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World Bank CCS Program activities in Botswana – Results and lessons learned

Brendan Beck[a]*, Natalia Kulichenko-Lotz[b]

[a] *Consultant, World Bank, London, UK*
[b] *Senior Energy Specialist, World Bank, Washinton D.C., USA*

Abstract

The World Bank Carbon Capture and Storage Trust Fund (CCS TF) was established in 2009 to support CO_2 capture and storage (CCS) capacity and knowledge building in developing countries †. CCS TF Phase 1 support for CCS in Botswana included an allocation of USD 1.4 million and had the objective of supporting the Government of Botswana in the following areas:

1. Identifying potential geological reservoirs that can be utilized to store CO_2 captured from coal-fired power plants;
2. Evaluating institutional and regulatory arrangements for CCS deployment in the country and recommendations for reinforcing institutional capacity; and
3. Providing training, education and capacity building at all stages throughout implementation, including a Study Tour for key individuals.

For all three studies, the WB selected Environmental Resources Management Southern Africa (Pty) Ltd (ERM) as the lead consultant, in association with Wellfield Geosciences (Botswana) and Carbon Counts Company (UK) Ltd.

The completed geological assessment found that there may be technical potential for geological storage of CO_2 in Botswana's geological formations within the Kalahari Karoo Basin, including three areas of interest -- the Passarge Basin, the Lephephe Graben and the Mmashoro Low. There is, however, a general lack of CO_2 storage-relevant geological data that needs to be developed, if a more accurate assessment of CO_2 storage potential is to be undertaken. The Passarge Basin was seen to be worthiest of additional investigation, which could be done through the re-

* Corresponding author. *E-mail address:* btvbeck@gmail.com

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examination of existing data or through new geological exploration. The Mashoro Low and Lephephe Graben are in close proximity to the centres of current coal-bed methane (CBM) exploration, suggesting that the integration of CBM exploitation and CO_2 storage processes could be considered.

The regulatory and institutional assessment reviewed how CO_2 storage could be implemented under the existing legislation and regulation, and identified the gaps, not covered within the existing framework. The assessment found that existing regulatory acts provide certain coverage for most of key elements of the CO_2 storage life-cycle, including: storage site prospecting; storage site development licensing/permitting; regulatory oversight; and, provisions for mid-to long-term liability where a holder of the waste management license incurs a 30-year liability period. However, some clarification is needed to ensure this is the case. Also, the establishment dedicated government body, mandated to lead the development of CCS would benefit the ongoing CCS program in Botswana.

If the Government of Botswana intends to pursue the development of the institutional and technical capacity for development and deployment of CCS technology in Botswana, the following activities should be considered:

- Building CCS awareness and strengthening coordination across government and industry;
- Establishment of a CCS technical implementation plan, including the preparation of a CCS roadmap; and
- Carrying out additional analysis of existing geological data relating to one or more of the formations identified.

Based on the experience gained from the execution of this study, the next phase of CCS development in Botswana, as well as similar activities elsewhere would benefit from:

- Increased government and stakeholder involvement in all stages of the study;
- A formally mandated government partner to support the undertaking of the study and to implement and take forward the findings; and
- External technical input/review from experts with experience in the development and execution of CO_2 storage projects. This could take the form of a project specific technical advisory panel or a technical panel we a broader mandate across all the CCS TF's activities.

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Keywords: World Bank; CCS; capacity building; developing countries; Botswana

1. Introduction

The World Bank Carbon Capture and Storage Trust Fund (CCS TF) was established in 2009 to support CO_2 capture and storage (CCS) capacity and knowledge building in developing countries. This support is intended to create opportunities for these countries to explore their CCS potential and, if appropriate, to facilitate the inclusion of CCS options into their low-CO_2 growth strategies and policies. Nine countries were selected in Phase 1 of the CCS TF support including Botswana.

The CCS TF Phase 1 support for CCS in Botswana included an allocation of USD 1.4 million and had the objective of supporting the Government of Botswana in the following areas:

1. Identifying potential geological reservoirs that can be utilized to store CO_2 captured from coal-fired power plants;
2. Evaluating institutional and legal arrangements for CCS deployment in the country and recommendations for reinforcing institutional capacity; and
3. Providing training, education and capacity building at all stages throughout implementation, including a Study Tour for key individuals.

The Environmental Resources Management Southern Africa (Pty) Ltd (ERM), in association with Wellfield Geosciences (Botswana) and Carbon Counts Company (UK) Ltd, were selected by the WB to undertake the studies and capacity building activities, outlined above. The beneficiaries and counterparts for the project were a number of institutions of the Government of Botswana, led by the Department of Geological Survey (DGS).

