CO_2 Storage Resource Catalogue

Cycle 5 Report

AMERICAS

August 2025

OIL AND GAS CLIMATE INITIATIVE

GLOBAL CCS INSTITUTE

HALLIBURTON

International Association of Oil & Gas Producers

Amounts of CO_2

Stored
0.021 Gigatonnes

Commercial
0.053 Gigatonnes

Sub-commercial
433 Gigatonnes

Undiscovered
7927 Gigatonnes

Appendix A : The Americas

Argentina, Belize, Bolivia, Brazil, Canada, Caribbean Island Countries, Chile, Costa Rica, Cuba, Colombia Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, United Staes of America, Venezuela

Document Summary			
Client	Oil and Gas Climate Initiative (OGCI)		
Title:	CO_2 Storage Resource Catalogue – Appendix A: The Americas		
Distribution:	OGCI, GCCSI, Halliburton	**Classification:**	Public
Date of Issue:	20/08/2025		
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Important notice

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1 Argentina

1.1 Summary

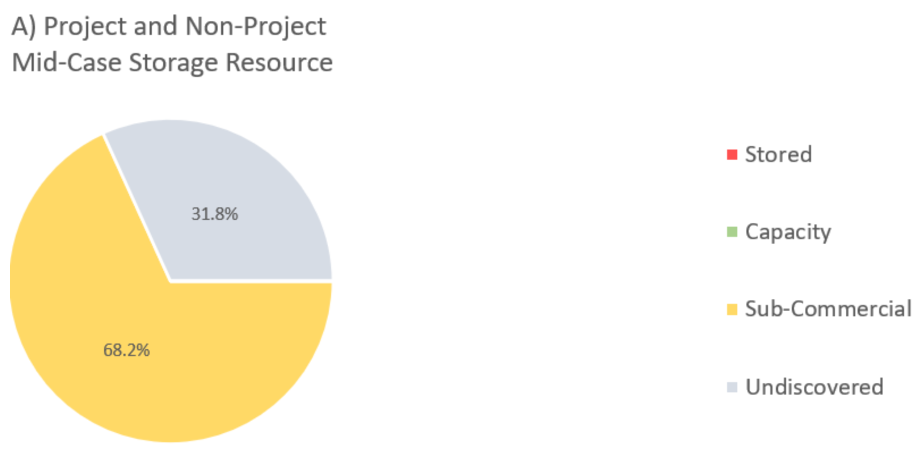
Argentina was assessed during Cycle 5 and storage resources were found to be predominately within the Neuquén and San Jorge Basins. The CSRC has identified a CO_2 storage resource for Argentina as follows:

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	9.789	0.000
Undiscovered	4.566	0.000
Aggregated*	14.355	0.000

* 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 Argentina.

Table 1-1: Storage resource classification summary for Argentina.

- Research on Argentina has been mainly academic.
- There is one saline aquifer storage site and three depleted field storage sites.
- Three sites (one saline aquifer and two depleted fields) are within the Neuquén Basin and one depleted field storage site within the San Jorge Basins giving a cumulative storage potential of 14,4355 Mt.
- Two of the storage sites are a country-wide summary, and do not detail methodology, site breakdown or any properties associated with the geology.
- Currently Argentina has no regulations for CCUS technologies, however it is supportive of CCS and recognizes it as an important energy technology in its energy strategy.



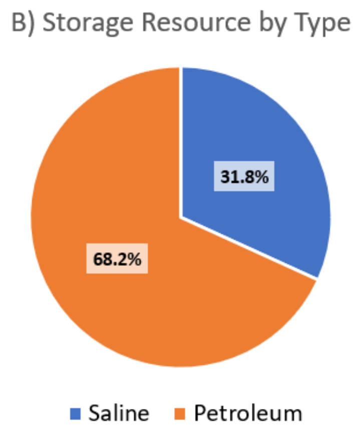


Figure 1-1: Argentina's spread of Storage Sites.

*Note: None of the Argentina's sites have an associated project specified.

A) Spread of storage resource in all Argentina's sites across SRMS classifications; both project specified and not. B) Split of Argentine's storage resources between saline aquifers and hydrocarbon fields, (include both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

1.2 Resource Statement

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

Graph above is log scale and graph below is linear. No project specified sites were identified.

1.3 Evaluation History

Argentina's storage resources were reviewed during Cycle 5. The assessment draws from two documents providing CO_2 storage resource potential for depleted fields and a saline aquifer with the Neuquén and San Jorge basins.

The first is a long-term energy prospective modeling report for South America by Postic, 2015 [1]. This thesis report includes a country-wide cumulative storage capacity for T-ALyC carbon storage options for South American countries including for Argentina; deep saline aquifers (4,566 Mt), storage in depleted field (9,389 Mt), enhanced oil recovery (2,863 Mt), enhance coalbed methane recovery (301Mt), curbing deforestation (1Mt) and afforestation/reforestation (1,561 Mt). Only depleted fields and saline aquifers have been recorded in the database. The table uses the Integrated Markal-EFOM System TIMES for South America and the Caribbean cumulative storage capacity. The TIMES model generator was developed as part of the IEA-ETSAP's methodology for energy scenarios to conduct in-depth energy and environmental analyses [2].

The second is the Atlas AR-CO_2, an Argentinean atlas for underground CO_2 storage potential by Grasetti et al., 2022 [3]. Oil and gas fields within the limits of the Neuquén and San Golfo Jorge basins were analyzed, considering each stratigraphic unit in the location of each field. The potential CO_2 storage sites are pairs composed of a stratigraphic unit and an associated hydrocarbon field and have been recorded in the database as depleted fields. With the Neuquén and Golfo San Jorge Basins being most important hydrocarbon producers in the country, they have the advantage of being extensively studied and developed, with proven seal structures, surface facilities, and transport lines.

1.4 Resource Review

Argentina has one saline aquifer storage site and three depleted field sites.

1.4.1 Major Projects

Wintershall Dea, YPF (Argentina's national energy company) and Dow (a global materials science leader), signed a Memorandum of Understanding (MoU) to jointly assess potential carbon capture and storage opportunities in Argentina [4]. The proximity to the industrial cluster with its CO_2 emissions in Bahía Blanca could also facilitate the production of natural gas-based, low-carbon hydrogen.

1.4.2 Depleted Oil & Gas Fields

There are very limited details in Postic's study providing a country-wide CO2 storage resource of 9,389 Mt [1]. Storage capacity methodology is undefined but assumed O&G replacement volume.

Within Grasetti et al. [3], the effective capacity for CO_2 storage of the different candidate sites was calculated using the volumetric method introduced by the Department of Energy of the

United States (USDOE) [5]. These values together with the author selected criteria allowed the ranking of candidates. Calculations in the study used CO_2-SCREEN, an open tool provided by the USDOE, and adopted the P50 as an estimate of the CO_2 storage capacity. The study has provided a breakdown of CO_2 storage by formation, but the resource has been classified as an Undiscovered – Basin Play, as the Carbon Storage Resource Catalogue does not infer information from graphs. This gives a value of 100 Mt for the Neuquén Basin and 300 Mt for the San Jorge Basin. Classification of these sites is Discovered as the Neuquén and Golfo San Jorge Basins are prolific hydrocarbon producers. The values are classified as inaccessible in the absence of any regulatory information that permits CO_2 storage.

A study of the Claromecó Basin Tunas and Bonete Formation coal beds was also made, excluded from the database.

1.4.3 Saline Aquifers

With very limited details given, Postic's country-wide value for Argentina's deep saline aquifers at 4,566 Mt is assumed to be a theoretical volumetric capacity. Classified as inaccessible in an absence of any regulatory information that permits CO_2 storage.

1.5 Regulatory Framework

The energy sector is the largest contributor (63%) to Argentina's greenhouse gas emissions [6]. Currently, Argentina has no regulations for CCUS technologies, however it is supportive of CCS and recognizes it as an important energy technology in its energy strategy. Private companies operating in the hydrocarbon and industrial sectors are starting to implement CCS technologies as part of their sustainability programs, however this remains basically related to enhanced oil recovery (EOR) to make it economically viable.

1.5.1 Issues for the Assessment

Postic's study [1] gives very few details on the study assessment. Grasetti et al. [3] assessment has considered the theoretical pore space as empty. It does not take residual hydrocarbons within the hydrocarbon fields into account, and the impact that they would have on pore space, into the assessment of CO_2 storage. Therefore, the numbers provided should be considered an overestimate.

1.6 Future Updates

1.6.1 Future evaluations

Any future updates should include information on Argentina's regulatory stance on geological CO_2 storage and the updates to MOU projects.

2 Belize

2.1 Summary

Belize was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Belize.

Table 2-1: Storage resource classification summary for Belize.

2.2 Evaluation History

There are no published reports or research to support that Belize has been investigating geological storage of CO_2. Belize has a small hydrocarbon industry with main fields located in the central western area of the country. Future depleted fields may be available for CO_2 storage but nothing is reported on this potential. In terms of saline aquifers, Belize features two primary sedimentary basins: the Corozal Basin in the north and the Belize Basin in the south. Both basins have thick sedimentary sequences which could indicate that there are formations at depths suitable for super critical CO_2 storage. The remote and challenging terrain of the basins will render them challenging for any potential storage development, however. Belize has a climate strategy that prefers carbon sequestration via nature-based solutions such as mangrove restoration and protection of seagrass habitats [1].

2.3 Regulatory Framework

Belize does not currently have any regulatory framework for geological CCS.

2.4 Future CRSC Cycles

Due to Belize's preferred route for decarbonisation through nature-based solution, future updates are unlikely to be necessary unless future depleted fields are repurposed for storage.

3 Bolivia

3.1 Summary

Bolivia was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Bolivia.

Table 3-1: Storage resource classification summary for Bolivia.

3.2 Evaluation History

There are no published reports or research to support that Bolivia has is investigating geological storage of CO_2. Bolivia does have a hydrocarbon industry, mainly centred around natural gas, so in the future may have depleted fields that could be considered for CO_2 storage. The key basins include the Altiplano, Chaco, and Subandean basins. Aside from depleted fields, there may be potential for saline aquifer storage but to date there is no research related to this. The Anitplano has very thick sequences of Tertiary sediments and the Chaco contains over 6000m of Devonian to Cenozoic sediments, potentially indicating both basins have reservoirs at suitable depths for supercritical CO_2 storage. Bolivia's climate strategy for carbon sequestration is via nature-based solutions such as an increase in native vegetation, conservation of biodiversity and increase reforestation [1].

3.3 Regulatory Framework

Bolivia does not currently have any regulatory framework for geological CCS.

3.4 Future Updates

Based on the Bolivia's preference for biological capture, future updates are unlikely to be necessary. Reviews on any use of future depleted reservoirs may be worth investigating.

4 Brazil

4.1 Summary

Brazil was assessed during Cycle 1 and was not updated in Cycle 2 or Cycle 3 or 4. The CSRC identified a CO_2 storage resource for Brazil as follows:

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.001	0.000
Capacity	0.000	0.000
Sub-Commercial	2.469	0.000
Undiscovered	0.000	0.000
Aggregated*	2.470	0.000

* 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 Brazil.

Table 4-1: Storage resource classification summary for Brazil.

- The aggregated storage potential in Brazil is 2.47 Gt and is entirely held within oil and gas fields. These are classified as Discovered but Inaccessible due to the lack of cessation of production dates, an EAD date, or a CCS specific regulatory and legal framework.
- The CSRC has identified 17 oil and gas fields in the Campos Basin with a storage potential evaluation, plus the summed evaluation of hydrocarbon fields in a further 10 geological basins.

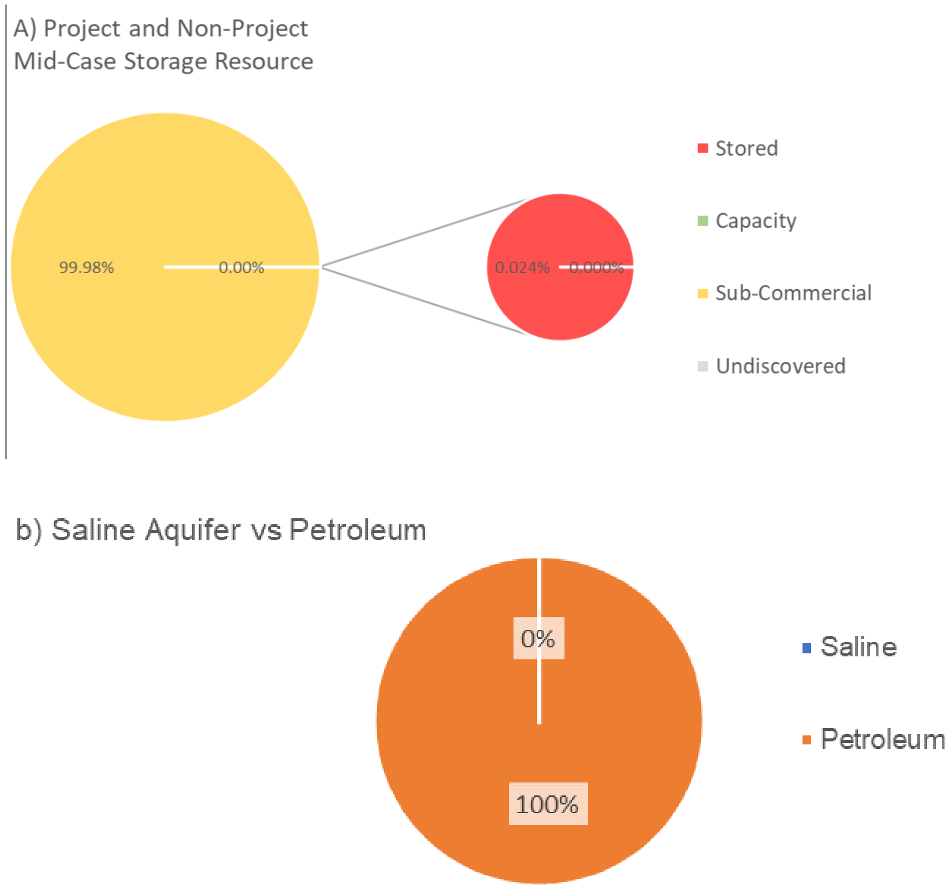


Figure 4-1: Brazilian spread of Storage Sites.

*Note: None of the Brazilian sites have an associated project specified.

a) Spread of storage resource in all Brazilian sites (28) across SRMS classifications. b) Split of Brazilian storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

4.2 Resource Statement

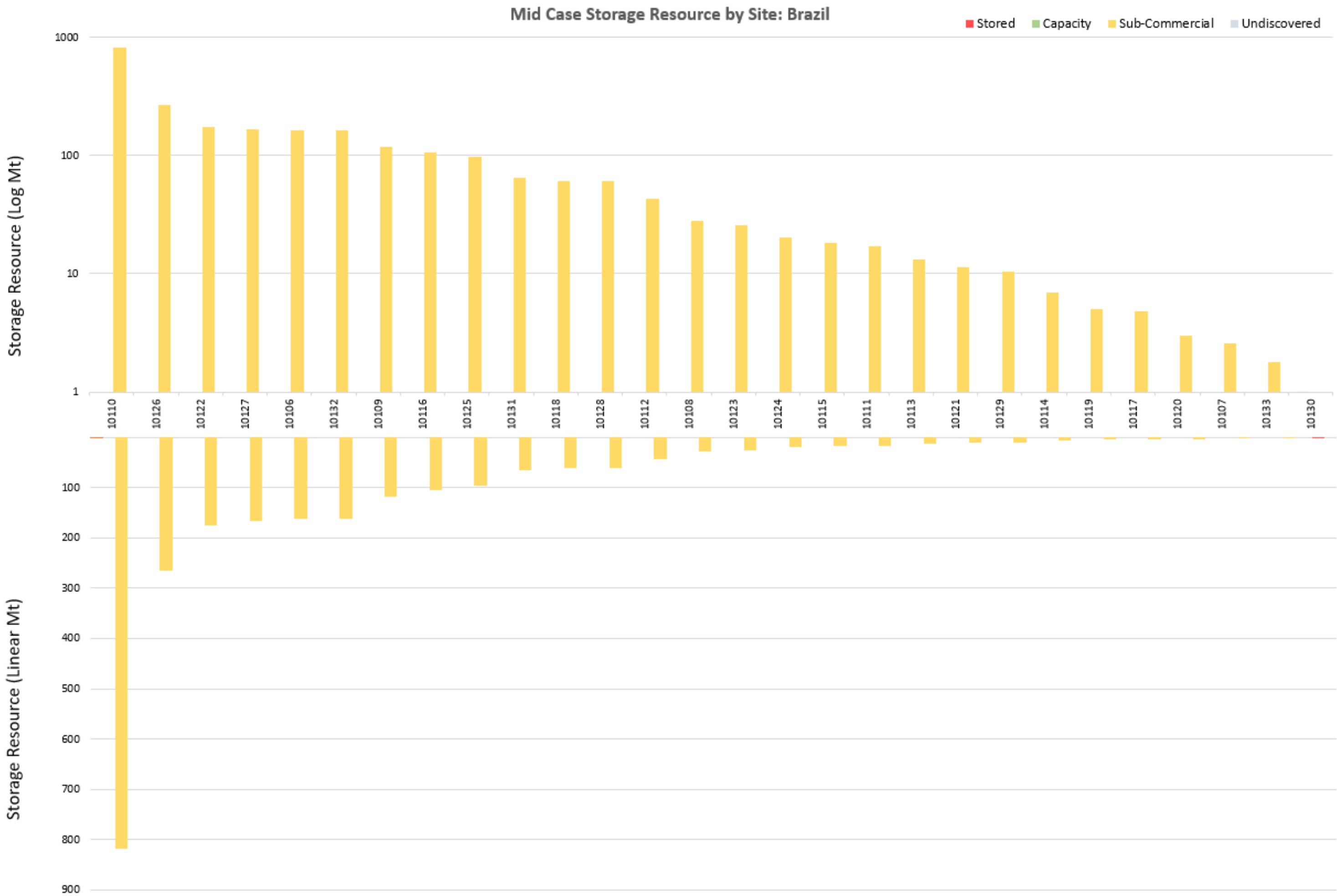


Figure 4-2: Storage resource summary for Brazil compiled in the CSRC.

