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The proposed CO_2 Test Injection Project in South Africa

Ceri J Vincent[a*], Nigel Hicks[b], Gillian Arenstein[c], Robert Tippmann[d], David van der Spuy[e], Jurie Viljoen[f], Sean Davids[e], Magda Roos[g], Marthinus Cloete[g], Brendan Beck[h], Lodewijk Nell[i], Rob Arts[j], Sam Holloway[a], Tony Surridge[h], Jonathan Pearce[a]

[a]British Geological Survey, Environmental Science Centre, Keyworth, Nottingham, NG12 5GG UK
[b]Council for Geoscience, 139 Jabu Ndlovu Street, Pietermaritzburg, RSA
[c]IMBEWU Sustainability Legal Specialists (Pty) Ltd, 53 Dudley Road, Parkwood, Johannesburg, RSA
[d]Climatekos Ltd, 145 – 157 St John Street, London, EC1V 4PW, UK
[e]Petroleum Agency South Africa, 7 Mispel Street, Bellville, 7530, Cape Town, RSA
[f]Council for Geoscience, 3 Oos Street, Bellville, 7530, RSA
[g]Council for Geoscience, 280 Pretoria Street, Silverton, Pretoria, RSA
[h]South African Centre for Carbon Capture and Storage, CEF House, 152 Ann Crescent, Strathavon, Sandton, Johannesburg, RSA
[i]EcoMetrix South Africa, Prism Business Park, Building 1, Ruby Close, Fourways, Johannesburg, 2055, RSA
[j]TNO, Netherlands Organisation for Applied Scientific Research, Princetonlaan 6, 3584 CB Utrecht, NL

Abstract

The South-Africa Europe Cooperation in Carbon capture and Storage (SAfECCS) project was initiated in 2011. The aim of the project is to support the South African Centre for Carbon Capture and Storage (SACCCS) Roadmap for Carbon Capture and Storage (CCS) in South Africa through assessing the potential for geological storage, the impact of the existing legal framework and the relevance of possible funding streams for the proposed Test Injection Project as well as by undertaking capacity building and knowledge sharing activities.

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[*] Corresponding author. Tel.: 0044 115 9363318; fax: 0044 115 936 3200.
E-mail address: cvi@bgs.ac.uk.

1. Introduction

The South African Centre for Carbon Capture and Storage (SACCCS) Roadmap for CCS in South Africa envisages three main phases of development; an onshore Test Injection Project initiated by 2016 (on a scale of tens of kilo tonnes of CO_2 stored), followed by a larger scale demonstration (hundreds of kilo tonnes of CO_2 stored) and finally commercialisation of CCS in South Africa (millions of tonnes of CO_2 stored) [1]. As part of the first phase, the Council for Geoscience (CGS) produced an Atlas on geological storage of carbon dioxide in the Republic of South Africa (RSA) that identified basins that have potential for CO_2 storage [2, 3]; including the Algoa Basin which lies on the south coast of South Africa and the Zululand Basin on the east coast (Fig. 1). Potential sites for geological storage of CO_2 were identified in the Zululand Basin by earlier research carried out by CGS and the Petroleum Agency of South Africa (PASA) that was funded by the UK Department of Environment and Climate Change (DECC), these results are not part of the SAfECCS project and so are not discussed here.

To continue the work undertaken for the Atlas, the South-Africa Europe Cooperation in Carbon capture and Storage (SAfECCS) project was initiated in 2011. It is funded by the EuropeAid Programme (70%) and the SACCCS (30%) and coordinated by the British Geological Survey (BGS). This paper describes the early results of the two-year SAfECCS project which will feed into the proposed Test Injection Project. The project informs the SACCCS strategy for CCS in South Africa through research into geological, financial and regulatory factors which could impact the Test Injection and supportive capacity building activities where knowledge is shared between European and South Africa partners.

2. Geology and CO_2 storage potential of the Algoa Basin

The SAfECCS project is building on research undertaken for the South African Storage Atlas by identifying potential sites for geological storage in the Algoa Basin to complement the earlier study which identified sites in the Zululand Basin. In the Atlas, the ‘theoretical’ storage capacity of the Algoa Basin was estimated using a CSLF-based methodology to be 404 Mt CO_2 in aquifer formations [2, 3]. The sites chosen for further geological characterisation by the SAfECCS project lie in the Sundays River Trough of the Algoa Basin. CGS and PASA are undertaking research to identify and characterise specific sites in the Sundays River Trough of the Algoa Basin that are potentially suitable for the Test Injection Project through detailed interpretation of onshore 2D seismic and borehole data lithology, gamma and resistivity logs and biostratigraphical data). A summary is presented below.

