CO_2 Storage Resource Catalogue

Cycle 4 Report

SUB-SAHARAN AFRICA

August 2024

OIL AND GAS CLIMATE INITIATIVE

GLOBAL CCS INSTITUTE

HALLIBURTON

International Association of Oil & Gas Producers

Amounts of CO_2

Stored
0 Gigatonnes

Commercial
0 Gigatonnes

Sub-commercial
21 Gigatonnes

Undiscovered
339 Gigatonnes

Appendix F : Sub-Saharan Africa

Mozambique
Nigeria
South Africa

Document Summary			
Client	Oil and Gas Climate Initiative (OGCI)		
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1.1 Summary

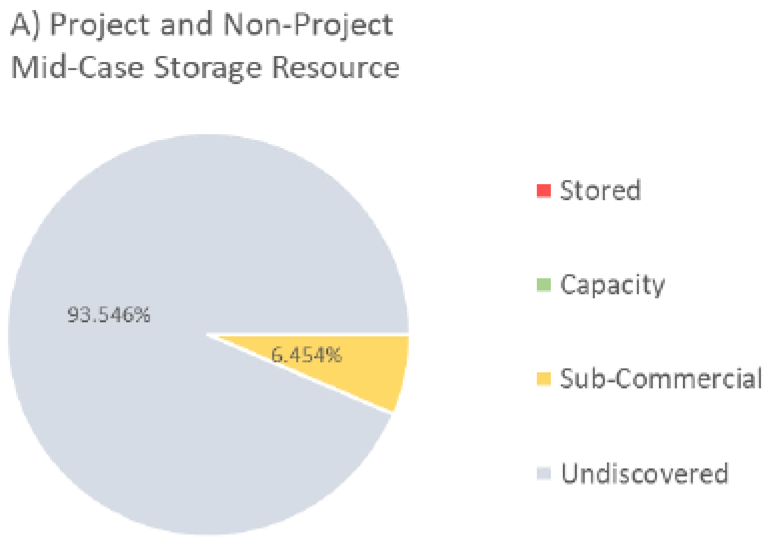
Mozambique was assessed during Cycle 3. The CSRC has identified a CO2 storage resource for Mozambique as follows:

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	1.13	0.00
Undiscovered	16.42	0.00
Aggregated*	17.55	0.00

* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of the country.

Table 1-1: Storage resource classification summary for Mozambique

- Storage resource potential is present in saline aquifers. Depleted field storage is likely to exist, particularly in the onshore area (offshore field are present but are unlikely to become available for storage within the earliest accessible date for Cycle 3), but no published details are available.
- Potential storage resource has been identified in 2 geological basins, the Mozambique and Rovuma basins, with 15 sites or regional locations identified. No projects have been identified.
- There is no current CCS-specific regulatory system.
- No CCS projects have been developed but current development of large-scale LNG facilities are attracting attention for carbon capture.



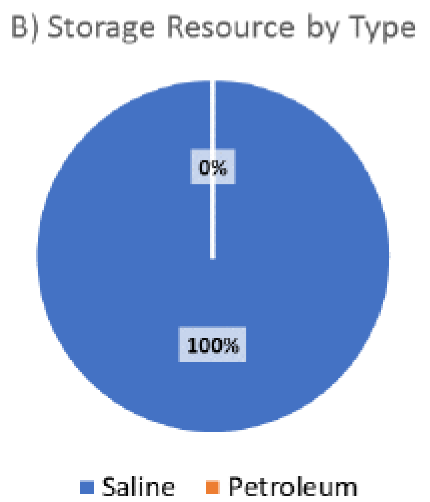


Figure 1-1: Mozambique spread of Storage Sites

a) Above: Spread of storage resource in Mozambique sites (15) across SRMS classifications, where a project has been specified. b) Spread of storage resource in all Mozambique sites across SRMS classifications; both project specified and not. c) Split of Mozambique storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