Graph above is log scale and graph below is linear. No project specified sites were identified.

4.3 Evaluation History

Brazil's storage resources were reviewed, and a preliminary assessment carried out, during Cycle 1. The assessment draws from three documents which currently provide the only information on CO_2 storage resource potential in Brazil.

The first is the 2016 Brazilian Atlas of Carbon Capture and Storage. This document is based on research by the Centre of Excellence in Research and Innovation in Petroleum, Mineral Resources and Carbon Storage (CEPAC) and was funded by the Global Carbon Capture and Storage Institute (GCCSI). The Brazilian Atlas evaluated the storage potential in oil and gas fields, both onshore and offshore, however quantitative evaluations were only available for fields in the Campos Basin. In addition, coalfields and basalts were evaluated but do not form part of this assessment [1].

The second is the Brazilian Carbon Geological Sequestration Map (CARBMAP) Project [2], an effort to create a geographic information system (GIS) to facilitate matching of CO_2 sources and sinks. Here the storage potential of Brazilian oil and gas fields in 11 basins was evaluated using the hydrocarbon reserve volumes.

The final source, published in 2013, evaluated the storage potential in 17 of approximately 50 hydrocarbon fields in the Campos Basin, using a voidage replacement method by Bachu et al. (2007) [3].

4.4 Resource Review

4.4.1 Major Projects

No major carbon storage projects were identified that could be assessed against the SRMS, during Cycle 1. The presalt oilfields in the Campos and Santos offshore basins contain high levels (8-12%) CO_2 in the produced fluids (Iglesias et al., 2014). Petrobras operate an active project which captures CO_2 from the hydrocarbon processing facilities and re-injects the CO_2 into the supergiant Lula field in the Santos Basin. This operation is utilising a 'hub and cluster' development which, uniquely, deploys 10 FSPO's. The primary focus is on CO_2-EOR however the reported aim is to cumulatively inject 40 Mt by 2025. By January 2019, 10 Mt had successfully been injected. Future assessments should re-visit this operation.

4.4.2 Depleted Oil & Gas Fields

The Campos region potential storage resource is estimated to be 0.95 Gt [3] but the published resource only represents a subset of 17 fields out of 50 in the basin and excludes the large pre-salt oilfields.

The CARBMAP Project identified a further 1.52 Gt in hydrocarbon fields across Campos and a further 10 basins [2].

All storage resources are classified as Discovered since they are oil and gas fields, however the absence of both a Cessation of Production (COP) date, or an EAD, indicating when the resource may become accessible for CO_2 injection, and the lack of a CCS-specific regulatory system limits them to "Inaccessible Storage Resources". It should be noted that even though a CCS regulatory framework is lacking, CO_2 continues to be injected underground for enhanced oil recovery under the existing petroleum regulatory system. For example, in the Reconcavo Basin, a CO_2 storage pilot project, has evaluated the impact of 20 years CO_2 injection into the onshore Buracica oilfield where a small 600,000t inventory has been injected for enhanced oil recovery [1].

4.4.3 Saline Aquifers

The CSRC found no specific published details of CO_2 storage potential in saline aquifers. A 2009 pilot project in which 12,000 t CO_2 was injected into the Rio Pojuca saline aquifer represents the only reported carbon storage [4].

4.5 Regulatory Framework

Brazil is classed as a 'moderately performing' nation by the 2018 GCCSI CCS Readiness Index with moderate scores for both CCS Readiness and Inherent Interest. Although Brazil's energy mix is 90% renewables, due to a large share of hydropower in the country, it is supportive of CCS and recognizes it as an important energy technology in its energy strategy. The government National Energy Plan 2030 was issued in 2007 and identifies CCS technology as one of the tools to reduce CO_2 emissions from fossil fuels. CCS is also recognized as a technology capable of boosting Brazil's energy security. As of May 2024, Brazil's Ministry of Mines and Energy approved a bill (Bill 1425/2022) which is aimed at building a legislative framework for CCS development in the country. This is exemplified by the Santos Basin CCS facility which has developed into a commercial-scale operation through implementation of CO_2-EOR, not carbon storage.

4.5.1 Issues for the Assessment

Both the Brazil Atlas and CARBMAP provide an early high-level overview of the potential storage resource and links basins to emissions centres to minimise transportation burden. However, the overall resource potential remains unquantified due to the lack of saline aquifer storage resource, and as such, the CSRC is significantly incomplete with regards to the classification.

4.6 Future Updates

4.6.1 Future evaluations

Future evaluations should focus on the potential for saline aquifer storage which is likely to be significant but is not represented currently in the CSRC. As the Pre-salt operations develop in the Campos and Santos offshore basins, additional resource potential may be identified. As regulatory developments progress, an update of Brazil's storage resources from Inaccessible to a more mature commercial classification should be undertaken.

5 Canada

5.1 Summary

The CSRC has identified the following CO_2 storage resource for Canada. It has been updated in Cycle 2, Cycle 3, 4 and 5 to reflect continued injection of CO_2 in active projects.

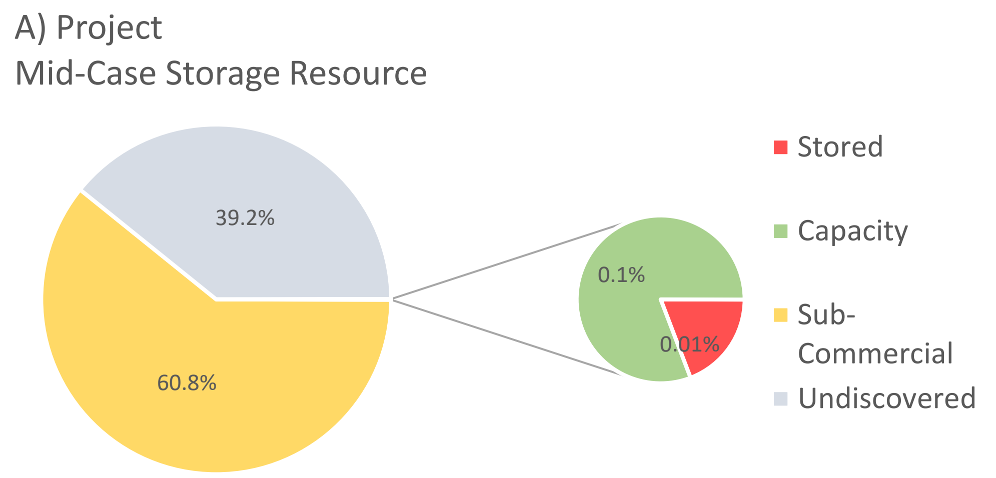
Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.012	0.012
Capacity	0.053	0.053
Sub-Commercial	43.641	6.169
Undiscovered	104.300	24.600
Aggregated*	148.006	30.833

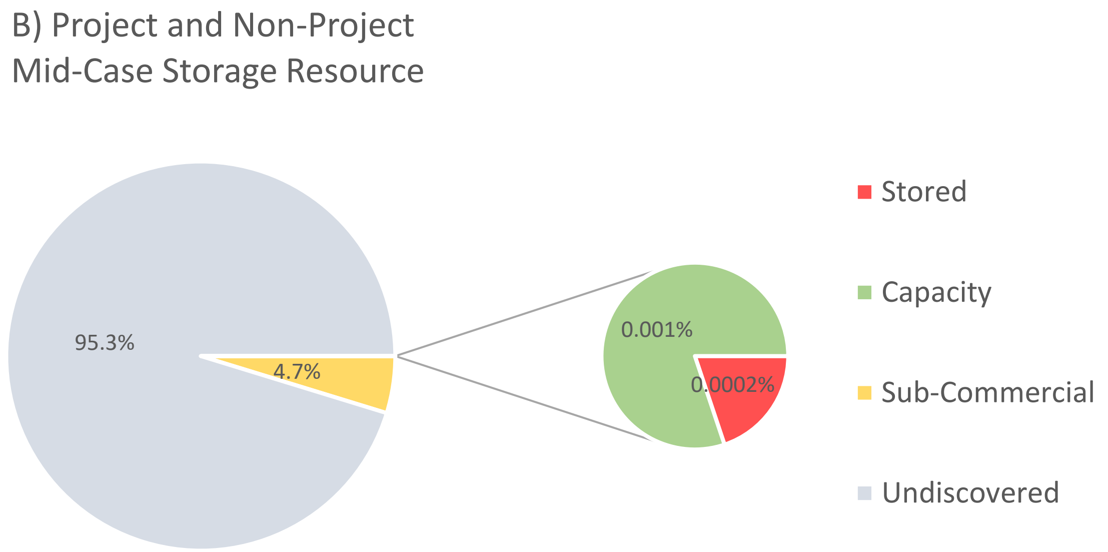
* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Canada.

Table 5-1: Storage resource classification summary for Canada.

- Storage resource potential is present in both saline aquifers and oil and gas fields.
- Potential storage resource has been identified in 4 geological basins with 67 sites or regional locations identified.
- Altogether, 11 projects have been defined. High level, province-scale resource estimates are also included in the Assessment for those provinces where a more detailed break-down of the storage resource is unavailable.
- As of May 2024, 8.2 Mt of CO_2 has been reported injected and stored by two CCS projects operating in Canada: Quest (7.7 Mt) and Aquistore (0.5 Mt).
- Five site characterisation projects have been undertaken over the past decade, but these have not been progressed since completion.
- Most published information on potential storage resource is geographically centred on the provinces of Alberta and Saskatchewan within the Western Canada Sedimentary and Williston basins, with additional potential identified in British Columbia, Ontario, and Quebec. The current regulatory system is moving towards a CCS specific framework with most progress at the provincial level. Alberta and Saskatchewan have both approved CO_2 injection legislation to support the active Quest and Aquistore projects.
- There are currently no well-publicised plans for any future large-scale CCS project in the pipeline, although opportunity exists with the Alberta Trunk Line (ACTL) CO_2 pipeline project. This 240km pipeline, capable of transporting up to 14.6 Mt CO_2/annum across Alberta, became operational in June 2020.

- A significant update to Cycle 4 has been ammendement to the Basal Sandstone record (Cambro-Ord Saline System (COSS)). Recent research [14] on this aquifer considered its resource potential from a notional project perspective. By considering the pressure response from injection this effectively halved the storage resource of this site. This research has not only made significant changes to the whole Basal Sand aquifer resource estimate but has consequentially revised the aggregated estimate for all of Canada. At cycle 3 the aggregated estimate was around 404 Gt. The revised study to the vast resources in the Cambro-Ord Saline System (COSS) has now changes the aggregated resource for Canada to 148 Gt. Discussion on this project is in section 2.4.5 *Basal Sandstone Aquifers.*


A) Project
Mid-Case Storage Resource
39.2%
60.8%
0.1%
0.01%
Stored
Capacity
Sub-Commercial
Undiscovered


B) Project and Non-Project
Mid-Case Storage Resource
95.3%
4.7%
0.001%
0.0002%
Stored
Capacity
Sub-Commercial
Undiscovered

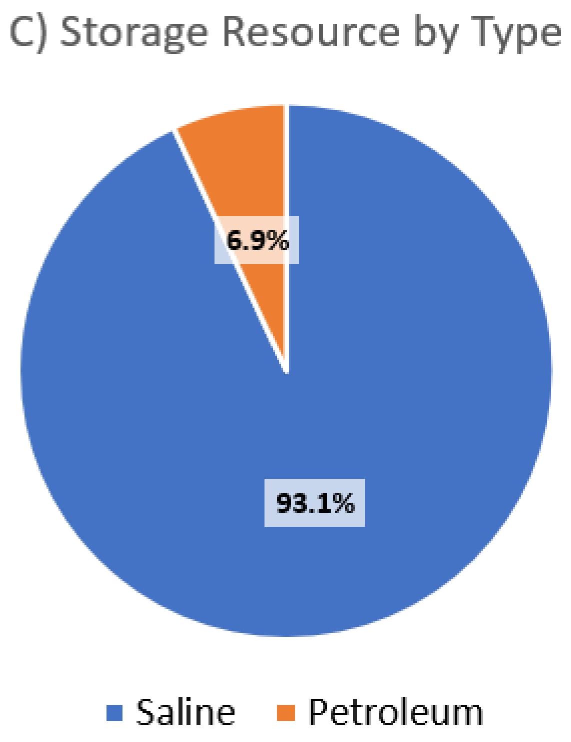


Figure 5-1: Canadian spread of Storage Sites.

