	Paul Zakkour (Carbon Counts)	Policy and legal issues/Licensing
15h00 - 15h20	Heleen de Coninck (ECN)	Public Perception
15h20 - 15h30	Questions	
15h30 - 16h45	**TEA**	
16h45 - 17h30	Panel discussion	What are the main barriers to CCS?
17h30	**CLOSE**	

Tuesday, 13th April 2010

WORKSHOP DAY 2 Venue: Hotel VIP Grand, Maputo		
Times:	**Speakers:**	**Content/ Themes**
CCS IN SOUTHERN AFRICA: Country Overviews (Chair: Almeida Sitoe)		
09h00 - 09h10		Welcome
09h10 - 09h30	Herman van der Walt - Sasol	South Africa
09h30 - 09h50	Peter Zhou - EECG	Botswana
09h50 - 10h10	Boaventura Cuamba - UEM	Mozambique
10h10 - 10h30	Harald Schütt - Amusha	Namibia
10h30 - 10h45	Discussion on Mozambique situation	
10h45 - 11h00	**TEA**	
BREAK OUT GROUPS (Chair: Geraldo Nhumaio) **To identify the capacity gaps and needs in the country/the Southern African Region**		
11h00 - 13h00	Break out into three groups to identify the capacity gaps and needs in the Mozambique/the Southern African Region	Geological Storage
		Capture Issues
		Policy/Legal
13h00 - 14h00	**LUNCH**	
REPORTING AND DISCUSSION ON GROUP RESULTS (António Saíde)		
14h00 - 14h30		Geological Storage
14h30 - 15h00		Capture Issues
15h00 - 15h30		Policy/Legal
15h30 - 16h00	**TEA**	
WORKSHOP REVIEW / CONCLUSION (António Cumbane)		
16h00 - 16h45	Group Chairs	Round Review and roles of key players in climate change:- Government, CCS, Private Companies, NGOs, Researchers
16h45 - 17h00	Next steps for CCS in Mozambique	
17h00 - 17h10		Closing Remarks
	CLOSE	

Appendix D Workshop programme Namibia

Thursday, 15th April 2010

WORKSHOP DAY 1 - Thursday, 15 April 2010 Venue: Habitat Research and Development Centre, Windhoek		
Times:	**Speakers:**	**Content:**
	INTRODUCTION AND CONTEXT	
09h00 - 09h15	Viviane Kinyaga - DRFN	Welcome
09h15 - 10h30	Theo Nghitila (Director of Environmental Affairs)	Opening address
10h30 - 11h00	**TEA**	
	TECHNICAL SESSION	
11h00 - 11h30	Harald Schütt	Climate change, energy and development
11h30 - 12h00	Tom Mikunda (ECN)	Capture Technology (Power and other Industry)
12h00 - 12h30	Neil Wildgust (IEA GHG)	Geological Storage (Overview and Reservoirs)
12h30 - 13h00	Roger Swart	Namibia's geology and its suitability for CCS
13h00 - 14h00	**LUNCH**	
	ECONOMICS, POLICY, LEGAL FRAMEWORK	
14h00 - 14h30	Chris Hendriks (Ecofys)	Costs of CCS
14h30 - 15h00	Heleen de Coninck (ECN)	Risk and Impacts
15h00 - 15h30	Paul Zakkour (Carbon Counts)	Policy and legal issues/Licensing
15h30 - 16h45	**TEA**	
16h45 - 17h30	**Panel discussion:** Roger Swart Harald Schütt Heleen de Coninck Neil Wildgust Chris Hendriks Paul Zakkour	What are the main barriers to CCS?
17h30	**CLOSE**	