1.2 Resource Statement

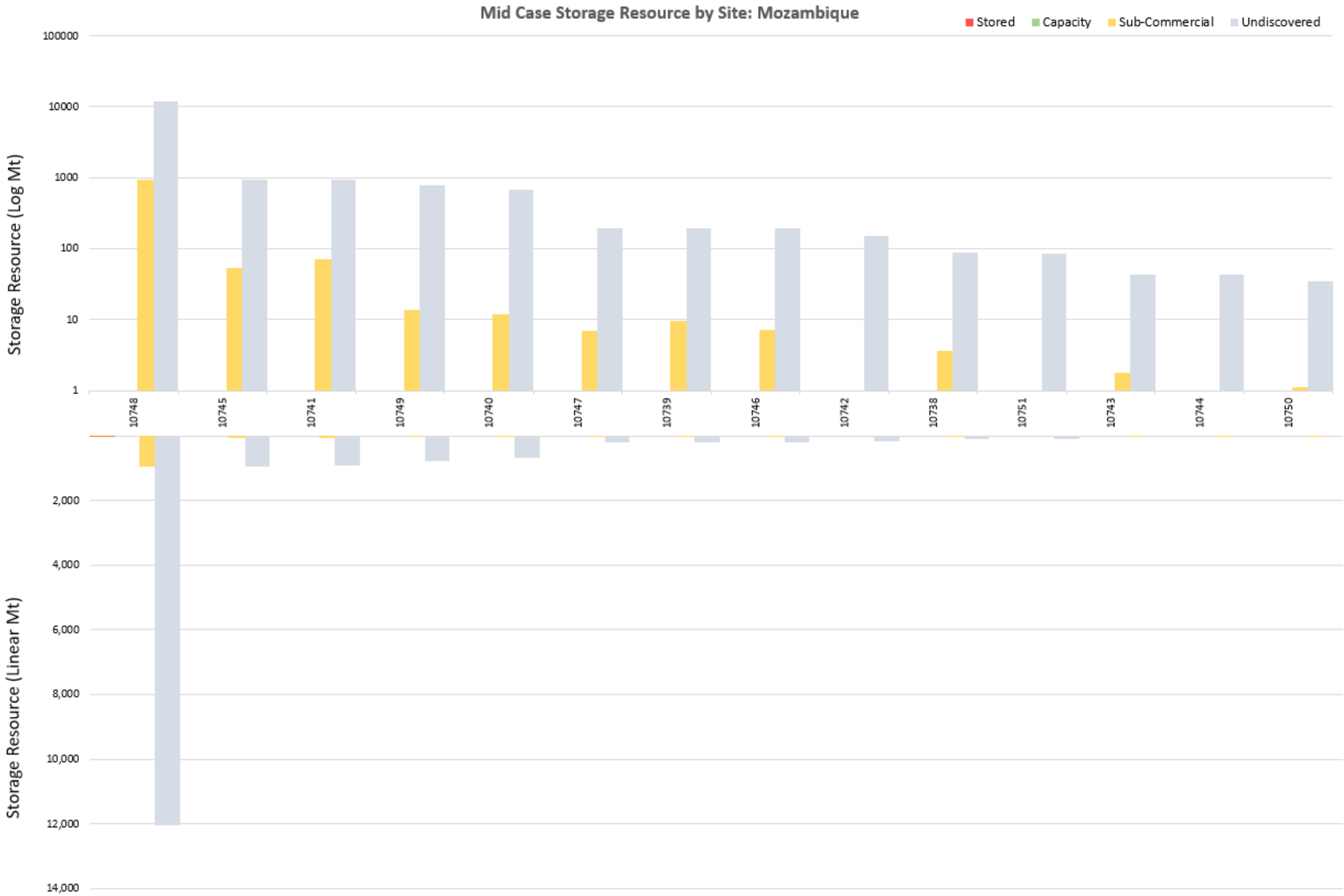


Figure 1-2: Storage resource summary for Mozambique compiled in the CSRC.

Graph above is log scale and graph below is linear.

1.3 Evaluation History

Mozambique was selected for review during the Cycle 3 Assessment. The focus of the assessment was on the two major, post-Gondwana break-up, sedimentary basins which comprise much of the country: the Mesozoic-Cenozoic Mozambique basin which occupies the central and southern parts of the coastal plain and extends out onto the continental shelf and slope, and the Rovuma basin in the north of Mozambique which is part of the extended east African marginal basins. While sedimentation was basin-restricted during early stages of basin development, by the late Cretaceous the sedimentary fill of both basins was very similar and represents a single depositional system on the continental margin [1].