The Algoa Basin is located north of Port Elizabeth on the south coast of South Africa (Fig. 1). It covers an area of about 3900 km^2 and forms the onshore portion of the large Outeniqua Basin which extends offshore. The Algoa Basin consists of a series of rift-related half-grabens which formed as a result of extensional tectonic episodes during the initial break-up of Southern Gondwana in the Mid-Jurassic. Basin fill comprises Middle Jurassic to Lower Cretaceous fluvial and shallow marine lithologies of the Uitenhage Group which is subdivided into a basal Enon Formation, middle Kirkwood Formation and upper Sundays River Formation (Fig. 2). Igneous intrusions are common in South African basins, but no dolerite dykes or sills are present in the Algoa Basin.

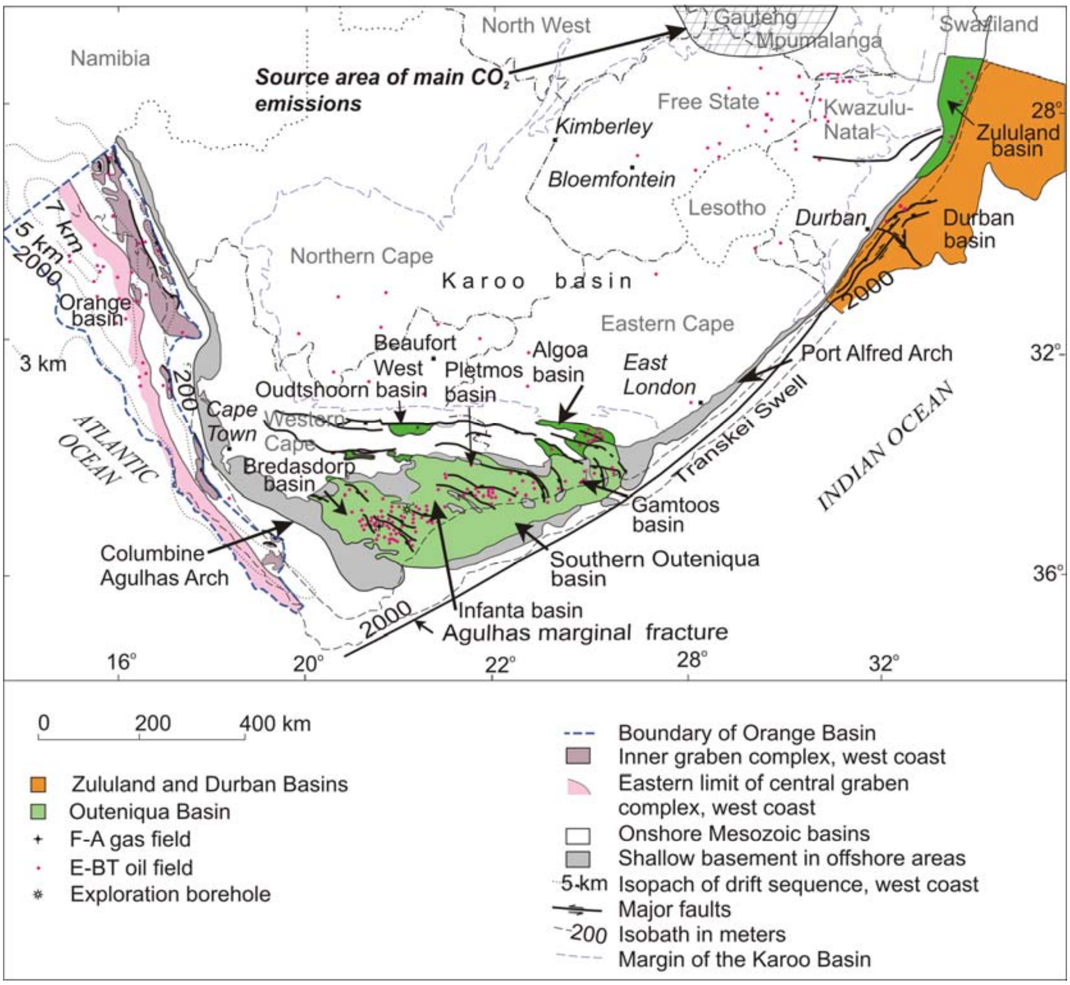

Figure 1: Location of Algoa Basin

Although the larger offshore Outeniqua Basin hosts most of South Africa's recoverable oil and gas reserves, the Algoa basin is not petroliferous. Soekor Ltd[†] discovered oil shows in a two boreholes, but there are no major accumulations [6]. No major mineral deposits are present in the area [7, 8] though occasional thin (mm thick) lignite coal seams are present. The southern part of the Algoa Basin is highly industrialized and populated and it has also been declared a Subterranean Groundwater Control Area [9] so is unlikely to be available for CO_2 storage.