2. Results

2.1. Geological Scoping

This summary is based on the ERM et al. 2015 reports commissioned by the World Bank – *Assessment of CCS potential in Botswana – Work Package 1: Geological Sequestration and Site Selection Scoping Report*, and *Assessment of CCS potential in Botswana – Summary and Conclusions.*

The geological assessment involved a desktop review of existing geological data available in Botswana including geological mapping, aerial surveys, geophysical logs, and borehole data. The geological assessment looked at the macro geological and structural environment with a focus on potential storage formations in the Central Kalahari Basin and the underlying Nama Group. The study was based on data derived by/archived at the Department of Geological Survey, archived with Wellfield Geosciences, as well as data derived from coal-bed methane (CBM) exploration.

The scope of the investigation for storage potential was based around the storage of 650,000 metric tons CO_2 per year which was considered to be a volume relevant to storage from a small coal-fired power station. Based on this requirement, the completed geological assessment found that there may be technical potential for geological storage of CO_2 in Botswana's geological formations within the Kalahari Karoo Basin, including three primary areas of interest - the Passarge Basin, the Lephephe Graben and the Mmashoro Low (*See Figure 1*). Other formations were considered but were ruled out due to lack of porosity, lack of depth, the presence of potable aquifers, the presence of hydrocarbons or potential for hydrocarbon exploration, and potential seismic risks.