The key source of information for this assessment is the DNV CO2 Storage Atlas [2](which evaluated the storage potential of saline aquifers in the Mozambique Basin, and a study by Carneiro and Alberto [3] which provides a preliminary evaluation of the storage potential in the Rovuma Basin. These two basins are the best understood of the five post-Gondwana sedimentary basins, primarily due to some hydrocarbon exploration and production activities in the offshore extent of the basins [4].

CCS has had limited attention in Mozambique as fossil fuels do not represent a major contributor to the country's energy mix (approximately 84% hydropower and only 16% from fossil fuels by end-2020 [5]. However, the discovery of significant gas accumulations in the offshore Ruvuma basin and four proven gas fields in the Mozambique basin, plus access to coal deposits, indicate that this may change in the future as energy demand increases. Three major LNG developments are under development in the country at the time of this assessment, with stated interest (by ExxonMobil) in carbon capture at the Rovuma LNG facility.

1.4 Resource Review

1.4.1 Major Projects

To date, no major projects have been identified in Mozambique, although as the development of natural gas processing plants and the LNG facilities progresses, this may change.

1.4.2 Depleted Oil & Gas Fields

There are four proven gas fields in Mozambique: the onshore producing Pande, Temane, Buzi, and Inhassoro fields. To date, no published information is available on any individual storage evaluations for these fields, it is indicated that >4 Gt storage in depleted fields may be possible. In 2011, 13Bcf was produced from the Pande and Temane fields but no evaluation of their CO2 storage potential is available. The large gas reserves in the north of the country (Ruvuma basin) are due to start production in 2024 (as per Total Energies statement: Total Mozambique LNG Project (totalenergies.co.mz). It is unlikely that depleted field storage resources will be available soon.

1.4.3 Saline Aquifers

1.4.3.1 Mozambique Basin

The DNV Storage Atlas made the first evaluation of theoretical storage capacity in the Mozambique basin (study area: 653,512km2). Using a combination of available geological cross-sections, and well data and logs they developed a GIS system for the basin. Four clastic saline aquifers (reservoir-seal pairs) were identified within the depth range 800m- 3500m.

- Sena Formation (Lower Cretaceous).
- Domo Sands (Upper Cretaceous)
- Upper Grudja Formation (Upper Cretaceous)
- Lower Grudja Formation (Paleocene)

Containment is considered to occur through several different trap types, structural and stratigraphic, with each saline reservoir formation being overlain by extensive shale-prone units. Sealing potential is proven in parts of the region in the Lower Grudja by the presence of hydrocarbons (gas). Further work would be required to provide assurance of containment at any individual location.

'Zones' of storage potential were delineated using depth and data availability (circular zones were established to include well data locations in the near vicinity of geological formation presence as determined from cross-section).

Simple volumetric calculations of storage resource indicate significant potential in the four saline aquifers identified:

Formation	Storage Resource: Low (Mt)	Storage Resource: High (Mt)
Sena Formation	122	244
Doma Formation	579	26630
Lower Grudja	1229	198899
Upper Grudja	462	2405

Table 1-2: Potential storage in the four identified saline aquifers

Even if the storage resource estimates provided by the DNV storage atlas represent significant over-estimations of available capacity, it is clear that the Lower Grudja Formation carries good storage resource potential.

The majority of the storage resource is assessed as being Undiscovered: Sequence Play.

However, as there are well data available, a small portion of each 'zone' is considered "Discovered' but awaiting detailed assessment due to the absence of any dynamic simulation of CO2 injection into the aquifers. The absence of any CCS-specific regulatory framework, nor any existing projects which have applied any other legislation to allow injection of CO2 does mean that the storage resources are currently considered 'Inaccessible'.

1.4.3.2 Rovuma Basin

The Rovuma (also 'Ruvuma' in some instances) is centred on the Rovuma delta near the border between Mozambique and Tanzania. The basin area within Mozambique is approximately 73000km2 [1]. Although significant gas discoveries have been made in the offshore sector of the basin, little is known about the onshore geology at depths greater than 800m. Data is restricted to two deep boreholes however there is extensive 2D seismic data available. No onshore hydrocarbon discoveries have been made.

A regional study by [3] identified three saline aquifers at depths greater than 800m which may have some storage potential. The Upper Jurassic-Lower Cretaceous Pemba Formation, the Lower Paleogene Alto Jongone Formations, the Eocene Quissana Formations, and the Oligocene to Pleistocene Mikindani Formation have been mapped within four delineated sectors in the Rovuma basin. Of these four sectors, only two sectors are considered to have good storage potential: the Palma-Mocimboa (in the north-east of the basin) and Macomia-North Pemba (in the extreme south of the basin) sectors.