The major feature of the basin is a large southeast deepening trough known as the Sundays River Trough which hosts the majority of the identified sandstone reservoirs. The high number of

[†] Soekor was formed in 1965 to search for onshore hydrocarbons. It was merged with Mossgas in 2000 to become Petroleum Agency, PetroSA

thick (30 m+) sandstones in the fluvial Kirkwood Formation found in the deeper part of the basin and especially the high concentration of sandstone-rich units in the upper part of the formation make it a prime exploration target for storage [4]. The fluvial sandstones of the Kirkwood Formation tend to be lenticular in nature and are surrounded by impermeable mudstones, which could form potential intra-formational seals. The basal sandstone units of the overlying, shallow marine Sundays River Formation are also of interest for CO_2 storage. However, the injectivity of both these sandstone-rich formations has not been quantified; permeability data are available and these were used to assess the sandstones, but without further research, the injectivity cannot be confirmed. Also, if the in situ pore fluids displaced by the CO_2 cannot migrate freely away from the storage site, the pressure in the reservoir could rise relatively rapidly, seriously reducing the amount of CO_2 which could be injected. The Kirkwood Formation has promising reservoir properties at some locations [10], having porosities up to 27% at 800m depth, and permeabilities up to 48 mD [11], however, both porosity and permeability decrease with depth in the Kirkwood Formation, likely due to a high clay content in the matrix [12], and porosities below 2500m are generally poor. The Sundays River Formation has porosities ranging from 11% at a depth of 1800 m to 23% at 800 m depth.

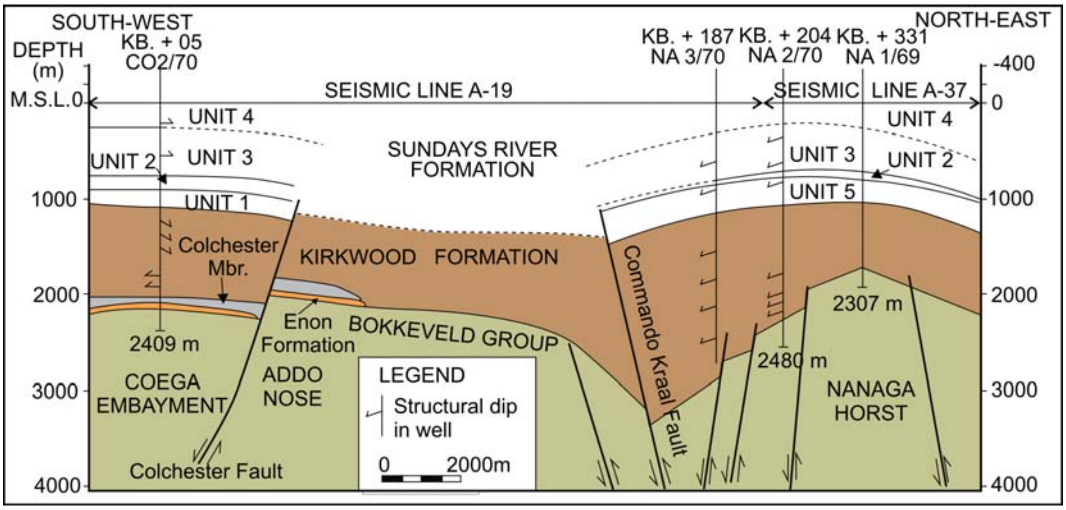

Figure 2: Geological cross section from the Coega embayment to the Nanaga Horst Block (Modified from [5]).