Friday, 16th April 2010

WORKSHOP DAY 2 - Friday, 16 April 2010 Venue: Habitat Research and Development Centre, Windhoek		
Times:	**Speakers:**	**Content/ Themes**
CCS IN SOUTHERN AFRICA: Country Overviews (Chair: Ms Viviane Kinyaga)		
09h00 - 09h10	Robert Schultz - DRFN	Welcome
09h10 - 09h30	Peter Zhou - EECG	Botswana
09h30 - 09h50	Boaventura Cuamba - UEM	Mozambique
09h50 - 10h10	Harald Schütt - Amusha	Namibia
10h10 - 10h45	Discussion on Country Situation	
10h45 - 11h00	**TEA**	
WORKSHOP REVIEW / CONCLUSION		
11h15 - 13h00	The rationale for CCS in Namibia	A group discussion on the rationale for CCS in Namibia, focusing on capture sources, storage potential and capacity building requirements.
13h00-13h15	Heleen de Coninck / Robert Schultz	Closing Remarks
	CLOSE	

Appendix E Workshop evaluation - Botswana

The results of the workshop evaluation by the participants are summarised in the figures below. On average over 70% of the participants gave a rating of good to very good for all the key indicators indicated in the graph. Only three indicators were rated as poor by less than 8 to 2% of the participants and these are the quality of the venue, audio visual equipment and the registration process efficiency.

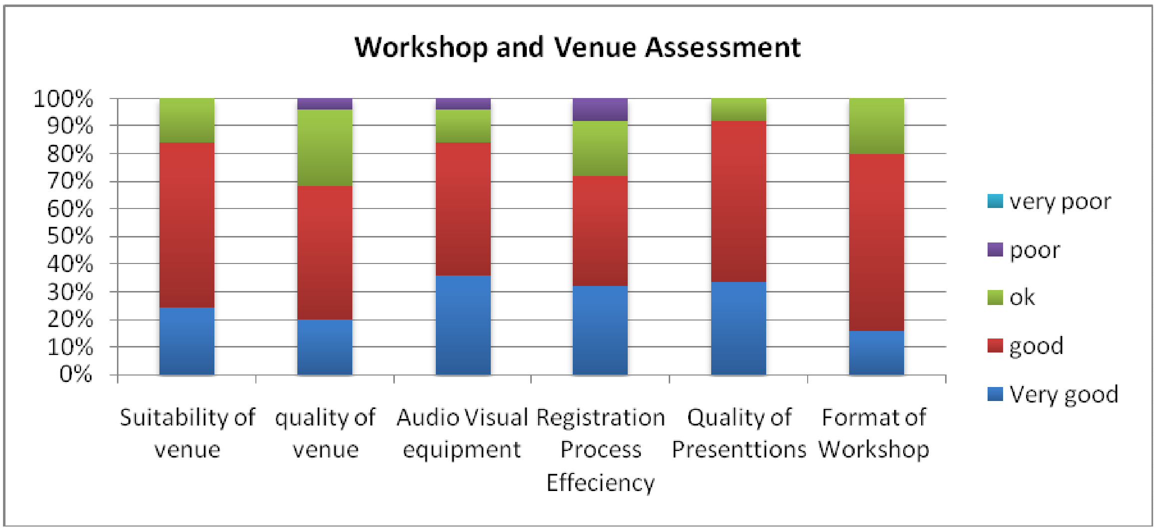
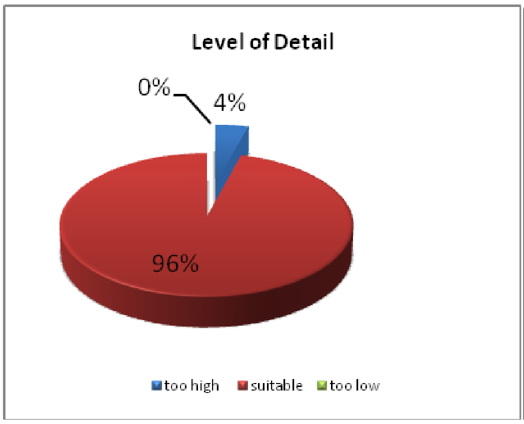


Figure E.1 *Workshop Assessment results*

With regards the level of detail of the representations, 96% of the participants were of the opinion that the level of detail was suitable and 4% though that it was too high. On whether the participants would attend another workshop organised by EECG and ECN, 83% said they would definitely attend and 17% expressed that they might attend.