In the northern Palma-Mocinboa da Praia sector, deep boreholes indicate the Alto Jingone and Quissanga formations may form suitable storage reservoirs, with some potential in the Mikindani formation. An offshore gas field, the M'nazi Bay field in the Tanzanian sector of the basin, acts as a good analogue for the former formations.

In the southern Macomia-North Pemba sector, the Tertiary units are either only sporadically present, or are too shallow to have storage potential, however the Lower Cretaceous Pemba Formation sediments and overlying Mifume Formation marls and carbonate mudstones form a reservoir-seal pair which may have some storage potential.

All storage resources in the Rovuma basin are considered Undiscovered due to the lack of surface well data within the mapped sectors. The absence of any CCS-specific regulatory framework means that the current classification of the sites is Inaccessible.

1.5 Regulatory Framework

As of Cycle 3, no CCS-specific regulatory framework exists in Mozambique.

1.5.1 Issues for the Assessment

While The storage potential assessed for Mozambique is limited due to the lack of published studies. In addition, the data that is available in the public domain provide minimal information of data sources and locations. Assessment of storage potential assumes that there is a degree of assurance on the containment potential of the site. In both the Mozambique and Rovuma basins significant work is required to improve the understanding of this element.

1.6 Future Updates

Update following any future release of information on CCS projects associated with the development of gas processing and LNG facilities.

2 Nigeria

2.1 Summary

Nigeria was assessed during Cycle 3. The CSRC has identified CO2 storage resource for Nigeria as follows:

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	0.00	0.00
Undiscovered	0.00	0.00
Aggregated*	0.00	0.00

* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of the country.

Table 2-1: Storage resource classification summary for Nigeria

2.2 Evaluation History

Nigeria was assessed as part of Cycle 3 of the CSRC. To date there is no published information of the carbon storage resource potential in Nigeria. However, at COP 26 representatives from Nigeria detailed the road map for Nigeria's energy transition [6] which included CCUS as one of the key measures of decarbonization. An outline of a suggested CCUS work programme included a technical assessment of Nigeria CO2 storage resources, an initial project prefeasibility study, and mention of pilot or commercial project studies. The CCS-specific work programme also included effort on the legal and regulatory framework to enable and support CCUS deployment. The International Finance Corporation and the World Bank are working with the Nigerian government to produce an atlas of CO2 emissions sources and potential sites for underground storage [7].

2.3 Resource Review

To date, no major projects or resource evaluations have been identified for Nigeria.

The Niger Delta area has been identified [8] as an area with some storage potential. Some 606 oilfields (355 of which are in the onshore sector) may provide storage resources as the majority are no longer in production. In addition, the Cretaceous sedimentary basins may hold storage opportunity. A theoretical study of the onshore Okota/Okpoputa field in the Niger Delta [9] examined the potential for CO2 storage and concluded that while the stacked reservoirs typical of this rea may provide multiple storage opportunities, the dominant growth fault structural style will require careful evaluation to ensure long-term containment.

3 South Africa

3.1 Summary

South Africa was assessed during Cycle 3. The CSRC has identified a CO2 storage resource for South Africa as follows:

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	19.91	0.00
Undiscovered	323.02	0.00
Aggregated*	342.93	0.00

* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of the country.

Table 3-1: Storage resource classification summary for South Africa

- Although storage resource is reported as being present in both saline aquifers and oil and gas fields, the greatest potential lies in saline aquifers.
- Evaluation of potential storage sites began in 2010. South Africa has developed one pilot project (no storage estimates available but the project plans to inject 10-50,000Mt in total) and one test injection project (up to 12.16Mt) to date.
- The storage resource potential of South Africa is based on one main study from Viljoen [10] and further smaller studies.
- The potential storage sites in South Africa are in the Onshore Algoa basin, Onshore Gamtoos basin, Onshore Zululand basin, Offshore Orange basin, Offshore East Coast basin and the Offshore Outeniqua Basin.
- 31 sites with assessed storage potential were identified in Cycle 3.
- South Africa has a low score of 40 in the CCS Chart of Legal and Regulatory Indicator system highlighting there is no CCS-specific regulatory system currently.