The SAfECCS interpretation and characterisation exercise identified seven sites with an estimated storage potential of millions of tonnes of CO_2 (Fig. 3) using a CSLF-based methodology [13]. The sites were assessed and ranked for their suitability as prospective CO_2 test injection sites, using the following criteria; storage capacity, injectivity, containment, site logistics and the presence of natural resources. Sites in the Nananga area, Colchester Trough (Brak River) and Springmount areas were identified as having the most favourable reservoir properties. The other four sites were ranked lower on the basis of lack of reliable data, high groundwater circulation or proximity to populated areas or national parks (

Table 1: Potential storage sites and ranking for the Algoa Basin

Ranking (based on score)	Site	Storage potential using 1% storage coefficient (Mt)	Storage potential using 4% storage coefficient (Mt)
1	Nananga	3.04	12.16
2	Colchester Trough – Brak River	2.33	9.33
3	Springmount	0.81	3.24
4	Seaview	0.78	3.11
4	Addo Trough	1.11	4.46
6	Colchester Trough	0.07	0.29
6	Alexandria	0.20	0.77

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The detailed geological assessment of the Algoa Basin will be published at the end of the SAfECCS project [4]. Static geological modelling and dynamic modelling of CO_2 injection will be carried out later in the project.

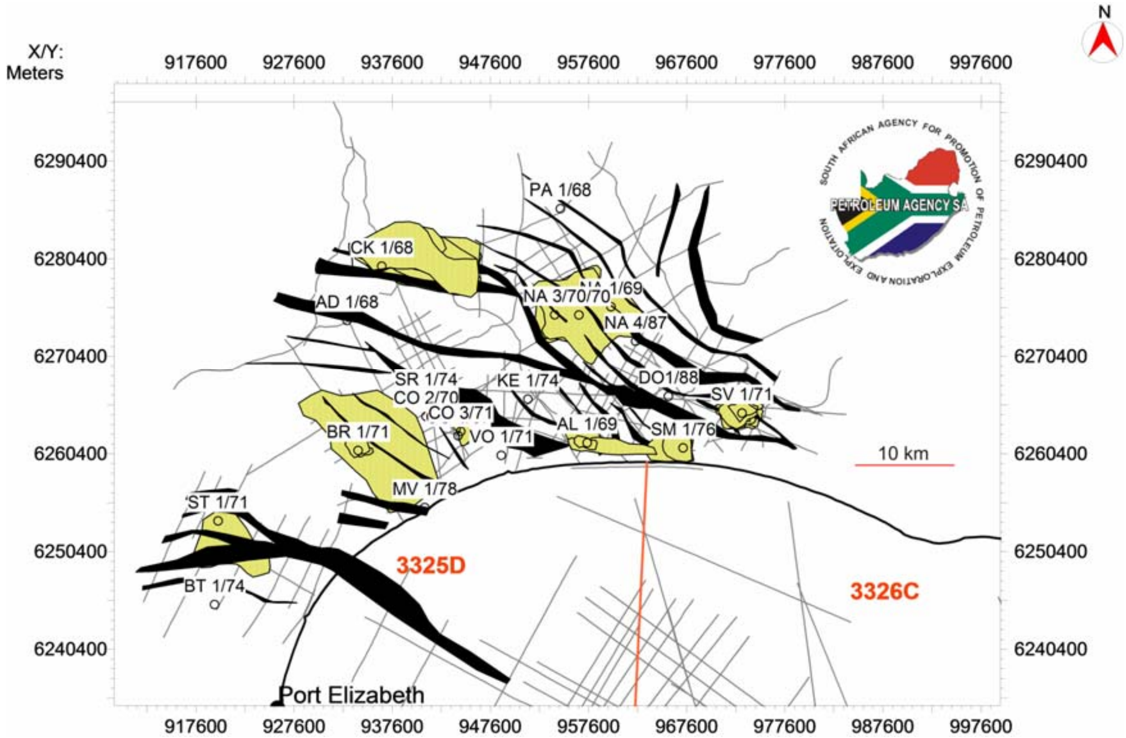

Figure 3: Location of sand-rich sites in the Algoa Basin with potential for storage. Thin black lines show seismic line locations. Thick black lines show major faults. Yellow polygons show sand-rich areas. Circles show borehole locations.

All sites identified by SAfECCS now need further detailed characterisation, as do the sites in the Zululand Basin, before one site can finally be chosen for the Test Injection Project. This will require acquisition of new data as currently there is insufficient information to undertake a test injection at these sites; for example, the injectivity would need confirmation. The condition and abandonment procedures of the existing boreholes must also be further investigated.