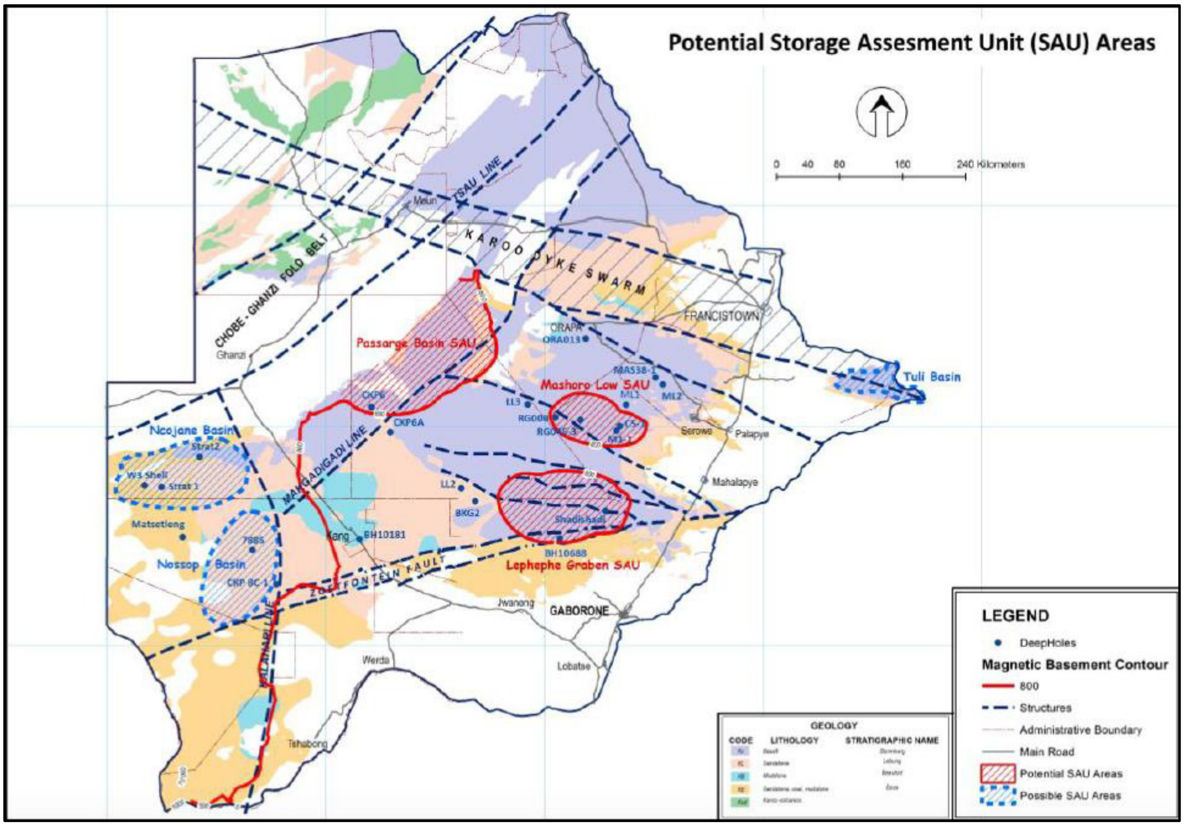

Figure 1: Potential Storage Assessment Unit Areas in Botswana

2.1.1. Passarge Basin

The Passarge Basin is located in central Botswana on the western margin of the Karoo Basin – south-east of the Ghanzi-Chobe fold belt and the associated Ghanzi Ridge. The basin is thought to be about 10,000m deep (depth to magnetic basement) and is data suggests that it is mostly infilled by end-Proterozoic to early Phanerozoic Nama Group sedimentary strata and overlain by Karoo Supergoup sedimentary strata. The Karoo strata in this area is estimated to be between 1,000m – 1,200m thick in the basin center and is seen as the possible CO_2 storage formation. Much of the data with regard to the Passarge Basin does however have to be derived from aeromagnetic surveys and older seismic surveys as there have not been any modern seismic lines or deep drilling undertaken in the basin.

With the boundary of the potential storage volume constrained by the 800m contour line for the depth to the base of the Karoo formation, and a conservative porosity assumption of 5%, it is estimated that the Passarge Basin could store 958 $MtCO_2$ or over 1,400 years of the initial annual storage requirement of 650,000 metric tons CO_2.

2.1.2. Lephephe Graben

The Lephephe Graben is located in central Botswana on the south-east margin of the Karoo Basin. It is thought that graben has a very substantial thickness of Stormberg basalt under which Ecca/Dwyka storage formations may be present although there are no boreholes in the graben to substantiate this. Rather a few seismic lines, an aeromagnetic survey, and a regional borehole are used to draw these inferences. The Lephephe Graben is in close proximity to ongoing coal-bed methane (CBM) exploration activities which could offer potentially synergistic opportunities in the future if CO_2 storage potential is confirmed. The Lephephe Graben is structurally created and controlled and the Karoo formation is therefore likely to be structurally impacted which may compromise the sealing properties of any caprocks in the graben which would rule out CO_2 storage if this was the case.

Assuming a suitable seal is present, and using the 800m contour line for the depth to the base of the Karoo formation as the boundary of the potential storage volume and a conservative porosity assumption of 5%, it is estimated that the Lephephe Basin could store 643 $MtCO_2$. This represents over 980 years of the initial annual storage requirement of 650,000 metric tons CO_2.

2.1.3. Mmashoro Low

The Mmashoro Low is located in central Botswana in the north-central section of the Kalahari Karoo Basin and has been actively explored for CBM. Although the boreholes drilled during this CBM exploration program do not fully penetrate the Karoo Supergroup, they do imply that lower members of the Karoo Supergroup may be present. The Karoo formation is however not expected below depths of 1000m which makes the Mmashoro Low Karoo formation marginal for CO_2 storage. Similarly to the Lephephe Graben, the co-location of CO_2 storage and CBM potential could present synergies however CBM activities could also view CCS investigations as being detrimental to their interests. Based on the same approach and assumptions used for the Passarge Basin and Lephephe Graben, the Mmoshoro Low could store 289$MtCO_2$, or 445 years of the test storage volume of 650,000 metric tons of CO_2 per year.

Based on the geological assessment undertaken, with a particular focus on the three formations above – the Passarge Basin, the Lephephe Graben, and the Mmoshoro Low, it was determined that there is some potential for CO_2 storage in Botswana. This finding was however strongly caveated by the fact that the data supporting the analysis was extremely limited and that a number of significant assumptions had to be made in order to complete the analysis. To address the significant data gap identified, the study proposed two next steps that could be undertaken in parallel or sequentially: 1) further analysis of existing geological data, and 2) the gathering of additional new geological data through a new geological exploration program.

It is recommended that the review of existing data could focus on the finding out more about the nature and deposition of Karoo sediments below 800m in all three formations of interest. This data could potentially be improved by re-logging and porosity testing the relevant cores, including the deep borehole cores held by the DGS. Re-examination could also be carried out on commercially drilled boreholes including those that have been archived with DGS as well as those retained by the exploration companies, if these can be accessed. A detailed review of all available geophysical data covering the Karoo Kalahari Basin, using modern processing techniques, would also be of benefit, including seismic, magnetetolluric and gravity survey data. Existing relevant boreholes could also be re-logged if they allow. If a new exploration program was to be undertaken to better understand the potential for CO_2 storage in Botswana it is recommended that efforts should focus on the Passarge Basin. Such an investigation could include geophysical surveys, drilling, geophysical logging, and various other physical and chemical downhole testing.

If a CO_2 storage pilot project was to be developed in Botswana it would be expected that both the further analysis of existing geological data, and the gathering of additional new geological data through a new geological exploration program would need to be undertaken before a suitable site could be confirmed.