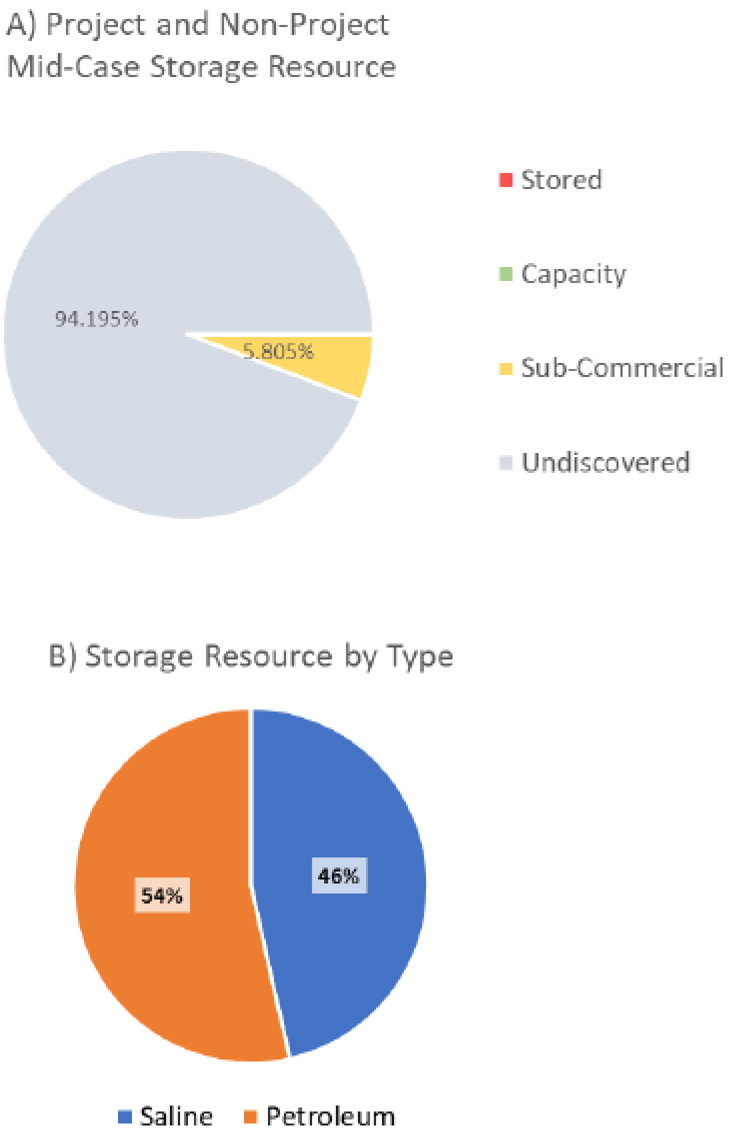


Figure 3-1: South Africa spread of Storage Sites

a) Above: Spread of storage resource in South Africa sites (31) across SRMS classifications, where a project has been specified. b) Split of South Africa storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