A) Spread of storage resource in Canadian sites (67) across SRMS classifications, where a project has been specified. B) Spread of storage resource in all Canadian sites across SRMS classifications; both project specified and not. C) Split of Canadian storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

5.2 Resource Statement

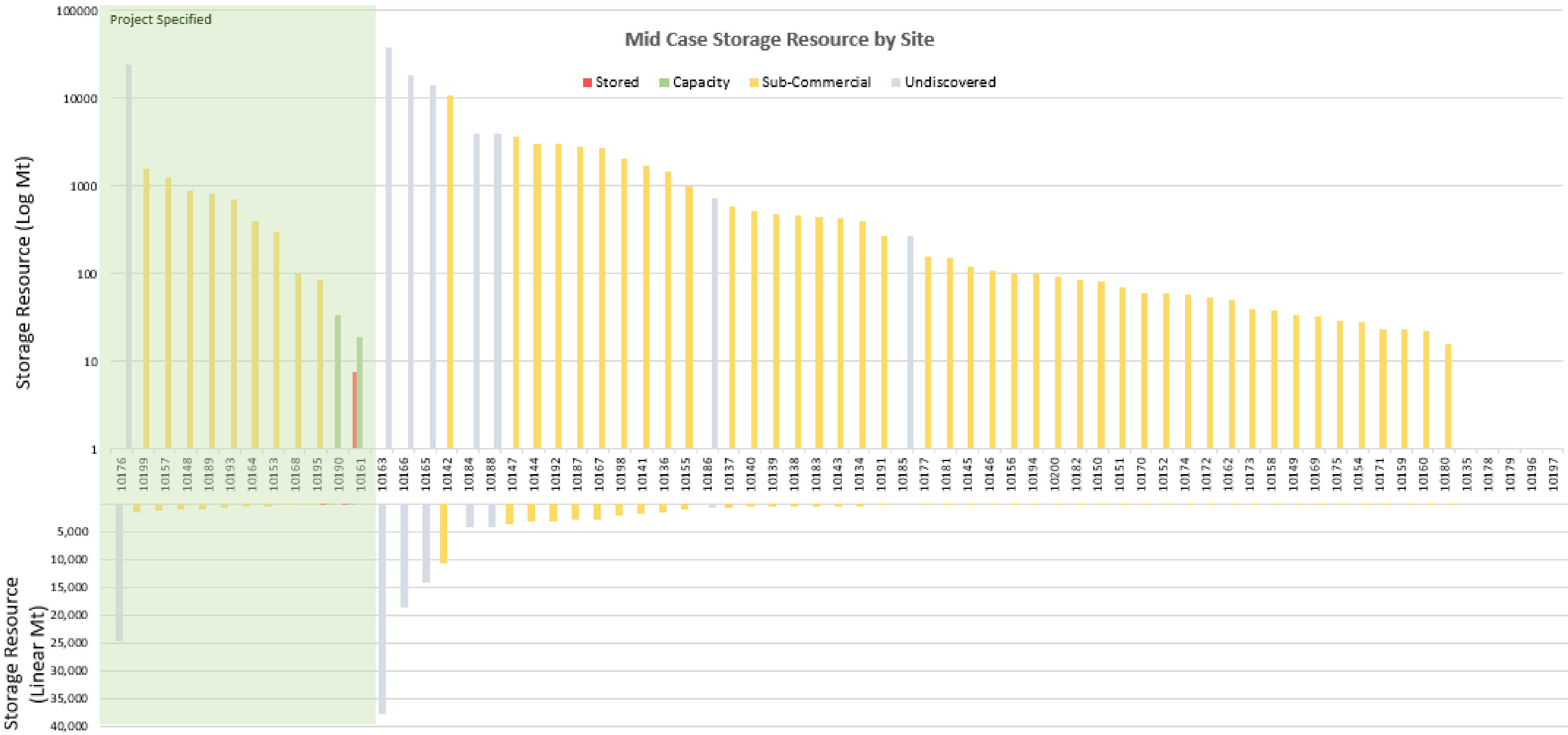


Figure 5-2: Storage resource summary for Canda compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

5.3 Evaluation History

Canada was selected as the priority country for review during the Cycle 1 Assessment. The approach taken was to review the published national and regional evaluations of storage potential, followed by a more detailed study of specific projects at the basin and local scale. As a starting point, both the North American Carbon Storage Atlas [5] and the 2015 DOE Atlas V [6] were used to derive high level estimates of the storage resource at the Country and Province level. US-DOE-funded projects, through the Regional Carbon Sequestration Partnerships (specifically the Plains CO_2 Reduction Partnership; PCOR), provided additional data and information. The storage potential in unmineable coals seams (Enhanced Coalbed Methane, or ECBM), basalt deposits, and organic-rich shale units has also been investigated by both the country-level atlases and the regional studies, but has not been included in this Assessment, as these resource types do not fall within the current SRMS.

5.4 Resource Review

5.4.1 Major Projects

In 2006, Canada's National Round Table on the Environment and Energy, a now defunct independent advisory board to the Canadian Government, reported that CCS technology had the potential to offer up to 40% of the required reductions in CO_2 emissions in Canada. In the following decade, various task forces created a case for CCS implementation in Canada, leading to over $3 billion in government and provincial support for CCS through a range of programs. As a result, several large-scale CCS demonstration projects, designed to inject at least 1 Mt CO_2/ year, were advanced. These included:

- Boundary Dam Carbon Capture project: a coal-fired electricity-generation project (SaskPower, Saskatchewan).
- Alberta Carbon Trunk Line (ACTL): a CO_2 pipeline project (Enhance Energy, Alberta).
- Quest CCS: Scotford oil sands upgrader (Shell, Alberta).
- Pioneer project: coal-fired electricity generation (TransAlta, Alberta).
- Swan Hills project: underground coal gasification and syn-gas electricity generation (Alberta).
- Fort Nelson CCS: shale gas processing plant (Spectra Energy, NE British Columbia).
- Weyburn: commercial CO_2 -EOR (Whitecap Resources (formerly owned by Cenovus Energy), Saskatchewan).
- Midale: commercial CO_2-EOR (Apache Energy, Saskatchewan).

Of these, only Boundary Dam, Quest, and Weyburn-Midale are actively either capturing or injecting CO_2; albeit predominantly for EOR, using CO_2 captured from the Boundary Dam site, or piping CO_2 from the Dakota Gasification syn-fuels plant in North Dakota (Weyburn-Midale fields).

As of the Cycle 2 Assessment, only the Quest CCS project (5 Mt by mid-2020) and the Aquistore project (325,000t by October 2020), which acts as a 'overflow' store for CO_2 captured at Boundary Dam, are currently injecting CO_2 into saline aquifers as part of fully integrated and monitored CCS projects. The Fort Nelson project completed initial site characterisation studies and is currently on-hold. The Pioneer CC project collapsed in 2012 for economic reasons related to the absence of either a national carbon trading market, or a method for capturing value from emissions credits. Swan Hills Syn-Fuels ran a demonstration project (the ISCG project) in 2009 but has since shifted the company focus.

5.4.2 Site Studies

Several saline aquifer site characterisation projects were carried out during the period 2004 – 2014. These attempted to identify or technically progress potential storage sites:

- WASP
- HARP
- Athabasca area
- St Lawrence Lowlands basin, Quebec (Becancour project)
- Michigan Basin, Ontario
- PCOR (Plains CO_2 Reduction Partnership Basal Cambrian System

These are included in the Cycle 1 assessment.

5.4.3 Application of the SRMS in North America

National atlases [6] and [5] have been used as a starting point for reviewing the resource potential of Canada and the USA. These publications report state-wide or province-wide resource estimates for USA and Canada. These estimates are generally large numbers for which there is no detail explaining source or geographic distribution of the data inputs. Both atlases do, however, provide an explanation of how the resource estimate was calculated, including providing low/mid/high values for the storage efficiency factors applied to saline aquifers.

The Cycle 1 used the 2015 DOE Atlas V [6] resource estimates in preference to the earlier 2012 NASCA [5] data. According to the Atlas V, the data presented is derived from the DOE-funded Regional Carbon Sequestration Partnerships. These partnerships have distinct study areas which are defined by geological basins, i.e., not state or province boundaries, and therefore there is often no clear alignment between the state and province-level reporting by the Atlases, and the Regional Partnership evaluation reports.

The CSRC Cycle 1 reviewed studies undertaken by the PCOR and Big Sky Regional Partnerships. The PCOR study area crosses the USA/Canada national boundary and covers those parts of British Columbia Alberta, Saskatchewan and Manitoba which sit within the Alberta and Williston basins. The partnerships also include several USA states: Montana (North-Central and Williston Basin), North Dakota, South Dakota, NE Wyoming (Powder River Basin) and NW Nebraska (Denver Basin).

For saline aquifers, the Regional Partnerships provide two levels of storage resource evaluation: DOE Phase I and II studies which provide high level resource estimates at the formation-level, and DOE Phase III studies which evaluated specific sites as detailed site characterisation studies or demonstration projects. As per the SRMS guidelines, formation level resource estimates have been classified as Undiscovered: Prospective Sequence Play due to the generally large area covered by the resource, and the lower level of confidence in the resource estimate. Site specific or demonstration studies have been classified as Discovered and then further classified based on their level of development (e.g., Not Viable).

These saline aquifer resource evaluations have been handled according to the level of published data available:

1. Where the Sequence Play resource estimates are considered to fully represent the State- or Provincewide resource estimate provided by the Atlas V, the CSRC Cycle 1 has nulled the State- or Province-wide resource estimate and a note has been attached to the assessment.

2. Where there is insufficient data available to fully supersede the State- or Province-wide resource estimate, the Atlas-derived estimate has been held and classified as Undiscovered: Prospective Basin Play.

3. If a resource estimate for a Sequence Play can be shown to only partly contribute to the State- or Province-wide resource estimate, the Sequence Play estimate is subtracted from the Basin Play estimate to avoid double counting within the Undiscovered SRMS maturity class.

4. Where no resource estimate is available in the 2015 DOE Atlas, the 2012 NASCA report has been used (this applies to the eastern Canada provinces which are not covered by the DOE Regional Partnerships).

5. Where storage resource estimates are available and classified as Discovered, the resource estimate has not been subtracted from the Sequence or Basin Play resource estimate to avoid aggregation across SRMS maturity classes. This has been noted in the 2019 Assessment notes for that site.

This approach has highlighted some issues:

- Mismatch of resource estimate values between different Atlases, e.g., the Atlas V estimate is significantly different to the equivalent NASCA estimate. This occurs for both oil and gas fields, and saline aquifers. Where possible the DOE Atlas has been used in preference to the NASCA Atlas to provide consistency of data inputs and volumetric calculations.

- Multiple evaluations of the same saline aquifer formation reporting quite different resource estimates. This is particularly true for the Cambro-Ordovician Basal Sand for which there are 3 different static volumetric estimates which use mid-range storage efficiency factors (E) of 2%, 9.1% and 14%. In this case, preference has been given to estimates derived from 3D static models which use the lower value of E, which here is 9.1% as opposed to 14% (while 14 % is used by PCOR for clastic lithologies where all net-to-gross terms are known [7], a more recent study [8] suggests that on a 50-year injection time-scale values of E greater than 2% may be overly optimistic). The alternative estimates are noted in the Assessment.

- Resource estimates are provided for a geological basin, i.e., they are not sub-divided by federal nation, or state/province. For the Basal Sand, which covers an international boundary, the approach taken is to use a percentage value of the resource estimate derived from a 2D model which did apportion the resource between USA and Canada and apply to the 3D static estimate.

- Aggregated Sequence Play resource estimates for a region do not equal the Basin Play resource estimates for that region. This suggests that either the Basin Play resource estimates contain additional data, which is not apparent from the regional studies available, or that the range of storage efficiency factors applied are quite different. This highlights the need for a consistent approach to storage resource calculation.

- Studies which use a simulation to evaluate the impact of pressure on the storage potential of a formation indicate that the storage resource is up to 1 magnitude lower than the equivalent volumetric estimate. Where this occurs, it is noted in the assessment and the country report and suggests that the volumetric resource estimate is likely to be invalid.

5.4.4 Depleted Oil & Gas Fields

The aggregated depleted field resource identified by the Cycle 1 Assessment is 11.2 Gt. This Sub-commercial resource

is assumed Discovered but is classed as currently Inaccessible due to a lack of information on abandonment dates for the fields. 7.1 Gt storage potential sits within identified oil and gas fields with the remaining 4 Gt derived from high level, province-scale studies which do not provide any level of detail on data source or distribution.

The 2012 NASCA report [5] states that over 50,000 oil and gas reservoirs, plus oil reservoirs with a gas cap, existed at the time of reporting in north-eastern British Columbia, Alberta, Saskatchewan, and Manitoba. Additional fields are also present in Ontario (below Lake Erie), Northwest Territories, and in the Canadian offshore (Nova Scotia and Newfoundland). Twenty-three (23) depleted fields have been included in the Cycle 1 Assessment. Inclusion was based on a few key criteria: a published evaluation of storage potential for an individual field or pool, having greater than 20 Mt reported storage potential, and appearing in a publicly available, searchable reserves database. None of the oil or gas fields in the Cycle 1 Assessment have an abandonment date or an EAD (Earliest Accessibility Date) assigned as the necessary information is not available in the public domain. A significant number of oil fields in Canada are currently, or have previously undergone, secondary or tertiary recovery and are flooded with the water or natural gas injected to enhance oil production, leaving little available pore volume for CO_2. These are typically not included in published storage resource estimates.

Most of the identified storage resource is in oil pools (5.9 Gt) which are located predominantly in Saskatchewan and Manitoba. Oil pool size in Alberta is generally small. Of nearly 8500 oil reservoirs under primary production in 2004 only 98 have a calculated storage resource > 1Mt [9], and only 1 oil pool was identified as having a resource greater than the 20 Mt cut-off applied by this study. Similarly, gas pools in Canada are typically small. Out of nearly 25,800 fields studied in the published literature, only 9 fields in Alberta and 7 in British Columbia qualify for the >20Mt cutoff; Saskatchewan and Manitoba do not contain any identified resource potential in gas fields. The total storage resource reported for gas pools is 1.2 Gt.

Regarding commercial readiness of the depleted field resource identified, no projects with a stated aim of injecting CO_2 directly into depleted fields for storage have been identified. CO_2-EOR is taking place in several locations but these projects and injected volumes do not form part of the SRMS at this stage. At the province level, British Columbia is least commercially mature with most of the stated storage resource sitting within the Undiscovered Province-wide classification.

Additional data included in the SRMS database were taken from online reserves data maintained by each province. In some cases, *e.g.,* Saskatchewan, these publications are not exhaustive and only provide data from a selection of active projects (i.e., high activity, new projects/pools, or changes to existing projects/pools).

5.4.5 Saline Aquifers

Most of the saline aquifer resource (3 Gt; 93%) is within Undiscovered resource, split between Sequence Play (83%) and Basin Play (10%). Sub-commercial resources make up a much smaller proportion (25.6 Gt: 6.6%) of the summed saline storage resource. Storage projects form only 15% (3.9 Gt) of the Sub-commercial resource however the only reported, non-EOR stored CO_2 in Canada is within the Cambro-Ordovician Basal Sand formation saline aquifers at the Quest and Aquistore projects in Alberta and Saskatchewan respectively where a total of 61

Mt is either already Stored or is permitted for injection (On-Injection).

Saline aquifers identified as holding storage potential in Canada include the diachronous Cambro-Ordovician Basal Sand clastic formation in the Williston and Alberta basins, and its temporal equivalent, the Mt Simon Sandstone in Ontario, Devonian carbonates located predominantly within the West Canadian Sedimentary Basin, and the Lower Cretaceous Viking Formation in the Alberta Sub-basin.

In terms of commercial maturity of saline aquifer storage potential, Alberta is significantly more advanced than other provinces, with identified potential resources at several stages of maturity. Saskatchewan is dominated by storage resource estimates for the Basal Sand, but only the Aquistore project is currently demonstrating successful injection. In comparison, British Columbia, Manitoba, and the eastern provinces of Ontario and Quebec contain significantly lower resource volume and are less commercially (and technically) advanced, except for the Fort Nelson CCS site in British Columbia.

Basal Sand Storage Potential. The Cambro-Ord Basal Sand (or Basal Aquifer) is one of the most widely studied aquifers. As such there are several different estimates of storage potential for the unit; all of which use different values for storage efficiency:

- Province-wide estimates of storage potential provided by the DOE Atlas V using a mid-range storage efficiency factor of 2.0%.
- A 2013 PCOR 2D static volumetric estimate which provides a split between the Canadian (75.2%; 85 Mt) and US (24.8%) portions of the Williston and Alberta basins and uses a P50 storage efficiency factor of 2.4%.
- Two (2014 and 2015) PCOR 3D static (geocellular) models for the combined USA & Canada area (373 Mt) which use P50 values for storage efficiency of 9.1% and 14% to calculate a volumetric estimate of storage (note: as discussed above, 14% is considered an unrealistically high storage efficiency factor on a 50-year injection timescale and so is not used in this assessment).
- Two numerical simulation studies which both look at injecting a set volume (63 Mt and 94 Mt) of CO_2 into the Basal Sand over a period of 50 years. Both use the 3D geocellular static model (or equivalent using the same dataset) developed for the 2014 volumetric case. By optimising injection location in areas of highest modelled transmissivity within Saskatchewan and eastern Alberta, the model was able to successfully able to simulate injection of 3100 Mt (63 Mt/year) without exceeding set pressure constraints using 5 injection locations (including the Quest site). It should be noted that the pressure map of the Basal Sand model indicates that there is little pressure space remaining in the high transmissivity areas of the aquifer following injection of this volume of CO_2 and, as such, may represent a near-capacity resource value. The alternative (94 Mt/year) simulation

attempt focussed injection at the Duffield-Warburg power generation facility (Alberta) but only achieved a maximum injected volume of between 298 Mt and 1280 Mt over the 50-year period. Detail is limited in both studies, but it appears from maps of the simulated subsurface pressure increase that the 2 study areas do not overlap as the 63 Mt/year study discarded the Warburg site as it failed to achieve the injection volume of 23 Mt/year set in that model for the Warburg site.