The CGS are developing a Geographic Information System (GIS) using Environmental Systems Research Institute, Inc. (ESRI) ArcGIS software to collate details of large point sources of CO_2 in South Africa along with potential CO_2 storage sites and other relevant information. This GIS will provide a platform for interaction and analysis and will allow qualitative assessment of options for the Test Injection Project. Details of around 87 of the larger point sources with total emissions of 497 $MtCO_2$/year have been provided by project partners and are included in the GIS [14]. The inclusion of all sources in South Africa will also allow the GIS to be used as a basis for future CCS projects. Details of CO_2 emissions for coal fired power plants, gas/liquid fuel turbine power plants, cement plants, chemical plants, refineries, metal industry plants, oil and gas production and pulp and paper mills are included in the current version of the GIS. Based on this investigation of potential sources, for the Test Injection Project, CO_2 will most likely be purchased and transported by road to the injection site, as unfortunately most of the sources identified lie many kilometres from potential storage sites (Fig. 4) and it would be expensive to build a long pipeline for the small scale Test Injection Project.

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3. Law and Regulation relevant to the Test Injection Project

Imbewu Sustainability Legal Specialists (Pty) Ltd (IMBEWU) is examining law and regulations relevant to storage and injection of CO_2 in the Algoa Basin, using the proposed Test Injection as a case study [15]. Through a parallel project, the Scoping Study, Imbewu is also undertaking an environmental legal analysis to identify applicable authorisations required for the capture and transport of CO_2 for the Test Injection Project and to determine the timescale for making the necessary applications.

Currently, there is no CCS specific legislation in South Africa. However, there are laws relating to waste disposal and environmental regulations which are expected to be relevant to the Test Injection Project[‡]. In 2008 the Department of Environmental Affairs released the Long-Term Mitigation Strategy (LTMS) Scenarios report [16], which identified and assessed a number of possible options to mitigate GHG, between 2008 and 2050, [§] CCS being one of the identified mitigation options. The South African government has commenced the initial stages of planning and developing a CCS regulatory framework or policy to allow for a more streamlined approach to the regulation of these projects and, in 2011, established an interdepartmental task team to drive this policy development.

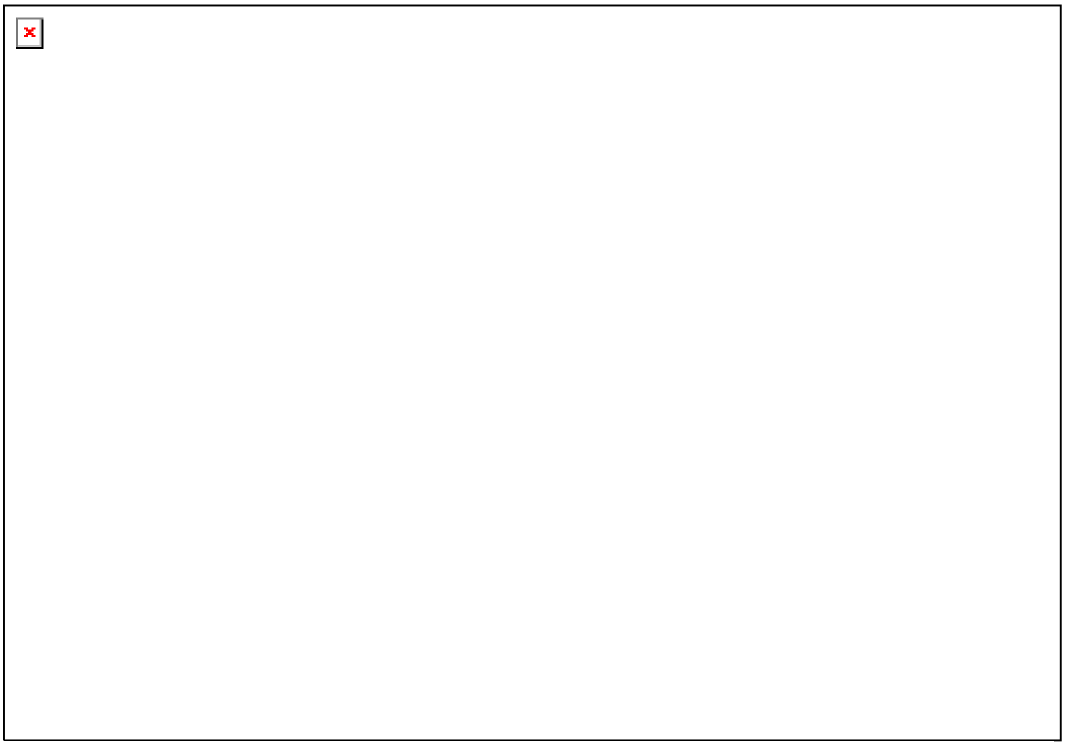

Figure 4: CO_2 emission large point sources and potential storage sites

The Constitution of the Republic of South Africa (Act 106 of 1998) provides for concurrent responsibility for the three tiers of government (national, provincial and municipal) in respect of a

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[‡] This investigation is being conducted through a piece of work commissioned by the Work Bank entitled “CCS Policy Framework Development”, which commenced in July 2012 and will be finalised in March 2013.