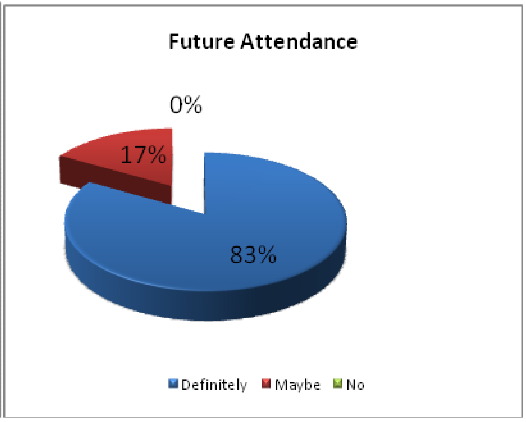


Figure E.2 *Assessment of level of Detail and future attendance*

Further comments that were made by the participants were varied and these are summarised below:

- Even though the organisation and the presentations were excellent, other stakeholders such as Private Sector Mining Companies and the Academia were not well represented. It was recommended that the stakeholders invitees should be widened as much as possible. These should also include organisations such as Lands, Environment and the Parliament Committee. Therefore there is need to organise another workshop to sensitise all major stakeholders.

- Future workshops could include a visit to South Africa as a benchmarking exercise or should be held at a possible potential site in Botswana.
- In future workshop should be started earlier than 9am to give presentations more time as the 20 mins allocated for the presentations was not sufficient. Also the dates should be arranged to avoid Friday as most participants are not likely to attend on Friday.
- Panel discussion and break out group should be given more time as these are areas that will give more oversight on the issues being discussed.
- In future workshop organisers and chairpersons should be stricter with time and speakers and participants encouraged to introduce themselves every time they make a contribution.
- There is room for improvement in the registration process.
- More detailed information will be useful for capture issues and more information for benchmarking.
- The presentations should be made with large font sizes and printed handouts of the presentations should be given to the participants. The handouts and any other reading material should be distributed well on time before the workshop to allow participants to familiarise with the material.
- Increase the number of days and include presentations from those already implementing CCS as this is an important issue.
- Lastly workshop should include an excursion to places of interest for the benefit of international speakers.

Appendix F Opening speech - Mozambique workshop

“The Carbon Capture and Storage (CCS) enables the Carbon Dioxide which is produced in the industrial processes and that from energy generation not to be released to the atmosphere, thus allowing the possibility of exploitation and use of energy resources of fossil nature without endangering the environment, contrary to what used to happen in the most recent past. The rise of this new generation of technologies still incorporates in it many important aspects which are still less dominated by scientists and technologists. Therefore, we are before an option to which we need to invest for research, development and capacity building for its effective use. In fact, it is very encouraging for us to know that the Eduardo Mondlane University (UEM), the biggest and the oldest institution of higher education in Mozambique, integrates, in its biggest activities sphere, the scientific contribution which is indispensable for the Country to move in the right and safe steps towards a development based on correct and appropriate scientific premises.

Therefore, I would like, once again and on behalf of the Government of Mozambique, to salute and congratulate UEM through his Honourable Rector, scientists from other national and regional Universities, for having put themselves in the front position to collaborate with different international institutions in the development of such technologies of Carbon Capture and Storage. We also want to express our appreciation to the international cooperation partners who gathered themselves for the fulfillment of this initiative, in particular, our acknowledgement to ECN from the Netherlands for undertaking, in partnership with our regional national institutions, the development of this project to which we deposit our full confidence for the capacity building and identification of potentialities for Carbon Capture and Storage. From now on, it is the Government of Mozambique’s concern to do all that it can in order to guarantee the use and maximization of the benefits which these technological options offer for the sustainable development of/but not limited to Mozambique”.