- Active injection operations which target the Basal Sand are currently operating at the Shell Quest CCS project (Alberta) and the Aquistore project (Saskatchewan)

At Cycle 3, the Basal Sand is classified as a Sequence Play (Undiscovered) and assigned a summed storage resource estimate of 75.2% of the 2014 3D static model volumetric calculation (284 Gt). It was noted that this is a very high estimate of storage resource potential given the numerical simulations which achieved almost one order of magnitude lower injection volumes.

The recent publication [14] on a Basal Cambrian site (Cambro-Ord Saline System (COSS)) has made a significant change to the resource estimates for both this site and consequentially the resource estimates for all the Basal Sand project sites. The study evaluated the resource as a notional project by using both a consistent volumetric and flow modelling approach. The notional project had the following specifications: vertical CO_2 injectors with a maximum injection well pressure of 50% above hydrostatic pressure, pressurizing the regional formation by two values during a 50-year injection period without formation water extraction and using maximum injection rate per well of 2 Mt/yr. The project also considered only a single geologic formation (i.e. The Basal Aquifer) and the geographic area north of Canada-United States border. The flow modelling approach used a pressure limit of both 30 and 15%. Comparison of the volumetric approach to the flow modelling approach provided similar results confirming that a volumetric approach can provide a robust first pass approach to storage estimates. Storage efficiencies from a combination of both volumetric and flow modelling results range form 0.46-0.52%. These are considerably lower than previous dynamic storage efficiency estimates that ranged from 7.4- 24% given by [15]. The previous studies did not take into account pressure limitations; either by the assumption that storage would continue for much longer than reasonable timescales (i.e. above a realistic injection period of ~50 years) or the assumption that pressure can be reduced by large-scale formation water extraction. The results of this study by [14] provided a base case estimate of 18.6 Gt, a mid-case of 24.6 Gt and a high case of 32.0 Gt for the Cambro-Ord Saline System (COSS). For the mid case this is 256 Gt less than estimates by [15] as cited in Cycle 3. These studies demonstrate the importance of having a project-based approach to resource calculations to provide a more realistic insight into resources based on potential project parameters, but also the significant effects that pressure limitations can have on a resource.

The Basal Sand project sites are classed as Discovered Sub-commercial: Contingent (Development Not Viable) resources for those where no current project evaluation is occurring, or Commercial: Capacity (Stored or On Injection) where CO_2 injection is taking place or permitted. By carrying the Prospective, Contingent and Capacity resource estimates in the database, there is a degree of 'double counting', however this to date only amounts to 6500 Mt (6.5 Gt). It also raises the question of whether any credence should be given to the static volumetric resource estimate given the issue of available pressure space for a 50-year injection project.

Devonian Aquifers Potential. The mid-upper Devonian section of the foreland basin is best developed in the Alberta sub-basin of the West Canadian Sedimentary Basin. At the basin scale, the section has been evaluated by the PCOR group with a summed storage resource of 14.2 Gt. The Devonian aquifers have also been targeted by several studies including the Athabasca area identifying possible storage resource associated with the oil sands operations in the area, large reefal build-up structures (HARP) and regional carbonates (WASP).

Lower Cretaceous Aquifer Potential: The Viking Formation, which sits within the Alberta Basin, has been evaluated by PCOR as having some storage resource potential. No storage projects have been identified within the formation.

The Cycle 1 Assessment carried an assumption that the DOE Atlas V (2015) province-wide estimates for saline aquifers represent the sum of any reported regional evaluations (e.g., by PCOR). As per the discussion in Sections 3.2-3.6, the SRMS entries at the province-level for Alberta, Saskatchewan and Manitoba have therefore been assigned a null value.

5.5 Regulatory Framework

Canada is the top-ranking nation in the GCCSI CCS Readiness index, meaning that it has been identified as a leader in promoting and deploying CCS. It is only lacking a strong policy to help drive investment for rapid deployment on a commercial scale. The regulatory competence for developing CCS legislation in Canada is shared between several national and provincial bodies. Regulatory development, in the form of design and implementation of CCS-specific legislation, has principally occurred at the provincial level in Canada. Several provinces have undertaken reviews and scoping studies to consider their existing regimes potential to manage CCS activities and, in some instances, this has resulted in the promotion of CCS-specific frameworks. The provincial governments of Alberta, Saskatchewan, and Nova Scotia have all made attempts towards the deployment of CCS-specific legislation in recent years, however it is the province of Alberta that has developed the most comprehensive CCS-specific model.

5.6 Issues for the Assessment

5.6.1 Data Validation

While the 2012 NASCA [5] report provides a useful early snapshot of storage resource potential in Canada, it has been superseded by province-wide resource statements published in the 2015 DOE Atlas V. In addition, the NASCA Viewer and website which provided web-based access to all NASCA data is no longer live. Information is provided on the method of calculation of storage potential in both reports, however there is little to no supporting detail as to the source of the data. However, the DOE Atlas also has significant shortcomings for application to the SRMS. The data presented as state-wide storable quantities are derived from studies carried out by the DOE Regional Partnerships. For Canada, this only includes information from the PCOR group (the WestCarb group does not appear to have published any studies for the west coast of Canada). For example, PCOR studies provide back-up for the overall,

basin-wide storage potential reported for the Cambro-Ord Basal Sand, but this not reported at the province-level.

5.6.2 Probabilistic Assessments

The data available for the Cycle 1 Assessment suffer from a lack of probabilistic analysis; most studies do not provide a range of estimates of storage resource. For studies which provide a storage resource estimate derived from a volumetric methodology, a range of storage efficiency factors may be used but these are applied to a single static model pore volume. Numerical simulations are rarely available for the sites reviewed by this report, and often only give a single storage resource value, assessing whether the site meets the stated benchmark resource.

Projects (sites with dynamic simulations which specify an injection volume and a development plan) may only report a single 'base case' resource value. At the only actively injecting projects, Quest and Aquistore, the resource classified as Stored or On-Injection refers to the permitted injection volume, not the maximum storage potential which is not reported.

5.6.3 National Atlas Data Discrepancy

There is a significant discrepancy between the storage resource figures provided in the 2015 DOE Atlas V and the 2012 NASCA report. For example, the Alberta saline aquifer storage resource in the NASCA report is given as 28 Gt, but the DOE report gives a mid-estimate value of 76.74 Gt, over 2x greater. Similarly, the values for Saskatchewan saline aquifer storage vary between 75 Gt in the NASCA report but greatly increase to 285.22 Gt (mid estimate; 149.72 Gt as the low estimate) in the DOE report.

The discrepancies cannot be wholly attributed to differing methodologies for calculating storage resource as both studies use the same volumetric equation and efficiency factors for saline aquifers. Discussion with the DOE-NETL team responsible for generating the Atlas V numbers suggests that the regional PCOR study data are not included in the NASCA numbers, as NASCA Canada generated their own estimates. It is suggested here that any figure for saline aquifers derived from the 2012 NASCA study should be considered a low estimate for those provinces which are covered by the DOE Regional partnerships.

By contrast, the depleted field storage resource estimates are higher (for each province) in the NASCA report relative to the DOE Atlas, for example, the Alberta depleted field resource is 12 Gt in NASCA but only 1.49 Gt in the DOE Atlas. The reasons for the discrepancies are not clear, NASCA states that the CSLF approach of using original oil or gas in place plus a recovery factor (and an efficiency factor based on local experience or simulations) was applied. The DOE Atlas applied two methods depending on the available data. Either an efficiency factor to convert produced volumes to CO_2 storage volumes, or a straight replacement (on volume-for-volume basis) of hydrocarbon by CO_2 was used [6]. Given the fact that only 3 years separates the publication of each report, the difference in values for storage resource at the province-scale should be used with caution.

In all cases, the 2015 DOE Atlas V data are used in preference to the 2012 NASCA data as they are the most recent storage estimate available. NASCA data are used if the Atlas V does not report for a province (this mainly applies to the eastern provinces).

5.6.4 Data Mismatch for Oil and Gas Fields

There is also an issue with data mismatches between the high level, province scale resource estimates, and the estimates based on site-specific resources, e.g., in Saskatchewan the province-wide total of 960 Mt reported is significantly less than the 4857 Mt resource reported in depleted fields in the public literature. In such cases, the province-wide resource has been entered as a null value in the database.

5.6.5 Availability of Resource Estimates

Storage resource potential in oil and gas reservoirs is only quoted for British Columbia, Alberta, Saskatchewan, Manitoba and Ontario as, while oil and gas reservoirs are present outside of these provinces, they are considered by the major reports to be too distant from major emissions sources and therefore not reported.

2.1.7 Future Updates

5.6.6 Future CSRC cycles

Required updates in future Assessment cycles should include:

- Annual adjustments to account for continued injection and any model updates at Quest and Aquistore. Annual reports are released for both projects (end-first quarter) and should be reviewed when released for database update.

- Update following any future release of DOE Carbon Storage Atlas, or equivalent publication. This should include any further information as to the source of the data used to generate the high, Province-level, estimates of storage potential. According to the team at the US DOE responsible for the Atlas, an updated edition is currently in-progress, but no release date was provided (M Sullivan, pers. comm, January 2020).

- Additional release of information on depleted field availability and storage resource calculations. All depleted field resource data are currently classes as Discovered - Inaccessible due to the absence of a published field abandonment date.

6 Caribbean Countries

6.1 Summary

The Caribbean Island countries of Antigua and Barbuda, Bahamas, Barbados, Dominica, Grenada, Saint Kitts and Nevis, Saint Lucia and Saint Vincent and the Grenadines were assessed during Cycle 5. These countries in the group above are reported as having no CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Micronesia.

Table 6-1: Storage resource classification summary for the Caribbean Island countries of Antigua and Barbuda, Bahamas, Barbados, Dominica, Grenada, Saint Kitts and Nevis, Saint Lucia and Saint Vincent and the Grenadines.

6.2 Antigua and Barbuda

6.2.1 Evaluation History

There are no published reports or research at a federal or academic level to support that Antigua and Barbuda has sites suitable for geological storage of CO_2. As part of a volcanic Island arc, with limited sedimentary formations, Antigua and Barbuda do not have suitable geology for deep geological storage of CO_2. Antigua is mainly composed of Limestone and volcaniclastics whilst Barbuda is a low-lying coral limestone reef.

Antigua and Barbuda has a climate strategy that includes carbon sequestration by protecting natural carbon sinks such as remaining wetlands, watershed areas, and seagrass beds [1].

6.2.2 Regulatory Framework

Antigua and Barbuda does not currently have any regulatory framework for geological storage of CO_2.

6.2.3 Future Updates

Due to a lack of suitable geology, low emissions and preference to nature-based CO_2 sequestration, Antigua and Barbuda will unlikely need future updates.

6.3 The Bahamas

6.3.1 Evaluation History

There are no published reports or research at a federal or academic level to support that the Bahamas has sites suitable for geological storage of CO_2. The Bahamas is characteristic of a carbonate morphology. In terms of CO_2 storage it is unlikely that a sedimentary sequence with suitable seals will be present. The Bahamas has a climate strategy that includes carbon sequestration via nature-based solutions such seagrass meadows and mangrove forests. The nation plans to sell blue carbon credits on the voluntary carbon market by the end of this year. Federal estimates state they can produce at least $300 million worth of blue carbon credits [2].

6.3.2 Regulatory Framework

Ther Bahamas does not currently have any regulatory framework for geological storage of CO_2.

6.3.3 Future Updates

Due to a lack of suitable geology, low emissions and preference to nature-based CO_2 sequestration, The Bahamas will unlikely need future updates.

6.4 Barbados

6.4.1 Evaluation History

There are no published reports or research at a federal or academic level to support that Barbados has sites suitable for geological storage of CO_2. Barbados is formed from an accretionary prism capped with limestone reefs. The accretionary rims have played a role in the migration of hydrocarbons and helped establish a small hydrocarbon industry in the country. Production is onshore and once fields are depleted this may in the future have potential for CO_2 storage is this proved economically and socially acceptable. Barbados has a climate strategy that includes carbon sequestration via nature-based solutions such Seagrass meadows and mangrove forests. [3].

6.4.2 Regulatory Framework

Barbados does not currently have any regulatory framework for geological storage of CO_2.

6.4.3 Future Updates

Barbados will unlikely need future updates, however any vision the country may have for use of depleted fields for CO_2 storage could be investigated in future cycles.

6.5 Dominica

6.5.1 Evaluation History

There are no published reports or research at a federal or academic level to support that Dominica has sites suitable for geological storage of CO_2. As part of the Lesser Antillean Archipelago volcanic island arc, with limited sedimentary formations and basins, Domnica does not have suitable geology for deep geological storage of CO_2.

6.5.2 Regulatory Framework

Dominica does not currently have any regulatory framework for geological storage of CO_2.

6.5.3 Future Updates

Dominica will unlikely need future updates due to unsuitable geology for CO_2 storage.

6.6 Grenada

6.6.1 Evaluation History

There are no published reports or research at a federal or academic level to support that Grenada has sites suitable for geological storage of CO_2 As part of the Lesser Antillean Archipelago volcanic island arc, with limited sedimentary formations and basins, Grenada does not have suitable geology for deep geological storage of CO_2.

6.6.2 Regulatory Framework

Grenada does not currently have any regulatory framework for geological storage of CO_2.

6.6.3 Future Updates

Grenada will unlikely need future updates due to unsuitable geology.

6.7 Saint Kitts and Nevis

6.7.1 Evaluation History

There are no published reports or research at a federal or academic level to support that Saint Kitts and Nevis has sites suitable for geological storage of CO_2. As part of the Lesser Antillean Archipelago volcanic island arc, with limited sedimentary formations and basins, Saint Kitts and Nevis does not have suitable geology for deep geological storage of CO_2.

6.7.2 Regulatory Framework

Saint Kitts and Nevis does not currently have any regulatory framework for geological storage of CO_2.

6.7.3 Future Updates

Saint Kitts and Nevis will unlikely need future updates due to unsuitable geology for CO_2 storage.

6.8 Saint Lucia

6.8.1 Evaluation History

There are no published reports or research at a federal or academic level to support that Saint Lucia has sites suitable for geological storage of CO_2. As part of the Lesser Antillean Archipelago volcanic island arc, with limited sedimentary formations and basins, Grenada does not have suitable geology for deep geological storage of CO_2.

6.8.2 Regulatory Framework

Saint Lucia does not currently have any regulatory framework for geological storage of CO_2.

6.8.3 Future Updates

Saint Lucia will unlikely need future updates due to unsuitable geology for CO_2 storage.

6.9 Saint Vincent and the Grenadines

6.9.1 Evaluation History

There are no published reports or research at a federal or academic level to support that Saint Vincent and the Grenadines has sites suitable for geological storage of CO_2. As part of the Lesser Antillean Archipelago volcanic island arc, with limited sedimentary formations and basins, Saint Vincent and the Grenadines does not have suitable geology for deep geological storage of CO_2.

6.9.2 Regulatory Framework

Saint Vincent and the Grenadines does not currently have any regulatory framework for geological storage of CO_2.

6.9.3 Future Updates

Saint Vincent and the Grenadines will unlikely need future updates due to unsuitable geology for CO_2 storage.

6.10 References

1. Antigua and Barbuda updated nationally determined contribution For the period 2020 – 2030 Communicated to the UNFCCC on 2nd September 2021. https://unfccc.int/sites/default/files/NDC/2022-06/ATG%20-%20UNFCCC%20NDC%20-%202021-09-02%20-%20Final.pdf

2. The Bahamas Intends to be the First Country to Sell Blue Carbon Credits, Updated: May 4, 2022. https://carboncredits.com/bahamas-sell-blue-carbon-credits/#:~:text=The%20Bahamas%20plans%20to%20sell,Move%20with%20Blue%20Carbon%20Credits

3. Government of Barbados. Barbados 2021 update of the first nationally determined contribution. https://unfccc.int/sites/default/files/NDC/2022-06/2021%20Barbados%20NDC%20update%20-%2021%20July%202021.pdf

7 Chile

7.1 Summary

Chile was assessed during Cycle 5, with very limited data about the countries CO_2 storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	2.552	0.000
Undiscovered	1.241	0.000
Aggregated*	3.793	0.000

* 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 Chile.

Table 7-1: Storage resource classification summary for Chile.