[§] Department of Environmental Affairs and Tourism (renamed the Department of Environmental Affairs), *Long Term Mitigation Scenarios*, 2007.

range of matters relevant to the implementation of the Test Injection Project. These, sometimes overlapping, areas of administrative competence add significant complexity to the process of obtaining environmental legal authorisations. Consequently, efficient management of the process will be vital for the development and operation of the Test Injection Project. In addition, the timing of the Test Injection Project will also affect the applicable legal framework as amendments to relevant regulations are expected, for example, the legal requirements for the environmental impact assessment has been amended twice in the preceding five years and if altered again before the Test Injection Project begins, may have different requirements for the Test Injection Project. Another example of relevant regulations are those governing remediation of contaminated land. These regulations are under development and may be applicable retrospectively, i.e. even if the Test Injection Project is initiated before these regulations come into force, if the Test Injection Project resulted in land contamination, these laws could still apply to the site operator. International regulations such as the Polluter Pays Principle could also be relevant if CO_2 were to cross boundaries and impact on a neighbouring country.

The constitution states that all South Africa citizens, both present and future, have the “right to an environment that is not harmful to their health or well being”. This section also supports legislation which prevents pollution and ecological degradation and sustainable development. Common law principles also protect the rights of landowners from neighbours’ activities having a detrimental impact on their property.

Resulting from the environmental right contained in the Constitution and the government’s obligation to ensure that the environment is protected for present and future generations, the National Environmental Management Act (NEMA), was promulgated and came into force on 29 January 1999. NEMA is the framework legislation for the management of environmental matters and it is under this Act that the Test Injection would be expected to consider, investigate, assess and report the consequences for, or impacts on, the environment of the activity to the competent authority i.e. the Environmental Ministry [15]. NEMA furthermore includes a number of founding environmental principles such as; inter-generational equity; precautionary principle; polluter pays principle; equitable utilisation of shared resources; and, sustainable development, which inform the interpretation and application of all related environmental legislative provisions. NEMA would require the Test Injection Project to develop an Environmental Management Programme/plan (EMP) to describe how the activities will be managed and monitored, and what mitigation and remediation strategies are in place. NEMA also places a “general duty of care” to take reasonable measures to prevent or minimise and rectify any environmental damage caused or that is likely to be caused.

As it is unlikely that the CO_2 will be retrieved or considered useful after storage, then it is likely in law to be considered to be disposal of a hazardous waste and so the National Environmental Management: Waste Act 56 of 2008 (NEM: WA) may also apply to the Test Injection. As there are no specific CCS regulations, for this project it as assumed that CO_2 would be classified as a hazardous waste as this has the strictest regulations and will allow SACCCS to prepare for the Test Injection with these restrictions in mind. The terms of NEM: WA will affect which regulations apply to the Test Injection. In terms of NEM: WA it is expected that the Test Injection will require a waste management license for the handling and storage of the CO_2 prior to injection [15].

As there are no specific legal provisions seeking to regulate ownership of pore space intended for CO_2 storage, it is likely that ownership of pore space will be regulated according to the common law and other peripherally relevant legislation. According to the common law principle of *cuis est solum* ("whoever owns the soil, it is theirs up to the heavens and down to hell") the land owner would also own the pore space, and, over time when the CO_2 became indivisible from the rock through long term mineralization, in the absence of contrary agreements, they would become the owner of the CO_2. The Mineral and Petroleum Resources Development Act 28 of 2002 stipulates that ownership of minerals found within South Africa belong to the state, however, as pore space is not a mineral and the CO_2 is not being mined, then this Act is not likely to affect CO_2 storage in its present guise.

The National Water Act of 1998 protects water quality through regulating water use. As CO_2 is injected, if brine were produced to maintain pressure control, then this bring would have to be disposed of in such as way as to avoid damaging water resources. Additionally, if the CO_2 were to migrate in the sub-surface and damage aquifers used for potable water then the storage site operator could be liable.