Jaime Himede, Deputy Minister of Energy, Mozambique, 12th April 2010

Appendix G International speaker biographies

Neil Wildgust is the project manager for geological storage at the IEA Greenhouse Gas R&D Programme, based in the UK. He is a chartered geologist with a background in hydrogeology and contaminated land assessment and he will give an introduction to geological storage of CO_2.

Chris Hendriks is a managing consultant at Ecofys, an international consultancy in the field of sustainable energy. He has over 20 years of experience in CO_2 capture and storage and will talk about costs of that technology.

Paul Zakkour is director of Carbon Counts, a consultancy specialising in international climate policy, regulation and financing. He has worked on CCS issues for more than six years and will talk about policy and regulation.

Boaventura Chongo Cuamba is Associate Professor at the Department of Physics, Faculty of Sciences at the Eduardo Mondlane University. He leads the Energy, Environment and Climate Research Group, an interdisciplinary research unit at the Faculty of Sciences of the Eduardo Mondlane University. Dr Cuamba has participated in the workshop on carbon capture and storage, which took place in Gaborone, Botswana in September 2007.

Peter Zhou has worked in the field of climate change since 1992, and on issues in the energy sector in Africa since 1984. An applied geophysicist by training, he is currently the Director of Energy, Environment, Computer and Geophysical Applications (EECG) Consultants Pty in Gaborone, Botswana. He has participated in various multilateral, bilateral and national projects, has also contributed to the UNFCCC process on issues related to technology transfer in 1999-2001 and as a CDM Methodologies panel member in 2002-2004. He organised the Southern African regional CCS-Africa workshop in September 2007 in collaboration with ECN and ENDA.

Heleen de Coninck works as a manager of the International Energy and Climate Issues at ECN Policy Studies. Since eight years, her main focus of work is international climate policy and technology, as well as CCS. Until 2005, she was part of the Technical Support Unit of the IPCC Working Group III where she coordinated the Special Report on CCS.

Tom Mikunda is a junior researcher in the International Energy and Climate Issues group at ECN's Policy Studies unit. Tom has a background in environmental science and environmental management. Since joining ECN in September 2009, his work has focused primarily on policy towards and regulation of carbon capture and storage.

Tony Surridge was previously engaged by the Department of Minerals and Energy from where he was from time to time responsible for matters related to electricity, renewable energy, environment, energy efficiency, energy database, coal and gas and petroleum and also drafted South Africa's first National Integrated Energy Plan. Since December 2006, Dr Surridge has been engaged by the South African National Research Institute where he establishment the South African Centre for Carbon Capture and Storage.

Herman van der Walt holds a position in the Health, Safety and Environment department of Sasol. Herman's is involved in the developments of Sasol's emission reduction strategy.

Ruud van der Brink is currently manager of the Hydrogen Production and CO_2 Capture group at the Energy Research Centre of the Netherlands. Ruud studied chemistry at the University of Amsterdam, and holds a PhD from Leiden University, The Netherlands on Environmental Catalysis. He works at the Energy Research Center of the Netherlands (ECN) since 1999, first as a researcher on the development of a catalytic process for the abatement of greenhouse gas nitrous oxide from nitric acid plants. From 2003, CO_2 capture technology development became a major part of his work.

Harald Schuett has previously worked for a German development agency, and now operates an independant management consultancy in Windhoek, Namibia. He is also a Project Leader for the Renewable Energy and Energy Efficiency Capacity Building Programme (REEECAP) at the Institute for Renewable Energy and Energy Efficiency (REEEI) at Polytechnic of Namibia.

Marthinus Cloete obtained a PhD from the University of the Witwatersrand on aspects of the Barberton Greenstone Belt geology. He is currently the Manager of the Analytical Laboratory- and the Regional Geochemistry Business Units of the Council for Geoscience. Dr Cloete is the project manger of a group that are assessing for the first time the CO_2 storage potential of South Africa and will producing an atlas showing the storage potential of all the on- and off shore basins with regard to deep saline aquifers, depleted oil and gas reservoirs and also unmineable coal seams.