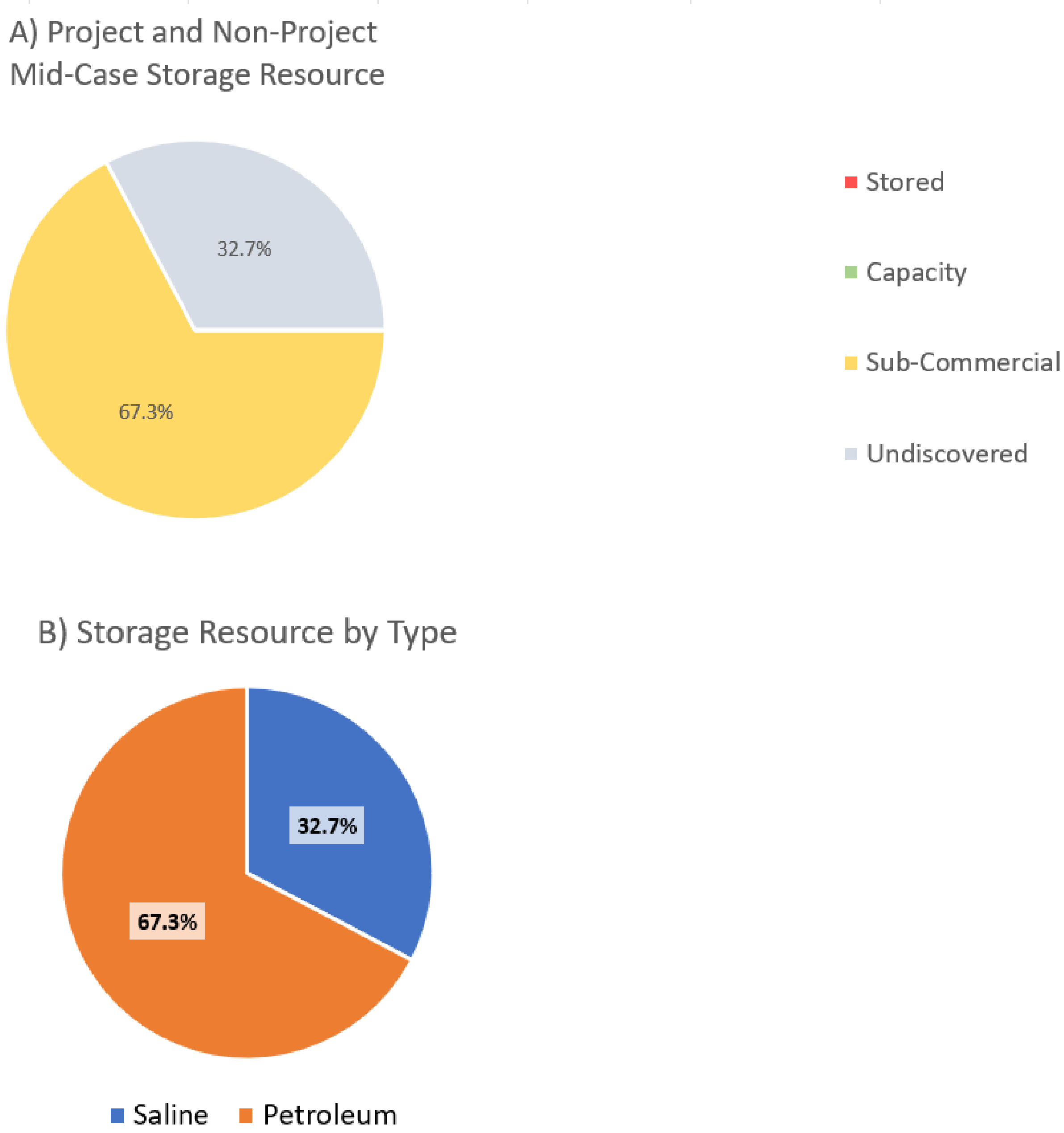


Figure 7-1: Chilean spread of Storage Sites.

A) Spread of storage resource in all Chilean sites across SRMS classifications. B) Split of Chilean storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

7.2 Resource Statement

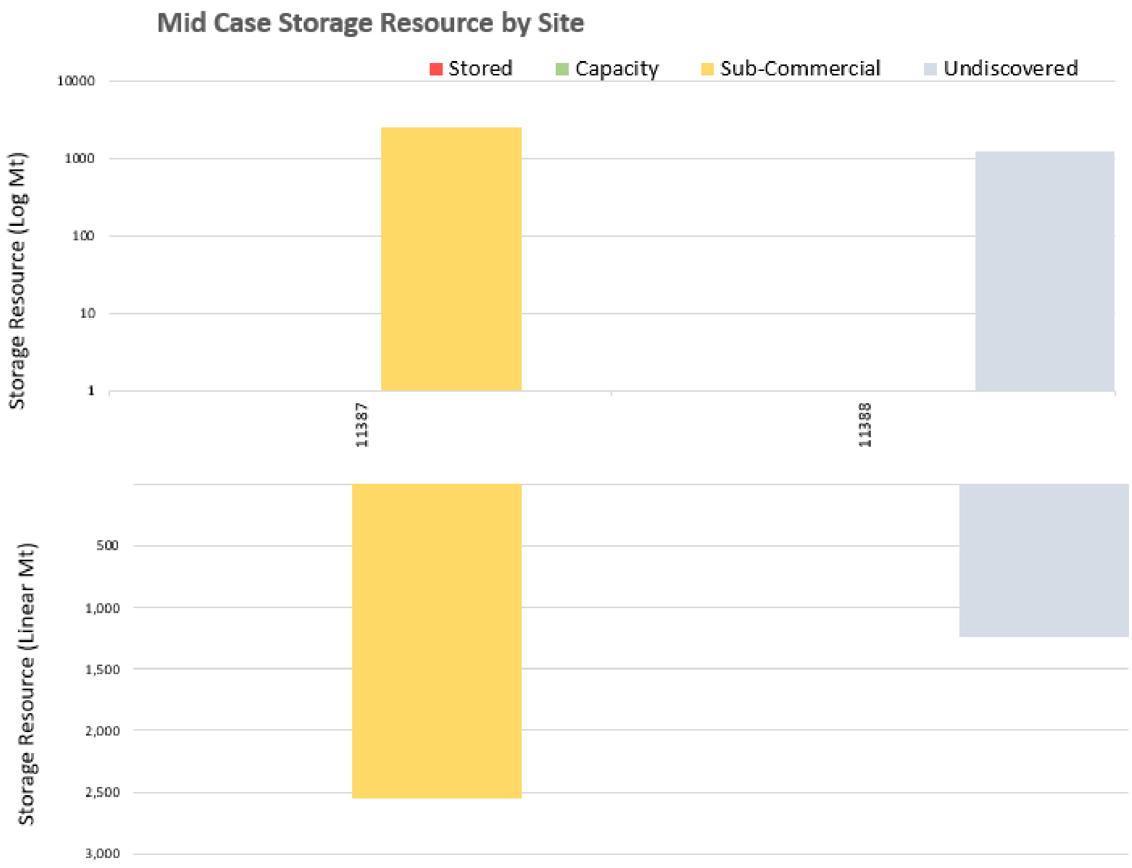


Figure 7-2: Storage resource summary for Chile compiled in the CSRC.

Graph above is log scale and graph below is linear. No project specified sites were identified.

7.3 Evaluation History

There is limited evaluation on Chile's CO_2 storage potential with data coming from a thesis by Postic in 2015 [1] which reviewed CO_2 storage potential as part of a long-term energy prospective study for South America. This thesis report includes a country-wide cumulative storage capacity for T-ALyC carbon storage options for South American countries including for Chile; deep saline aquifers (1,241 Mt), storage in depleted field (2,552 Mt), enhanced oil recovery (778 Mt), enhance coalbed methane recovery (82 Mt), curbing deforestation (0 Mt) and afforestation/reforestation (229 Mt). Only depleted fields and saline aquifers have been recorded in the database. The table uses the Integrated Markal-EFOM System TIMES for South America and the Caribbean cumulative storage capacity. The TIMES model generator was developed as part of the IEA-ETSAP's methodology for energy scenarios to conduct in-depth energy and environmental analyses [2].

7.4 Resource Review

Chile has one saline aquifer storage site and one depleted field site.

7.4.1 Major Projects

There are no major projects.

7.4.2 Depleted Oil & Gas Fields

There are very limited details in Postic's study providing a country-wide CO_2 storage resource of 2,552 Mt [1]. Storage capacity methodology is undefined but assumed O&G replacement volume.

7.4.3 Saline Aquifers

With very limited details given, Postic's country-wide value for Chile's deep saline aquifers at 1,241 Mt is assumed to be a theoretical volumetric capacity. Classified as Inaccessible in an absence of any regulatory information that permits CO_2 storage.

7.5 Regulatory Framework

Chile has recently committed to reaching carbon neutrality by 2050, with an ambitious NDC for 2030 as a step in the process to reduce 45% of net emissions [3]. The commitment has been met with strong political support, with conversion to renewable energy (70% by 2030) as the primary mitigation option [4]. Currently, there are no regulations for carbon capture use and storage in Chile, and CCUS has not been considered as one of the technologies indicated in the planned strategy by the Ministries of Environment and Energy to achieve these goals [5].

7.5.1 Issues for the Assessment

There are very limited studies done in Chile to assess the resource for CO_2 storage. Those that have been done do not detail methodology, site breakdown or any properties associated with the geology.

7.6 Future Updates

7.6.1 Future evaluations

Future updates would look for additional site reviews completed as Chile builds it's CO_2 value chain.

8 Colombia

8.1 Summary

Colombia was assessed during Cycle 5, with moderate data available regarding the countries CO_2 storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	26.489	5.419
Undiscovered	1.793	0.060
Aggregated*	28.282	5.479

* 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 Colombia.

Table 8-1: Storage resource classification summary for Colombia.

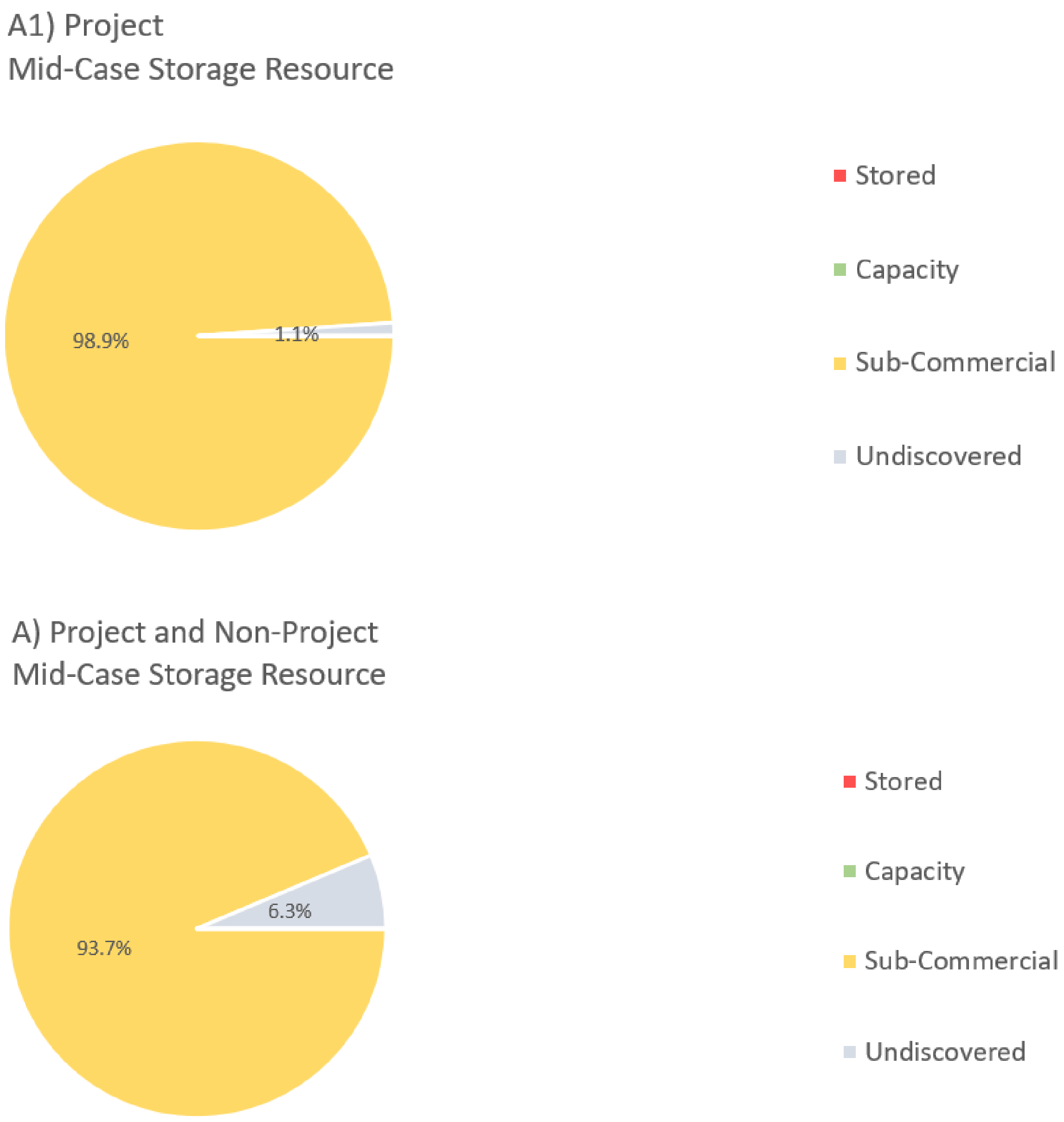


Figure 8-1: Colombian spread of Storage Sites.

A) Spread of storage resource in all Colombian sites across SRMS classifications. B) Split of Colombian storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

8.2 Resource Statement

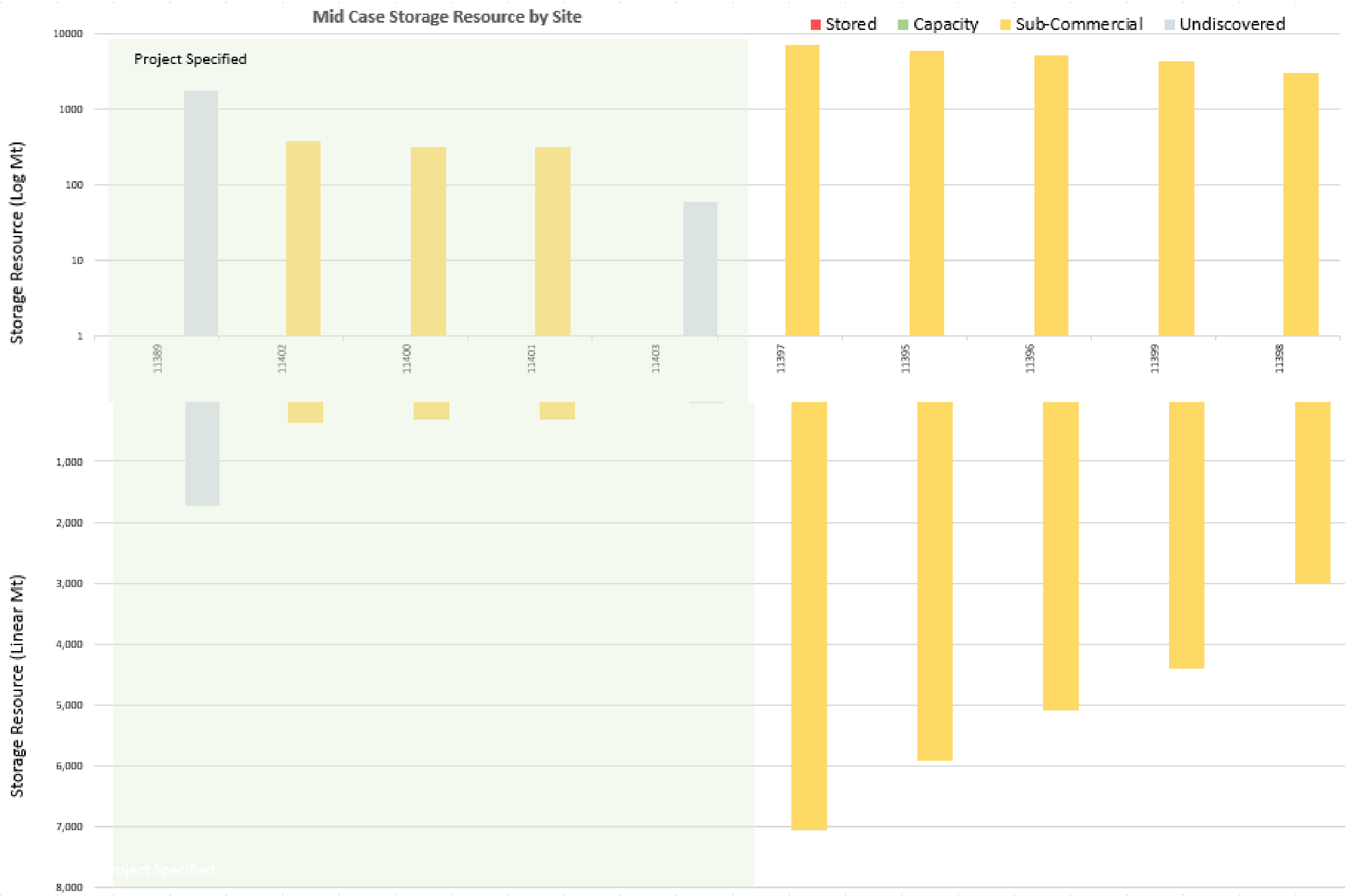


Figure 8-2: Storage resource summary for Colombia compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

8.3 Evaluation History

The thesis by Postic in 2015 [1] reviewed CO_2 storage potential as part of a long-term energy prospective study for South America. This thesis report includes a country-wide cumulative storage capacity for T-ALyC carbon storage options for South American countries including for Colombia; deep saline aquifers (1,733 Mt), storage in depleted field (3,564 Mt), enhanced oil recovery (1,097 Mt), enhance coalbed methane recovery (114 Mt), curbing deforestation (3,764 Mt) and afforestation/reforestation (1,258 Mt). Only depleted fields and saline aquifers have been recorded in the database. The table uses the Integrated Markal-EFOM System TIMES for South America and the Caribbean cumulative storage capacity. The TIMES model generator was developed as part of the IEA-ETSAP's methodology for energy scenarios to conduct in-depth energy and environmental analyses [2].