There are also municipal laws which will impact the Test Injection, based on the specific location of the storage sites.

It is expected that, as for closure of mines and nuclear waste disposal sites, the proposed Test Injection Project will require a closure certificate to be issued by the competent authorities before the Project can be closed legally. In the post-closure phase, given the timescale over which the CO_2 storage site is expected to achieve long term stability (i.e. for the CO_2 to dissolve into the pore waters and then to form a mineral solid), a clause of South African mining legislation which makes provision for transfer of environmental liability to a person deemed suitable by the minister may allow transfer of long term liability for the storage site. However, this has not yet been tested and it is likely that if transfer of liability is permitted that the competent authority will limit their liability and that the State may require a financial contribution from the Storage Site Operator [15].

4. Financing options

Identifying a carbon or climate finance component is crucial for the SAfECCS project as the Test Injection is expected to require funding on a scale of a few hundred million Rand[**] to pay for the capital expenditure. Climatekos (CE), with support from EcoMetrix South Africa (EM), is investigating funding and financing options from national and international sources that are likely to be available within the timeframe of the Test Injection Project. Options include public funding sources, private finance and climate finance including grants, equity, alongside climate finance risk reduction and finance enhancement mechanisms. It is almost certain the Test Injection Project will require a combination of these funding sources. Depending on how the Test Injection Project is designed, it will allow for the application of some of these mechanisms but exclude others [17]. Based on the current project design, the most likely funding strategy relies on grants plus potential in-kind contributions from the private sector. Equity investments via larger cash injections would depend on how soon a commercial case could be made or rather how attractive an overall, long

[**] One hundred million Rand is around 12.2 million dollars

term investment proposition would become when packaging the test injection together with the subsequent phase(s) of the South African CCS road map

In order to raise finance for the Test Injection, the key aims of the project and the benefit to funders will need to be clearly described and the importance of the Test Injection in the implementation of the SACCCS Roadmap ,and therefore, its importance in future climate change mitigation must be emphasised. Based on experience from CCS demonstrations worldwide, energy or rather commercial components, even if still in an early or rather applied research stage, need to be promoted from the beginning through existing or emerging climate finance mechanisms (see below). It should also be made clear however, that the roadmap requires that each stage is successful before the next step is initiated and as such the link between the proposed Test Injection Project, demonstration and commercialisation cannot be guaranteed. As a result of this and the demonstrative nature of the project, it is most likely that public funding sources will be required to supplement industrial funding. If government funding can be secured, it would be expected to be a strong incentive for attracting additional financial support [17].

Previously, tax incentives in RSA have focussed on energy efficiency. However, in the 2012 budget review, a local carbon tax is being considered which would apply to carbon dioxide equivalent (CO_2e) emissions (with a tax free allowance of 60% of CO_2e emissions), at an amount of 120 ZAR[††] in 2013/14, increasing at a rate of 10% annually until 2019. This would impact on many industrial sectors to varying degrees (depending on how the CO_2 is generated) including electricity generation, petroleum refining, steel manufacture, waste processing, sugar refining and cement manufacture.

A number of private funding companies were identified by EM from the Johannesburg Stock Exchange as being relevant to CCS, either as a supplier of CO_2, as potential technology providers or as partners in existing CCS projects. International private companies could also be approached if a clear commercial case could be made. Private companies could potentially be approached to support the Test Injection Project either through direct financial contribution or through tax deductions, provision of capital items or expertise at reduced cost or sharing in the risk/liabilities of the project. Potential benefits to private entities that support the Test Injection Project could include a stake in any intellectual property generation, preferential rights to carbon credits and/or carbon offsets generated by later stages of the SACCCS Roadmap and development of CCS expertise for future projects.

National grants to support activities such as job creation, collaboration with Higher Education Institutes and development of local technologies could be used to co-fund or provide loans for the Test Injection Project if these aspects are included in the project design.

International climate finance mechanisms are the most obvious potential contributor to the Test Injection Project or rather a potential door opener for a first round of public seed funding and further public or private finance thereafter. This is an early stage pilot project, and lacks the scale at this stage to apply for many of the other international grants and loans which are designed to bridge the gap between project preparation and commercialization, or to fund projects mitigating emissions on a larger scale. Once the technicalities for CCS projects under the Clean Development Mechanism (CDM) are clarified, and therefore allow for the development of related methodologies

[††] 120 Rand is approximately 14.6 dollars (28/9/12)

and the actual registration of projects with the CDM Executive Board, this mechanism would be the most developed among the carbon finance or climate finance mechanisms thus far. The CDM allows projects to sell Certified Emission Reduction (CER) credits in order to offset costs. However, as CCS is relatively new in the CDM, it could take a few years to access this option. Additionally, the Test Injection on its own will only store a relatively small amount of CO_2 and so will only be eligible for a small amount of credits.