3.2 Resource Statement

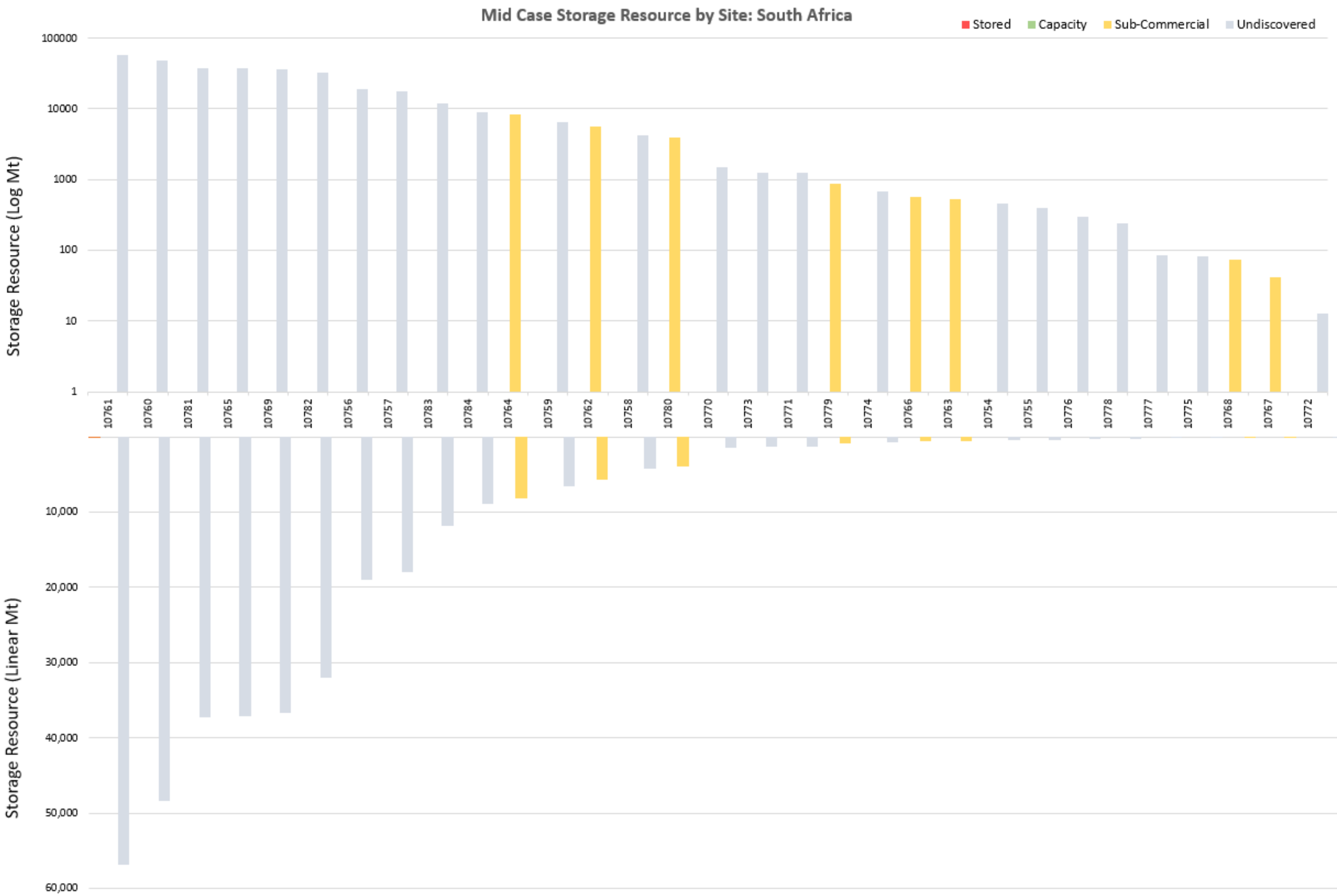


Figure 3-2: Storage resource summary for South Africa compiled in the CSRC.

Graph above is log scale and graph below is linear.

3.3 Evaluation History

Evaluation of potential storage resources in South Africa began in 2010 after a country-wide Storage Atlas was published [11]. This was shortly followed by a major study by Viljoen (2010) which provided high level evaluations of multiple sites across South Africa [10]. The report presented volumetric methodologies for estimating resource in saline aquifers and depleted fields (and coalbeds which are not included in the CSRS). A total of twelve (12) saline aquifer estimates and six (6) depleted fields identified by the Viljoen study have been assessed during this Cycle 3.

In 2013, a test project evaluated six sites [12] in the onshore Algoa Basin. Out of the six sites only one, the Nangana site, reached the CSRC 10Mt threshold. As this value represents the high end of a range derived by simple volumetric resource calculation (and thus is considered to be an overestimation of potential storage resource), this site will not be included in the database.

Also in 2013, a Parsons Brinckerhoff study [13] carried out a modelling study of storage resources across 12 sedimentary basins, both onshore and offshore. Unfortunately, access to the full report was not achieved during Cycle 3 (a set of summary presentation slides provides a high-level overview). The results showed that the onshore basins had zero or very low dynamic capacity so only six offshore basins were evaluated for storage by the study, estimating potential storage resources over 150Mt. The Durban & Zululand basin has an estimated 3.3 Gt (3,256 Mt) and the Orange basin has 6.2 Gt (6,216 Mt). Unfortunately, the presentation, while in the public domain, does not present any maps or wells associated with the limited storage resources information. If the original report by Parsons Brinkerhoff can be found it would increase the reliability of the storage resource assessment.