More recent publications looked at saline aquifers in more detail. Rodriguez, 2022 [3] completed a ppreliminary screening and ranking assessment for CCUS in Colombia sedimentary basins. This was built upon further in the Rodriguez 2023 paper [4] which focused on evaluating CO_2 storage capacity of saline aquifers in the Llanos Basin. In this assessment, Rodriguez used data from over 300 wells to identify four main reservoir/seal pairs along the Llanos Basin: 1) The Middle Cretaceous sandstone sequence and the Middle to Upper Cretaceous lower shale; 2) The Upper Middle to Upper Cretaceous middle sandstone and upper shale sequence; 3) The Upper Cretaceous fluvial deltaic sandstone sequence and the Paleogene lower shale sequence; 4) The fluvial Paleogene shale-sandstone intercalations sequence and the Lower Neogene shale. The paper uses these four reservoir/seal pairs to define the saline aquifer storage sites.

The Lopez et al. 2023 [5] paper presents a workflow that shows evaluation of the 8,000 km^2 Middle Magdalena Valley Basin, a mature oil and gas province with most of the hydrocarbons being produced from conventional fields in the Cenozoic section predominantly from fluvial/alluvial environments. The area has been taken through a screening process looking at items such as temperature, pressure, petrophysical and constitutive features for reservoirs and cap rocks. Some sweet spots have been identified using a notional storage development plan, but these are not delineated in the publication, and no maximum storage resource is given.

Regarding depleted fields, Younis et al. [6] published an academic paper in 2023 exploring the spatiotemporal evolution of bioenergy with carbon capture and storage and decarbonization of oil refineries with a national energy system model of Colombia. This study assesses four clusters of CO_2 sinks in Colombia and builds on the work of Cardozo et al. [7] as a proxy for Cluster 1. The study conducts a scenario analysis based on the Shared Socioeconomic Pathways (SSP) framework, adapted to Colombia. SSP1 reflects a future in which global collaboration fosters a transition towards sustainable development. By contrast, SSP3 depicts a scenario of global fragmentation with a national focus. SSP2 corresponds to a middle-of-the-road scenario where the current progress towards sustainable development goals continues slowly. The geological storage potential in SSP1 and SSP2 scenarios corresponded to the upper and lower ranges of the technical potential in depleted oil and gas fields, while that of SSP3 scenario was based on the CCS-EOR potential only. Representative locations of the four (1-4) carbon sink clusters are shown. Location 1 is the largest, situated in Santander, Location 2 is on the Nariño and Putumayo border, Location 3 is on the Bolivar, Magdalena and Atlántico border and Location 4 is on the Huila and Meta border.

Additionally, Godec et al. (2013) [8] provided a study of storage potential in coalbeds and Yanez et al. (2020) [9] a study of storage potential via enhanced oil recovery but these have been excluded from the database.

8.4 Resource Review

Colombia has six saline aquifer storage sites and four depleted field sites.

8.4.1 Major Projects

In 2023, the IEAGHG hosted the first national workshop on CCUS for Colombia focused on opportunities and challenges [10], in which information on the projects underway assessing carbon storage potential in Colombia were discussed.

There projects include the National University at Medellin assessing onshore storage locations, support from the Inter-American Development Bank for the national CO_2 storage assessment including offshore, Ecopetrol looking at their CO_2 emissions from their refineries and the potential for those to be captured with three CCS projects and several storage possibilities onshore identified, and Colombian cement company, Argos, are assessing decarbonization options, which identified CCS as a crucial part [10]. Unfortunately, none of these projects have been shared publicly in detail to be able to be included in the database.

8.4.2 Depleted Oil & Gas Fields

Cardozo et al. [7] calculated the theoretical CO_2 storage potential in the central sector of the Middle Magdalena Basin in Colombia, and based on the method of Bachu et al. [11] for oil and gas reservoirs, the authors estimated the theoretical CO_2 storage potential at 9 Gt. The present analysis by Younis et al. [6] is based on the four clusters of CO_2 sinks defined by Yáñez et al. in 2021 [12]. Analysis is based on the method of Bachu et al. [11], with additional amendments to consider the possible risks related to seal characterization for CO_2 retention and trapping, CO_2 mineralization, fluid interaction, or injectivity. These uncertainties were addressed by applying confidence ranges to the chance of success of the trap, reservoir, and seal integrity. The corresponding probabilities for trap, reservoir, and seal integrity were assumed to range between 0.4 and 0.7, 0.8–1.0, and 0.5–0.7, respectively.

The study provides analysis based on two Shared Socioeconomic Pathways (SSP) frameworks. The difference between SSP1 and SSP2 is the efforts exerted towards climate change mitigation and adaption (SSP1 assuming carbon neutrality by 2050), and the proportion of biomass supply (larger in SSP1).

A technical storage potential for Cluster 1 was provided as 1.44–4.41 Gt, and under SSP1 pathway, Cluster 1 has 81% of 5.4 Gt, calculated as 4,410 Mt. Using the percentages provided in the paper, the corresponding values for Clusters 2, 3 and 4 have been calculated as 318.6 Mt, 318.6 Mt and 371.7 Mt respectively. The values are classified as Inaccessible in an absence of any regulatory information that permits CO_2 storage.

To achieve the 5.4Gt across the four clusters, the paper provides a notional development plan of injection rates of 218 Mt/yr, which equates to approximately 25 years of injection.

8.4.3 Saline Aquifers

With very limited details given, Postic's country-wide value for Colombia's deep saline aquifers at 1,733 Mt is assumed to be a theoretical volumetric capacity. Classified as Inaccessible in an absence of any regulatory information that permits CO_2 storage.

Rodriguez, 2023 [4], used the U.S. DOE methodology (2011) [13] for structural and stratigraphic traps was used to obtain the CO_2 theoretical storage capacities. These are reported as 5,920 Mt, 5,100 Mt, 7,060 Mt, 2,990 Mt respectively, for the four reservoir/seal pairs described in the Evaluation History section above. Prospective storage resources were calculated with R&A Software, aiming to obtain P10, P90, and Pmean values for the four different saline aquifers in the Llanos basin. Classification of this site is Discovered as there are over 300 wells within the Llanos Basin, with evidence in the images of the publication that all stratigraphy has been penetrated by wells (estimated to be 150). However, it is 'development not viable' as there is no active appraisal or evaluation plan. The values are classified as Inaccessible in the absence of any regulatory information that permits CO_2 storage.

Lopez et al. study [5] notes that the basin modelling workflow used detailed not only the reservoir presence and quality, but also cap rock integrity with its related thickness, lithology and capillary pressures. This allows more accurate information on the storage capacity as well as on the CO_2 column height that a given location could deliver.

2 MTons/yr of CO_2 injection for a period of 30 years were modelled for sweet spots in the study via a reservoir fluid flow simulator giving a potential storage site of 60 Mt. Although there are over 100 wells within the Middle Magdalena Valley Basin, the classification of this site is Undiscovered due to lack of site-specific data. It is Inaccessible in an absence of any regulatory information that permits CO_2 storage.

8.5 Regulatory Framework

Currently, Colombia has no regulations for CCUS technologies, however it is supportive of CCS and recognizes it as an important energy technology in its energy strategy. The Colombia Ministry for Mines and Energy have an energy transition roadmap to carbon neutrality by 2050, with a strategy that includes energy demand management, energy efficiency, reducing fugitive emissions, more renewable energy such as geothermal, wind and solar, fossil fuel substitution, and CCUS and BECCS. With CCUS, they estimate that 15% of the national energy emissions could be mitigated [10]. A draft Decree exists to enable this new carbon neutrality strategy and already has tax benefits in place for CCUS technologies.

8.5.1 Issues for the Assessment

Postic's study [1] gives very few details on the study assessment.

Rodriguez's assessment [4] assumed storage efficiency for all the reservoirs was estimated at 4% (Ringrose, 2015 [14]), however this should be considered high for saline aquifers at a regional scale. The reservoir/seal pair of 'Upper Cretaceous fluvial-deltaic sandstone with Paleogene lower shale' is a continuous, homogeneous, and relatively thin reservoir exhibiting a favourable distribution of porosity and permeability, making it a promising candidate for CO_2 storage. However, its current use for reinjecting production water from oil and gas activities increases the risk of CO_2 leakage and reduces the available pore space for CO_2 storage. It is also noted that the quality of the upper seal for the 'Upper Middle to Upper Cretaceous middle sandstone with upper shale' reservoir/seal pair deteriorates as it extends northward, increasing the risk of CO_2 migration to upper reservoirs.

Lopez et al. [5] sweet spot areas were tested using a dynamic simulation, using a notional development plan of 2 Mt/year over a period of 30 years. No boundary limitations or details of the modelling pressure were provided. The number may be an underestimate, as only a single resource volume has been given for one sweet spot, and no information on the number of reservoir simulations run.

Younis et al. [6] study does not specify the number of fields in each of the clusters.

8.6 Future Updates

8.6.1 Future evaluations

Future evaluations should address any legislation updates and if this has helped encourage any projects or research.

9 Costa Rica

9.1 Summary

Costa Rica was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Costa Rica.

Table 9-1: Storage resource classification summary for Costa Rica.

9.2 Evaluation History

There are no published reports or research to support that Costa Rica has been investigating geological storage of CO_2. Costa Rica has potential for hydrocarbon production but as yet this is not developed. Therefore, future storage for CO_2 in depleted fields is unlikely. Based on the absence of exploration, there will be very limited data available for any potential storage insight in saline aquifers. Costa Rica has been aiming to reduce greenhouse gases for several years. Costa Rica's main strategy for any form of carbon sequestration is to improve biodiversity and agricultural practices, increasing reforestation and also aims to also protect and restore blue carbon ecosystems [1].

9.3 Regulatory Framework

Costa Rica does not currently have any regulatory framework for geological CCS.

9.4 Future Updates

Based on Costa Rica's preference for biological capture and limited potential for depleted oil and gas fields and lack of research, future updates are unlikely to be necessary.

10 Cuba

10.1 Summary

Cuba was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Cuba.

Table 10-1: Storage resource classification summary for Cuba.

10.2 Evaluation History

There are no published reports or research to support that Cuba has been investigating geological storage of CO_2. Cuba does have hydrocarbon reserves and an active hydrocarbon industry, although the reserves are reported as relatively small and hence any depleted reservoirs may prove uneconomical for CO_2 storage. Cuba does have several sedimentary basins that could have potential storage in saline aquifers: the Santo Domingo and Santa Clara basin which have up to 1600 m thick sedimentary infill, and the Cienfuegos and Trinidad basins which both have sedimentary thickness reported to be up to and over 1000 m thick. Significant research would need to be undertaken to investigate any potential for CO_2 storage in these basins. Cuba's main strategy for any form of carbon sequestration is via improving reforestation [1].

10.3 Regulatory Framework

Cuba does not currently have any regulatory framework for geological CCS.

10.4 Future Updates

Based on Cuba's preference for biological capture and moderate emissions status, future updates are unlikely to be necessary as the country may not view CCS as an economically viable option. However, based on the potential for depleted oil and gas fields, future updates could continue to monitor any developments in this sector.

11 Dominican Republic

11.1 Summary

Dominican Republic was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Dominican Republic.

Table 11-1: Storage resource classification summary for Dominican Republic.

11.2 Evaluation History

There are no published reports or research to support that the Dominican Republic has been investigating geological storage of CO_2. The country has been considering its potential for hydrocarbon production but is currently only in the exploration phase so as yet there is no data to support future CO_2 storage potential in this sector. Potential hydrocarbon provinces exist in the Cibao, Enriquillo, Azua, and San Pedro de Macoris basins which are both on and offshore. In addition to oil and gas accumulations, saline aquifers may also be present in these basins, although exploration for hydrocarbons will likely be a priority.

The Dominican Republic's main strategy for any form of carbon sequestration is via improving reforestation and agricultural practices but most notably it's Nationally Approved Mitigation Action: "Blue carbon, conservation and restoration of mangroves in the Dominican Republic (NS-189)" [1].

11.3 Regulatory Framework

Dominican Republic does not currently have any regulatory framework for geological CCS.

11.4 Future Updates

Based on the Dominican Republics' preference for biological capture and low emissions status, future updates are unlikely to be necessary. Future potential in any depleted fields will not need to be considered for many years due to the infancy of the hydrocarbon industry.

12 Ecuador

12.1 Summary

Ecuador was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Ecuador.

Table 12-1: Storage resource classification summary for Ecuador.

12.2 Evaluation History

There are no published reports or research to support the investigatgation of geological storage of CO_2 in Ecuador Ecuador does have a hydrocarbon industry, although no plans have been made to use this for future CO_2 storage The vast majority of Ecuador's oil production comes from the Oriente Basin in the Amazon region which may cause issues with any future CO_2 storage based on environmental concerns. The country has moderate CO_2 emissions relative to the word highest emitters and at present its main strategy for any form of carbon sequestration is via improving reforestation and agricultural practices [1].

12.3 Regulatory Framework

Ecuador does not currently have any regulatory framework for geological CCS.

12.4 Future Updates

Based on the Ecuador’s preference for biological capture. future updates are unlikely to be necessary. Reviews on any use of future depleted reservoirs may be worth investigating.

13 El Salvador

13.1 Summary

El Salvador was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 El Salvador.

Table 13-1: Storage resource classification summary for El Salvador.

13.2 Evaluation History

There are no published reports or research to support that El Salvador has been investigating geological storage of CO_2. It has nominal hydrocarbon reserves that are not developed and hence there are no depleted fields to consider for storage. Due to its geology and proximity to geothermal heat, it is mainly involved in energy production from geothermal activity so emissions from hard to abate industry is low compared to other countries. The geology of El Salvador is also prone to frequent earthquakes which will pose a containment risk to any CO_2 storage project. This further indicates the low potential of this country for CO_2 storage.

El Salvador's main strategy for any form of carbon sequestration is via improving reforestation and agricultural practices [1].

13.3 Regulatory Framework

El Salvador does not currently have any regulatory framework for geological CCS.

13.4 Future Updates

Based on El Salvador's preference for biological capture, low emissions status, and unsuitable geology, future updates are unlikely to be necessary.

14 Guatemala

14.1 Summary

Guatemala was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Guatemala.

Table 14-1: Storage resource classification summary for Guatemala.

14.2 Evaluation History

There are no published reports or research to support that Guatemala has areas suitable for geological storage of CO_2. The country does have an underutilised hydrocarbon industry but has no plans to develop this for any form of storage in the future. Guatemala's main strategy for any form of carbon sequestration is via improving reforestation and agricultural practices [1]. Relative to other countries with high CO_2 emissions, Guatemala's emissions are very low and hence the drive for CCS project is also low.