2.2. Legislative and Institutional Assessment

This summary is based on the ERM et al. 2015 reports commissioned by the World Bank – *Assessment of CCS potential in Botswana – Legal and Regulatory Options*, and *Assessment of CCS potential in Botswana – Summary and Conclusions.*

The legislative and institutional assessment reviewed how CO_2 storage could be implemented under the existing legislation and regulation, and identified the gaps within the existing framework which need to be addressed to enable CO_2 storage. The three key elements to any CO_2 storage regulatory framework included:

1. Permitting and approval processes to cover the development of the CO_2 storage project including, exploration, site characterization and site development activities;
2. Oversight for the operation and closure of the storage project including monitoring, closure, and site remediation.
3. Allocating liability across the CCS project life cycle including in the short- to medium-term during the operation and closure of the project, as well as over the long-term, post-closure period.

The analysis assessed all the relevant legislation in Botswana relating to geological activities and environmental/climate change matters that could impact the development of CO_2 storage project. Specifically, the analysis reviewed:

- the Waste Management Act (WMA);
- the Petroleum (Exploration and Production) Act (PEPA);
- the Mines and Minerals Act (MMA);
- the Environmental Assessment Act (EAA);
- the Water Act (WA); and
- the Atmospheric Pollution Act (APA).

Based on the analysis it was determined that Botswanan legislation already covers many activities that are analogous to CO_2 storage. Drawing on this experience it was considered that it would be a fairly minor undertaking to establish a regulatory framework for CO_2 storage with few, if any, gaps. Details on how key elements of the CO_2 storage life-cycle could be addressed with the existing framework can be seen below:

- Storage site prospecting – the PEPA could license CO_2 storage site prospecting currently without any amendment.
- Storage site development licensing/permitting – the WMA could form the primary legislation for storage site development provided that the CO_2 storage site was considered a waste management facility under the Act. PEPA and MMA provisions, such as *Work Practices* and *Environmental Obligations* could then be referenced in the *Waste Management License* to address any gaps in the WMA. Additional, bespoke, requirements could also be applied through the EAA. Some clarification is required here on the jurisdiction of the WA and additional consideration would need to be given if CO_2 storage was done in conjunction with enhanced CBM.
- Regulatory oversight – the use of the WMA as the primary legislation for CO_2 storage would make the Department of Waste Management and Pollution Control (DWMPC) the competent authority. The DWMPC would then be supported by the Department of Environmental Affairs, through the issuing and management of any *Environmental Authorization*, and the Botswana Geosciences Institute as the custodian for the subsurface in the country.
- Liability – the WMA gives provisions for mid- to long-term liability where a holder of the *Waste Management License* incurs a 30-year liability period. The same Act implies that liability for the site could transfer to the state thereafter, in the event that no pollution had been caused over the period.

In the near-term, the above piece-meal regulatory approach is thought to be sufficient for supporting first of a kind, pilot CO_2 storage project, however this would need to be verified with the departments concerned. In the longerterm, if larger projects are to be developed, this approach may need to be revised to streamline the process and to provide more certainty for project developers on what will be required from a regulatory standpoint.

2.3. Capacity Building

This summary is based on the ERM et al. 2015 report commissioned by the World Bank – *Assessment of CCS potential in Botswana – Summary and Conclusions.*

The capacity building task had the aim of raising the awareness and understanding of CCS in Botswana and building a lasting link between Botswanan CCS stakeholders and the international CCS community. Participation in the capacity building program included representatives from all the key Botswana departments that are likely to be involved in CCS. The capacity building program comprised two elements:

1. CCS Study Tour and Training Course; and
2. Capacity building/training workshops.

The CCS study tour included the following components:

- Johannesburg, South Africa – where the delegation met with: the South African Centre for CCS; the Department of Energy; Sasol; the Council for Geosciences; and the Fossil Fuels Foundation;
- London, UK – where the delegation met with: the Carbon Capture and Storage Association; the Department of Energy and Climate Change; the Office of Carbon Capture and Storage; the Foreign and Commonwealth Office; the International Energy Agency (IEA) Clean Coal Centre; and Shell;
- Austin, USA – where the delegation participated in a CCS course ran by the University of Texas at Austin, its Bureau of Economic Geology, Gulf Coast Carbon Center and Jackson School for Geosciences with support from: the IEA Greenhouse Gas R&D Programme; the Cooperative Research Centre for Greenhouse Gas Technologies; and Denbury Resources.