In 2017, Hicks and Green [14] studied saline aquifer storage potential in the Durban basin, using a volumetric methodology to estimate the storage for nine seismically defined units. These data present at sequence level in the SRMS and so supersede the data from Viljoen. They concluded a storage resource of 5.4 Gt is available in the Durban Basin which is in reasonable agreement with the earlier study (5.2 Gt).

The Storage Atlas [11], presents a roadmap which "provides a phased outline of the work required for achieving a commercial roll-out of CCS technology in South Africa". Initially, evaluation of CCS potential was to be completed in 2004 followed by the production of the carbon atlas in 2010. The rest of the roadmap plans for a test injection project, the Pilot CO2 Storage Project (PCSP), a demonstration plant injecting 100s thousands of tonnes, and moving towards commercial-scale injection and storage. In 2020, the government passed a resolution appointing the Council of Geoscience as the implementation state agency for the planned CCUS programme.

As of 2018, South Africa has a GCCSI Indicator score of 40 [15], an evaluation of a country's geological storage potential, maturity of their storage assessments and progress in the deployment of CO2 injection sites.

3.4 Resource Review

3.4.1 Introduction

Although there is some identified storage potential in depleted fields in South Africa, most of the reported storage resource potential lies in saline aquifers in the offshore basins.

3.4.2 Major Projects

In South Africa there are currently no major projects as defined by the CSRC. If supplementary information and data can be accessed (for example Parson Brinkerhoff study report), this statement may be updated.

3.4.3 Depleted Oil & Gas Fields

No detailed review of storage potential in depleted oil and gas fields is available in the public domain. No specific calculations have been made yet for the depleted oil and gas fields. In the Viljoen report six estimates were given for gas and oil fields in the offshore Outeniqua, Orange and Durban/ Zululand basins depleted fields but published information on the depleted oil and gas fields is limited and currently indicates that none of the fields would be available for use as a storage resource within the next 30 years (EAD set at 2052).

3.4.4 Saline Aquifers

The majority of the work undertaken evaluating storage potential in South Africa has focussed on saline aquifers.

The storage resource for saline aquifers in South Africa is classified as undiscovered by the SRMS but 17 sites were still logged in the database with potential storage over 10Mt. These were site entries located in the Onshore Algoa, Onshore Gamtoos, Onshore Zululand, Offshore Orange, Offshore East Coast (Durban and Zululand) and Offshore Outeniqua (Bredasdorp, Infanta, Pletmos, Southern Outeniqua) basins. Most of these estimates are "basin play" with the exception of the Durban Basin data obtained from Hicks [16] where data was available at "sequence play" and superseded that from the earlier Viljoen.

In general, the offshore storage potential is considered greater than that in the onshore basins due to more clearly defined reservoir-seal pairs. In particular, the onshore Mesozoic basins carry some risk to containment as seal effectiveness is not proven. In addition, the Karoo basin is the largest defined geological basin (covering more than 60% of South Africa) is not a suitable storage resource due to the lack of permeability and porosity [10].

3.5 Regulatory Framework

South Africa has been evaluated under the 2018 GCCSI CCS readiness index [15]. However, there are no CCS-specific regulatory or legal frameworks that could directly assist a project in

South Africa.

As of 2020, Countries in the Middle East and Africa have again received assessment scores at the lower end of the spectrum, highlighting once more that their legal regimes include only a few CCS-specific or existing laws that are applicable across parts of the CCS project lifecycle. South Africa has no CCS-specific regulatory system.

3.5.1 Issues for the Assessment

Lack of dynamic modelling and ready access to site-specific data was the main issue for this assessment cycle. Since 2010, South Africa has undertaken several country-wide evaluations of storage potential however some of the detail of these is not readily accessible in the public domain or has been undertaken at a high level, at basin scale. This means that the Catalogue risks a significant under or overestimation of storage potential, or at a minimum a poor representation, of the details of the available resource and more work is required.

3.6 Future Updates

3.6.1 Future CSRC Cycles

Should any further development in the South Africa storage systems occur, this should be reviewed on an annual basis to ensure the Global Storage Catalogue is up to date.

If access to the Parsons Brinkerhoff report used in the Alderson presentation becomes available, any additional detail should be used to update, and potentially mature the site entries in the Catalogue.

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