The Peten Basin is the most explored basin for hydrocarbons, may have saline aquifer potential for CO_2 storage. It is filled with thick Cretaceous-Tertiary carbonate and clastic sequences which overlie late Jurassic sediments. The remaining Amatique and Pacific basins are under explored so little is known about any potential geological framework that may be suitable for CO_2 storage in saline aquifers.

14.3 Regulatory Framework

Guatemala does not currently have any regulatory framework for geological CCS.

14.4 Future Updates

Based on the Guatemala preference for biological capture and low emissions status, future updates are unlikely to be necessary. However, if a significant hydrocarbon energy ever existed then future depleted oil and gas reservoir may be a consideration.

15 Guyana

15.1 Summary

Guyana was assessed during Cycle 5 & 6. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Guyana.

Table 15-1: Storage resource classification summary for Guyana.

15.2 Evaluation History

There are no published reports or research to support that Guyana has been investigating geological storage of CO_2. The Guyana Basin is located on the passive margin of the country and is filled with Cretaceous-Tertiary sediments comprising of carbonates and clastics. Potential reservoir-seal pairs in saline aquifer sectors of the basin may exist and carry potential for CO_2 storage;many of the sediments are at depth suitable for maintaining CO_2 in super critical conditions [1]. This basin is also a hydrocarbon province, although this is relatively immature and unlikely to be viewed for any CO_2 storage for several years. The CO_2 emissions Guyana emits are very low compared to other nations and the investment in a CO_2 storage industry may prove economically challenging, especially due to the natural carbon sinks the country can enhance. Guyana's main strategy for any form of carbon sequestration is most notably by improved agroforestry practices and increasing forest acreage (including mangroves) [2].

15.3 Regulatory Framework

Guyana does not currently have any regulatory framework for geological CCS.

15.4 Future Updates

Based on Guyana's preference for biological capture and low emissions status, future updates are unlikely to be necessary.

15.5 References

1. Ynag, W., and Escaloina, A. 2011. Tectonostratigraphic evolution of the Guyana BasinAAPG Bulletin, v. 95, no. 8, pp. 1339–1368

2. Guyana, Guyana’s Revised Intended Nationally Determined Contribution 2016. Guyana's revised NDC - Final.pdf

16 Haiti

16.1 Summary

Haiti was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Haiti.

Table 16-1: Storage resource classification summary for Haiti.

16.2 Evaluation History

There are no published reports or research to support that Haiti has areas suitable for geological storage of CO_2. As a country with a history of some major earthquakes, the tectonic configuration of Haiti is unlikely suitable for CO_2 storage. There is also no history of hydrocarbon production and hence storage in any depleted fields cannot be considered as a future storage option.

16.3 Regulatory Framework

Haiti does not currently have any regulatory framework for geological CCS.

16.4 Future CRSC Cycles

Due to the unsuitable geological conditions for storage in Haiti, future updates are unlikely to be necessary.

17 Honduras

17.1 Summary

Honduras was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Honduras.

Table 17-1: Storage resource classification summary for Honduras.

17.2 Evaluation History

There are no published reports or research to support that Honduras has investigated areas for geological storage of CO_2. There is also no history of hydrocarbon production and hence storage in any depleted fields cannot be considered as a future storage options. Honduras is also looking to invest in reforestation to help achieve its NDC goals with regards to CO_2 emissions reduction.

Honduras's geology is characterized by a mix of metamorphic, sedimentary, and volcanic rocks, The country sits near the junction of the North American, Cocos, and Caribbean plates, leading to significant faulting, geothermal and some seismic activity. Honduras does have some large sedimentary basins; The Mosquitia and Tela Basins have had some exploration for hydrocarbons and contain sediments that comprise of a mix of volcaniclastics intervals and sequences of carbonates and clastics. The basins are in remote areas with rich biodiversity and hence are unlikely to be considered suitable for CO_2 storage.

17.3 Regulatory Framework

Honduras does not currently have any regulatory framework for geological CCS.

17.4 Future CRSC Cycles

Due to the lack of suitable geological locations for storage in Honduras, future updates are unlikely to be necessary.

18 Jamaica

18.1 Summary

Jamaica was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Jamaica.

Table 18-1: Storage resource classification summary for Jamaica.

18.2 Evaluation History

Jamaica is frontier hydrocarbon provide with some evidence of active petroleum systems. Since there is no hydrocarbon production, then CO_2 storage in depleted fields is not an option for the foreseeable future. Jamaica's sedimentary basins are located offshore. The Yallahs Basin lying at a depth of 1300m contains 500m of sediments and may have potential as a saline aquifer. The Walton Basin has been explored for hydrocarbons may also have some intervals that could be investigated or carbon storage. To date, there are no published reports or research to support that these areas are suitable for geological storage of CO_2. CCS is recognised by Jamaica in its climate strategy as one route to help decarbonise heavy industry, but no further details on this are available [1]. There is also ongoing research to investigate biological CO_2 capture in Jamaica such as mangrove restoration.

18.3 Regulatory Framework

Jamaica does not currently have any regulatory framework for geological CCS.

18.4 Future CRSC Cycles

Future updates could revisit Jamaica's strategy for climate change to assess if any further steps have been taken to consider CCS.

19 Mexico

19.1 Summary

Mexico was assessed during Cycle 2. The CSRC has identified a CO_2 storage resource for Mexico as follows:

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.0	0.0
Capacity	0.0	0.0
Sub-Commercial	89.5	0.0
Undiscovered	11.3	0.0
Aggregated*	100.8	0.0

* 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 Mexico.

Table 19-1: Storage resource classification summary for Mexico.

- There are currently a total of 76 sites across nine basins in Mexico.
- There are no project-specified sites in the Mexican dataset.
- There are no active CCS projects operational in Mexico, however pilot capture plants have been proposed.
- The Mexican Government has recognised the requirement for CCS in meeting its commitments to the Paris Agreement, yet lacks a developed CCS policy to allow projects to progress.

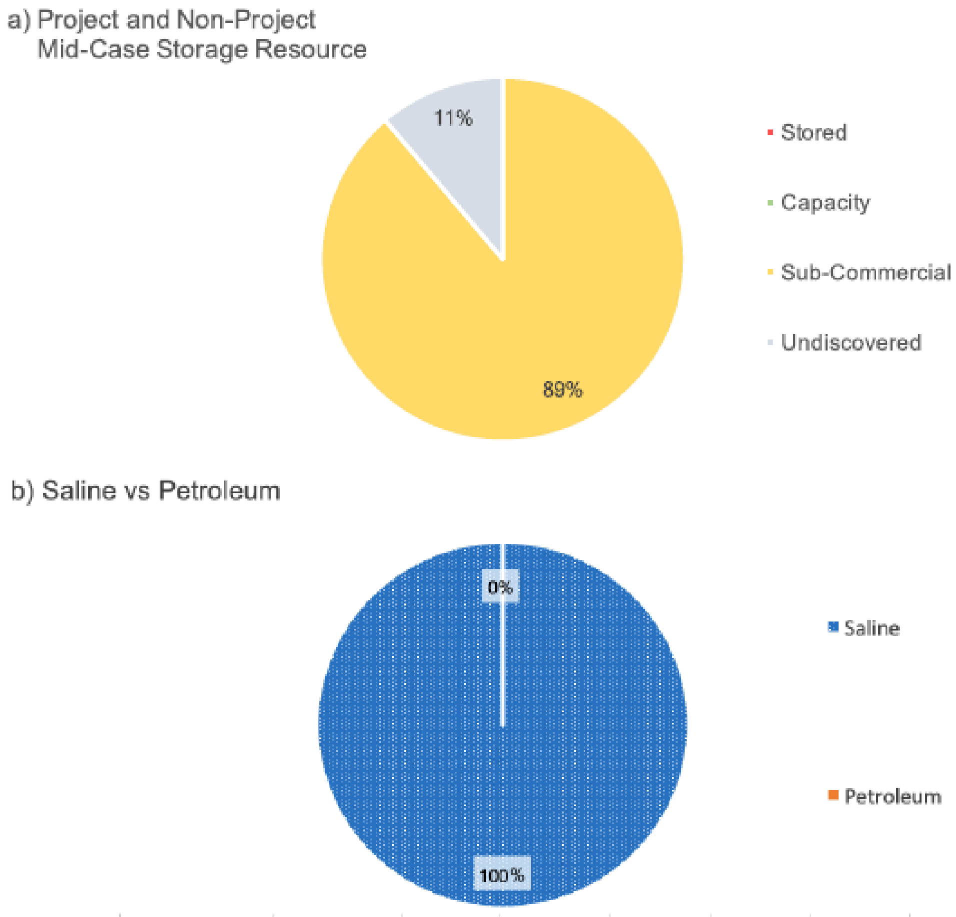


Figure 19-1: Mexican spread of Storage Sites.

a) Spread of storage resource in Mexican sites (76) across SRMS classifications, where a project has been specified. b) Spread of storage resource in all Canadian sites across SRMS classifications; both project specified and not. c) Split of Canadian storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

19.2 Resource Statement

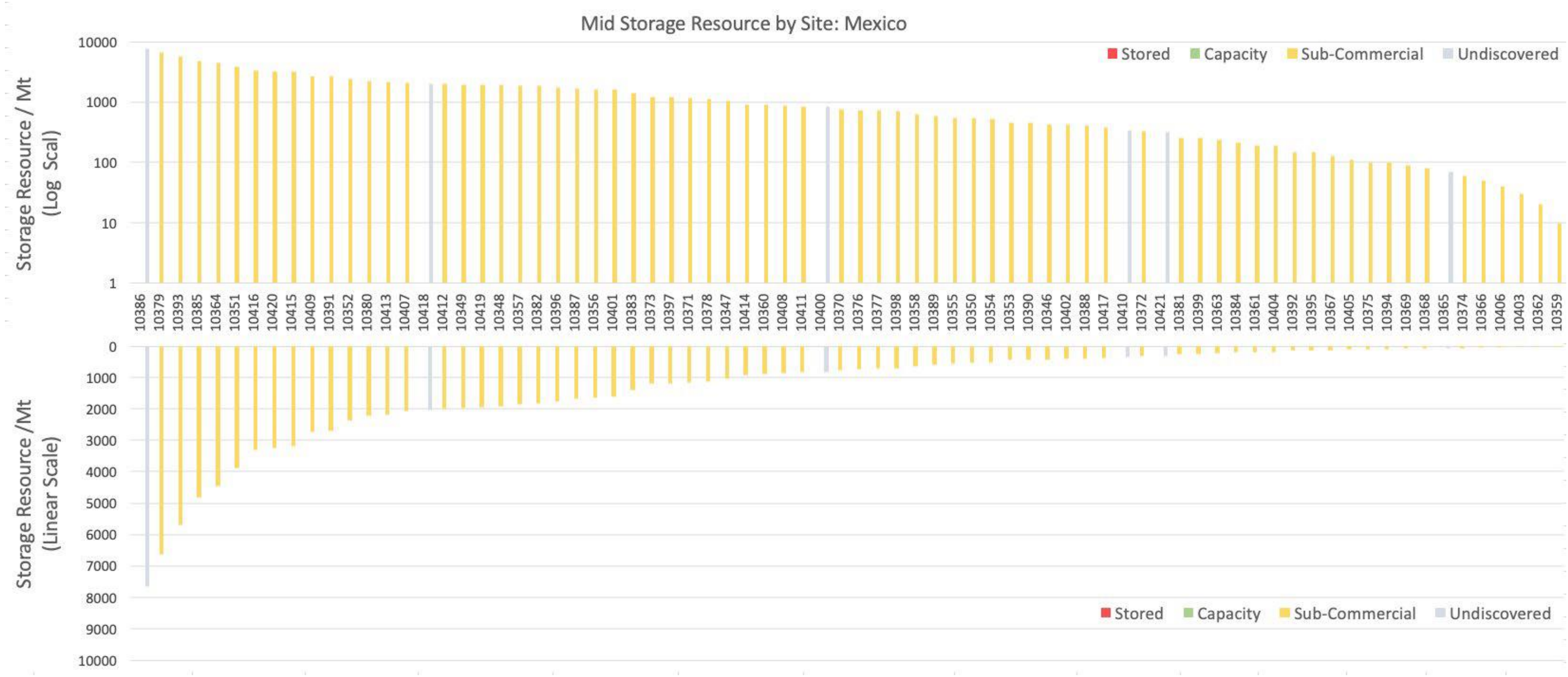


Figure 19-2: Storage resource summary for Mexico compiled in the CSRC.

Graph above is log scale and graph below is linear. No project specified sites were identified.

19.3 Evaluation History

Only two sources were available for the estimation of CO_2 storage resource within Mexico; where the North American CO_2 Storage Atlas (NASCA) [10] is the main source, with supplementary information provided by Moja (2016) [11]. Both sources reference the same storage resource evaluations for 76 sites across nine basins. These evaluations were conducted in two phases:

In the first phase, the basins were separated into the exclusion or inclusion zones, where excluded basins exhibited high seismicity, geothermal or volcanic activity and thus are not recommended for geological storage.

In the second phase, a theoretical storage resource was calculated for prospective sectors within basins in the inclusion zone. Maps displayed in the Appendix of the NASCA suggest that this evaluation was largely undertaken in areas around existing wells. The CSLF equation for saline aquifer storage was used to calculate the potential storage resource for geological formations at depths between 800 to 2,500m. The equation does not consider geological constraints to storage resource, injectivity, hazards, or solubility and mineral trapping, and importantly does not apply a storage efficiency factor. As such, the authors consider the calculated storage resource to be a theoretical maximum.

The evaluations were published in 2012 and no further work has been completed to assess Mexico's CO_2 storage potential, except for EOR feasibility projects.

19.4 Resource Review

19.4.1 Major Projects

No major CCS projects were identified in Mexico during Cycle 2.

Pilot capture plants were noted to be in development in the coming year by Heras (2018) [12], however no further details of either project could be sourced in the public domain. These capture pilots were to be located in Poza Rica and CO_2 EOR in Minatitlan, both the in Veracruz area.

19.4.2 Depleted Oil & Gas Fields

No CO_2 storage evaluations for Mexican depleted hydrocarbon fields were identified in the CSRC. Due to the wealth of fields in the country, it is likely that any future evaluations of storage resource in depleted fields would benefit the apparent potential within Mexico.

19.4.3 Saline Aquifers

The NASCA (2012) identified a total of 101 Gt of storage resource, split across 9 basins which line the eastern coastline of Mexico [10]. Largely, this resource was calculated for an area surrounding a legacy well, and as such, could be classified as Discovered. A smaller portion, 11.3 Gt, was classified as Undiscovered due to its distance from well data points. The lack of a developed CCS policy in Mexico, means the identified storage resource cannot be developed under the current regulatory constraints. Consequently, all storage resource potential in Mexico is classified as either Undiscovered Inaccessible or Discovered Inaccessible. Should this position change, the storage resource can mature from the Inaccessible classification.

19.5 Regulatory Framework

Mexico's rating in the GCCSI Policy Indicator Report 2018 [13] increased significantly since the previous assessment in 2015. This is due to Mexico attracting funding from the World Bank to complete feasibility studies for demonstration projects, and for the establishment of the Mexican CCUS Centre, through which two pilot capture plants have been proposed. In October 2019, the Secretaría de Medio Ambiente y Recursos Naturales (SENERNAT) introduced a carbon market pilot program which includes stationary sources of CO_2 from the energy and industrial sectors, whose emissions exceed 100,000 tonnes per year. The pilot program is to last for 36 months, from 1st January 2020, and will transition into an Emissions Trading Scheme from 2022 [13].

19.6 Issues for the Assessment

Lack of recent and detailed reporting of CO_2 storage resource. The maturity of the CO_2 storage resource in Mexico is very low due to the lack of detailed reporting and developed CCS policy.

The reported resource also suffers from a lack of development since the initial evaluation published in 2012. An update to this work should be considered to build on the important work completed to date.

19.7 Future Updates

19.7.1 Future evaluations

A focus of future evaluations on CCS rather than CCUS for EOR would be welcome to allow inclusion in the Global CO_2 Storage Catalogue. Far more detailed reporting and evaluation of the CO_2 storage resource is also required to accurately represent Mexico's full potential.