The two capacity building/training workshops were both held in Gaborone, Botswana. The first workshop provided an introduction to CCS and presented the initial findings of the geological and institutional and regulatory analysis. The second workshop presented the final results of the analysis and had a discussion of potential next-steps for the development of CCS in Botswana.

3. Next Steps

This summary is based on the ERM et al. 2015 report commissioned by the World Bank – *Assessment of CCS potential in Botswana – Summary and Conclusions.*

In order to continue to build on the progress made through the CCS activities undertaken to date in Botswana, a number of recommendations were made regarding: institutional arrangements; policy mainstreaming; and, technical research, training and development.

Institutional arrangements recommendations included:

- a Governmental focal point should be agreed to be the driving force for CCS in Botswana – the DGS offered to provide this role. If DGS is given a mandate for this role, they should nominate a single staff member to be the focal point; and
- an Interdepartmental CCS Project Team be established to support the focal point, and the development of CCS in Botswana more broadly.

Policy mainstreaming recommendations included:

- CCS should be considered for inclusion in future Botswana climate change and energy policy documents such as the 3rd National Communication to the United National Framework Convention on Climate Change, and the National Climate Change Strategy;

- the findings of these studies should be presented to other relevant Government officials and bodies including: the National Climate Change Committee; the Deputy Permanent Secretary; and, the Minister of Environment; and
- a Botswana CO_2 Storage Atlas; Botswanan CCS Roadmap; and a CCS Implementation Plan be developed to help communicate and progress CCS nationally.

Technical research, training and development recommendations included:
- DGS should commit at least one staff member to CCS with the aim of establishing an ongoing CCS research program; and
- a CCS training and capacity building needs assessment be undertaken and once the assessment has been completed, international CCS organization should be engaged to assist with addressing the capacity building and training needs identified.

4. Lessons Learned

4.1. Government and Stakeholder Participation

CCS is a cross-cutting technology that needs significant input from many technical players and government departments. Accordingly, to establish a national CCS program requires commitment and participation from a wide range of government departments and stakeholders. To some extent the aim of programs such as the World Bank CCS program in Botswana is a way to build such engagement in a country however engaging stakeholders in the scoping stage of the program, prior to the commencement of formal activities, may improve the likelihood of maintaining this engagement over the course of the project. This in-turn would increase the likelihood of actions and recommendations being implemented after the completion of the project. This additional engagement in the scoping stage of the project would delay the commencement of the project however the benefits of this process should out-way this negative.

4.2. Mandated National CCS Focal Point

The DGS was the primary counterpart for the World Bank CCS program in South Africa. DGS were identified as the logical partner for the program given their knowledge and understanding of Botswanan geology and their role as the lead for national geological research and geological data archiving. DGS do not however have a formal government mandate for their CCS role. In the World Bank CCS program in South Africa, the counterpart is the South African National Energy Development Institute (SANEDI) who have been mandated by the South African Government to be the focal point for technical CCS research and development in South Africa. This mandate, gives SANEDI full jurisdiction over the CCS program in the country as well as convening power within the government. Such a mandate would have assisted DGS in their efforts to drive CCS in Botswana and may have enabled them to convene the stakeholders relevant to CCS as an earlier stage in the program cycle, which may bring the benefits discussed in Section 4.1.

4.3. Ongoing Technical Input/Review of CCS in Developing Countries

Before the completion of this Botswanan CCS program of activities, an external technical review was undertaken. The expertise required for the review was drawn from the international CCS community given, in a country new to CCS, there does not exist the expertise locally to undertake such a review. This situation was mirrored for the South African CCS program and would be expected for any similar CCS program in any developing country. In the case of Botswana and South Africa, the technical experts were identified by the World Bank CCS experts through their contacts in the CCS industry and those experts contributed their time for free. This ad hoc, in-kind approach to engaging expert technical support has worked well to date however it will stretch these experts more and more if additional projects and studies are to be carried out. There would also be benefit to be able to draw on this expert support throughout the project cycle rather than only at the end of the project where there is limited scope to adjust the outcomes. To address this, consideration could be given to the establishment of a standing international technical committee of CCS experts. Such a committee could be formed under the auspices of the World Bank CCS TF, or alternative international organization such as the IEA, IEA GHG, or the Global CCS Institute, or collaboratively between these organizations. Experts could then be selected to ensure all elements of CCS are covered and could be engaged for a set term with an agreed level of time commitment and potentially with some remuneration. Such a committee could then work more efficiently than multiple ad hoc committees, could work to disseminate experience and best practice between projects, and could also be more easily accessible for CCS project/study developers who are less well connected with the international CCS community and may struggle to convene a committee on their own.

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