International funding from a number of multilateral funds such as the Global Environment Facility, the Green Climate Fund (expected to be operational 2014), the Partnership for Market Readiness or the Public-Private Infrastructure Advisory Facility could also be of interest for the Test Injection Project. Nationally Appropriate Mitigation Actions (NAMAs) are an emerging finance mechanism through the climate negotiations under the UNFCCC (United Nations Framework Convention on Climate Change) which may allow for more developed countries or private entities to fund or invest in developing countries. Bilateral funding options supported by specific countries including as Germany, the UK, Japan and France could also be considered as contributors to the Test Injection Project [18].

5. Capacity building activities

Capacity building and knowledge sharing activities are a key part of the SAfECCS project. TNO and BGS have shared their experience in the geological evaluation of storage sites through the organisation of a full week Geoschool in October 2011 in South Africa, followed by a field visit to outcrops of the reservoir rock in the Algoa Basin organised by the CGS. BGS also provided targeted GIS training for CGS. Further detailed modelling software (Schlumberger Petrel and Eclipse) training will also be undertaken by SAfECCS team members from CGS and PASA. This training is being offered by TNO and will take place over three weeks. Dissemination of the final project results is foreseen through a workshop in January 2013.

6. Next steps for the Test Injection

Using these initial results and input from other relevant projects, as part of the SAfECCS project, SACCCS will identify what further work needs to be carried out for the Test Injection, including ensuring the site has a thorough geological characterisation to enable safe geological storage for the Test Injection Project. When the SAfECCS project is complete, SACCCS will consider the results, along with those of the Test Injection Scoping Study and possible geological sites in the Zululand Basin, and determine the most suitable location for the Test Injection Project. The assessment of laws and regulations which will impact the injection and storage of CO_2 from the SAfECCS project (including monitoring and mitigation plans) will be combined with the assessment of laws and regulations which affect CO_2 transport and construction of the site infrastructure and the timescale for applying for relevant permits from the Scoping Study. This legal assessment will also guide SACCCS in selecting a suitable site and may also impact on the design of the Test Injection Project, for example, the amount CO_2 injected could be planned to avoid triggering certain aspects of the regulations. The financial assessment carried out by the SAfECCS project has highlighted many potential funding streams and will assist SACCCS in constructing the Test Injection Project model in order to take advantage of the most appropriate options available.

A summary of the interim results from the SAfECCS project was presented here. At the end of the project, the detailed results will be presented in a series of deliverables that will be made publicly available.

7. Summary

The initial results of the SAfECCS project have identified potential sites that could be used for the Test Injection Project; the Nananga, Colchester Trough (Brak River) and Springmount areas could all potentially store a few million tonnes of CO_2, which would be sufficient for the Test Injection Project. All these sites also have promising porosity and permeability within lenticular sandstone bodies with good intra-formational mudstone seals. However, more detailed characterization is required in order to understand how the sites will respond to the injected CO_2.

The review of the impact of the current legal and regulatory framework in South Africa indicates that the Test Injection Project can be carried out under the existing regime. However, as there are no specific laws relating to CCS, then aspects from the Constitution, Common Law, National Environmental Management: Waste Act (NEM: WA) and the National Water Act are all expected to play a part. In terms of long term liability, drawing parallels from closure of mines and nuclear waste disposal sites, it seems possible that liability could be transferred to the state, but this would have to be further explored.

In terms of financing the Test Injection Project, there are a number of potential funding streams from national and international sources. As the Test Injection Project is a small scale demonstration which plays an integral part in the SACCCS roadmap, it is believed that a combination of funding streams, most likely including public funding and national grants as well as private funding, will be required. In order to secure funding, the Test Injection Project model, aims, importance with respect to the SACCCS Roadmap and large scale mitigation and benefits to financial contributors will need to be clearly defined and demonstrated.

The SACCCS Roadmap for CCS in South Africa clearly has a key role to play in the future of CCS in South Africa and the SAfECCS project results will support implementation of the Roadmap.

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