A significant amount of subsurface data is likely to be available in Mexico, due to its active hydrocarbon industry. Further use of this data for CO_2 storage evaluations and more detailed reporting of these evaluations would significantly benefit the reported resource and help to increase its maturity.

20 Nicaragua

20.1 Summary

Nicaragua was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Nicaragua.

Table 20-1: Storage resource classification summary for Nicaragua.

20.2 Evaluation History

There are no published reports or research to support that Nicaragua been investigating geological storage of CO_2. The geology of Nicaragua is unlikely to be suitable for CO2 storage; Nicaragua is part of the North American plate bordered by the subducting Cocos Plate. This is marked by active volcanism and earthquakes are frequent, which will be of concern for the containment of any geological CO_2 storage project. In addition, any sedimentary basins are mainly filled by volcaniclastic sediments that are again not generally suitable as a storage formation. As part of its NDC, Nicaragua intends to investigate biological CO_2 capture through land use and forestry [1]. Nicaragua has no hydrocarbon industry and such CO_2 storage in depleted fields is not an option for the future.

20.3 Regulatory Framework

Nicaragua does not currently have any regulatory framework for geological CCS.

20.4 Future CRSC Cycles

Future updates are unlikely to be necessary due to unsuitable geology in Nicaragua for CO_2 storage.

21 Panama

21.1 Summary

Panama was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Panama.

Table 21-1: Storage resource classification summary for Panama.

21.2 Evaluation History

There are no published reports or research to support that Panama has areas suitable for geological storage of CO_2. Panama has a very small population and contributes only 0.045% of global greenhouse gas emissions. With a high forest coverage that amounts to about 65.4%, Panama is also one of the only three countries that are carbon negative. In terms of CO_2 sequestration, Panama's Nationally Determined Contributions (NDC) commits to restoring national forests by 50,000 ha, which would absorb approximately 2.6 million tons of CO_2 by 2050.Panama sits on microplate is made of oceanic crust basalt. It is formed due to the collision of the Cocos, Nazca, and Caribbean. This results in frequent active volcanism and earthquakes. A large are of the geology in Panama is unsuitable for CO_2 Storage. The onshore Chucunaque Basin filled with over 10km of sediments may have potential, but the area is remote and very undeveloped. Therefore, the geological conditions in this country are unsuitable for any geological CO_2 storage projects.

21.3 Regulatory Framework

Panama does not currently have any regulatory framework for geological CCS.

21.4 Future CRSC Cycles

Future updates are unlikely to be necessary due to the absence of suitable geology and low emissions contribution.

22 Paraguay

22.1 Summary

Paraguay was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Paraguay.

Table 22-1: Storage resource classification summary for Paraguay.

22.2 Evaluation History

There are no published reports or research to support that Paraguay has been investigating storage of CO_2. Paraguay is a densely forested nation currently being supported by REDD+ - This is a UN Framework Convention on Climate Change. It provides financial incentives for developing countries to reduce greenhouse gas emissions from deforestation and forest degradation and better manage existing forest carbon stocks. This is likely to be route Paraguay will favour for any decarbonization strategies [1]. Paraguay is also translating carbon markets into regulations.

Paraguay does not have an active hydrocarbon industry at present but has over 50 exploration wells drilled with a discovery made in 2014. The Chaco region in the northwest of the country is considered the most prospective. It is also an area of focus for forestry management. Whilst not applicable now to CO_2 storage opportunities, this may mean depleted oil and gas fields could be available in the distant future.

22.3 Regulatory Framework

Paraguay does not currently have any regulatory framework for geological CCS.

22.4 Future Updates

Future updates are unlikely to be necessary in the near future; however, any depleted fields may hold some potential, but this will not be for many years yet.

23 Peru

23.1 Summary

Peru was assessed during Cycle 5, with very limited data about the countries CO_2 storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.056	0.000
Undiscovered	0.000	0.000
Aggregated*	0.056	0.000

* 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 Peru.

Table 23-1: Storage resource classification summary for Peru.

- There are limited evaluations of CO_2 storage potential within Peru, mainly academic studies.
- There are three storage sites within depleted fields providing a cumulative storage capacity of 55.97 Mt.
- Storage sites are within the Talara Basin in the Parinas Formation of the Bellavista and Calzada oil fields.
- Currently there are no regulations for carbon capture use and storage in Peru.

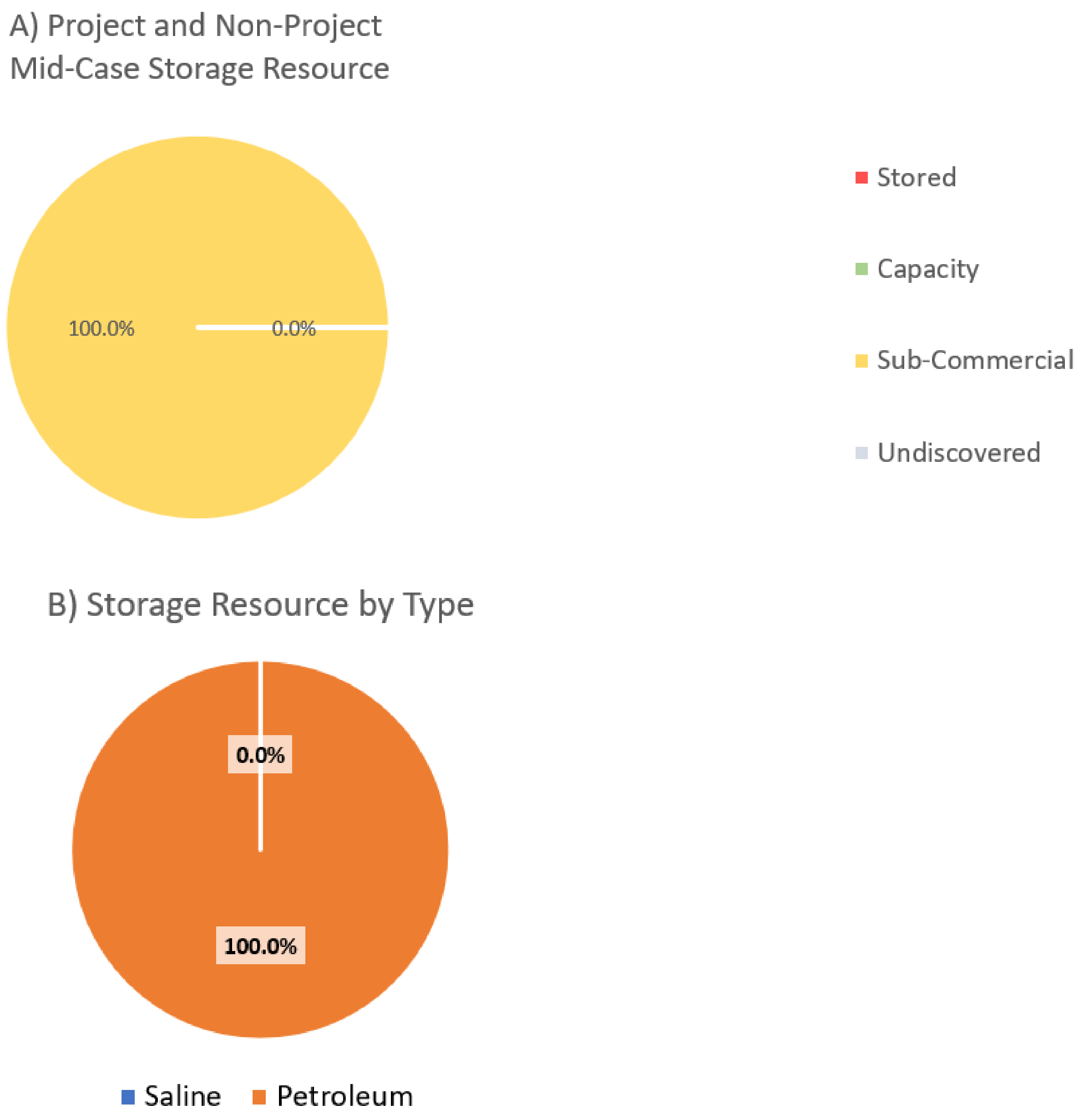


Figure 23-1: Peruvian spread of Storage Sites.

A) Spread of storage resource in all Peruvian sites across SRMS classifications. B) Split of Peruvian storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

23.2 Resource Statement

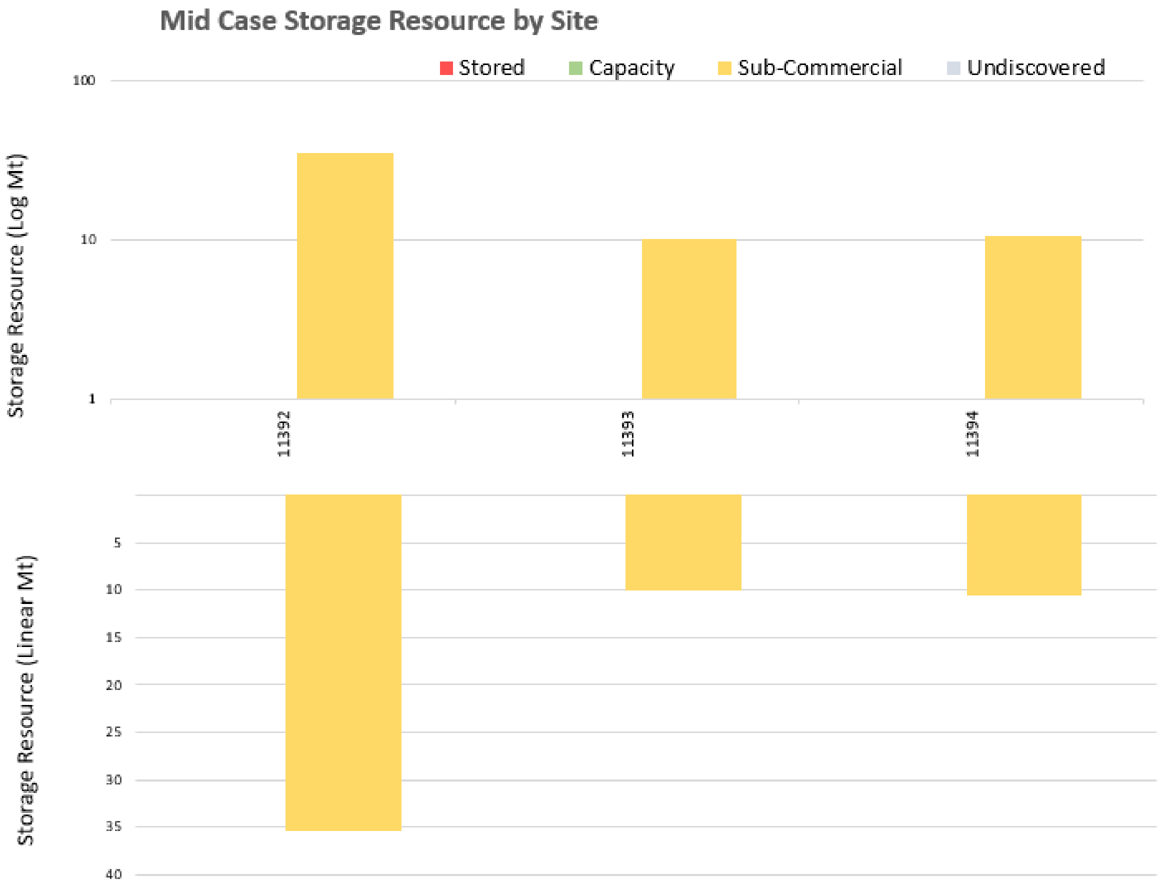


Figure 23-2: Storage resource summary for Peru compiled in the CSRC.

Graph above is log scale and graph below is linear. No project specified sites were identified.

23.3 Evaluation History

There are limited evaluations of CO_2 storage potential within Peru.

Llamas and Cienfuegos, 2012 [1] developed a multicriteria decision methodology to detect suitable areas for storing CO_2. This was utilised by Carlotto in 2019 [2] to review CO_2 storage potential in depleted fields of the Talara, Sechura, Maranon and Ucayali basins, with storage capacity reported in millions of barrels (MMBLS) or million stock tank barrels (MMSTB). The review for the Talara Basin was built upon further by Pomar-Castromonte et al. in 2021 [3] evaluating CO_2 storage capacity of the Pariñas Formation within the Bellavista and Calzada fields.

23.4 Resource Review

Peru has zero saline aquifer storage sites and three depleted field sites.

23.4.1 Major Projects

There are no major projects.

23.4.2 Depleted Oil & Gas Fields

Pomar-Castromonte et al. [3] evaluates CO_2 storage capacity of the Parinas Formation belonging to the Talara Basin through analytical modelling based on mass balance equations and numerical modelling using IMEX CMG. The evaluation of the Bellavista and Calzada oil deposits involves CO_2 storage capacity estimations with CO_2 and reservoir fluid (oil and water) interaction. The number of wells in the Bellavista oil deposit is 42, and three (3) within the Calzada oil deposit.

The Parinas Formation is made up of fine conglomerates, little consolidated, of rounded to sub-rounded shape and of good selection. It is composed of thick sandstone banks and presents favourable parameters for the geological storage of CO_2 (porosity of 17.6%, a permeability of 640 mD, a depth ranging between 950 m and 1570 m, and a seal rock that overlies the rock of the formation, Aylas, 2021). This seal rock has a permeability that is practically equal to zero, which is favourable to prevent the upward flow of CO_2 towards the surface (Aylas, 2021 [4]).

To calculate the basic storage capacity of the reservoir rock of the Parinas Formation (Bellavista and Calzada fields) the formula proposed by Bachu et al. (2007) [5] is used. The Calzada oil deposit is subdivided into two areas, basically differentiated by the value of the recovery factor (Rf). Calzada 1 has a recovery factor of 9%, and Calzada 2 has a recovery factor of 11%. In total, the basic CO_2 storage capacity is 20.6 million tons, approximately.

For the Bellavista Field, a theoretical volumetric capacity was provided, before subsequent studies using Bachu et al. 2007 [5] and Thian & Zhao, 2008 [6] determined the dynamic simulation numerical model capacity.

The values for both fields are classified as Inaccessible in an absence of any regulatory information that permits CO_2 storage.

23.4.3 Saline Aquifers

Peru has no identified saline aquifers for CO_2 storage. However, this may change if there is a regulatory shift to permit CO_2 storage in Peru.

23.5 Regulatory Framework

In 2016, Peru passed a climate law (the first of its kind in the region) that establishes a greenhouse gas inventory system known as INFOCARBONO [7]. This is a useful tool for sectors wishing to design policies, plans or other management tools for reducing greenhouse gas emissions and promoting carbon sequestration.

Peru's climate change framework law (Law No. 30754) published in 2018 establishes principles and approaches for managing climate change, including provisions for carbon sequestration [8]. Currently, there are no regulations for carbon capture use and storage in Peru, but this might change as the country adds regulations and policies related to climate change.

23.5.1 Issues for the Assessment

To calculate the basic storage capacity of the reservoir rock of the Parinas Formation (Bellavista and Calzada fields) the formula proposed by Bachu et al. (2007) [5] is used. The fundamental assumption of this formula is that the volume occupied by hydrocarbons produced and / or extractable can be filled by CO_2. Another important assumption is that CO_2 can be injected up to the original or virgin pressure of the reservoir (prior to the extraction of hydrocarbons).

23.6 Future Updates

23.6.1 Future evaluations

Future updates would look for additional site reviews completed as Peru builds it’s CO_2 value chain.

24 Suriname

24.1 Summary

Suriname was assessed during Cycle. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Suriname.

Table 24-1: Storage resource classification summary for Suriname.

24.2 Evaluation History

There are no published reports or research to support that Suriname has been investigating storage of CO_2. However, Suriname does have a hydrocarbon industry which it is actively developing, particularly in its offshore areas. Significant oil and gas discoveries have been made in the Guyana-Suriname Basin. These fields may hold potential for CO_2 storage in the future, once depleted. With regards to onshore, Suriname's geology is dominated by a Pre-Cambrian shield comprised of volcanic and metamorphic rocks. Hence the onshore area has limited geological CO_2 storage potential.

24.3 Regulatory Framework

Suriname does not currently have any regulatory framework for geological CCS.

24.4 Future Updates

Future updates are unlikely to be necessary in the near future; however, any depleted fields may hold some potential, but this will not be for many years yet.

25 Trinidad and Tobago

25.1 Summary

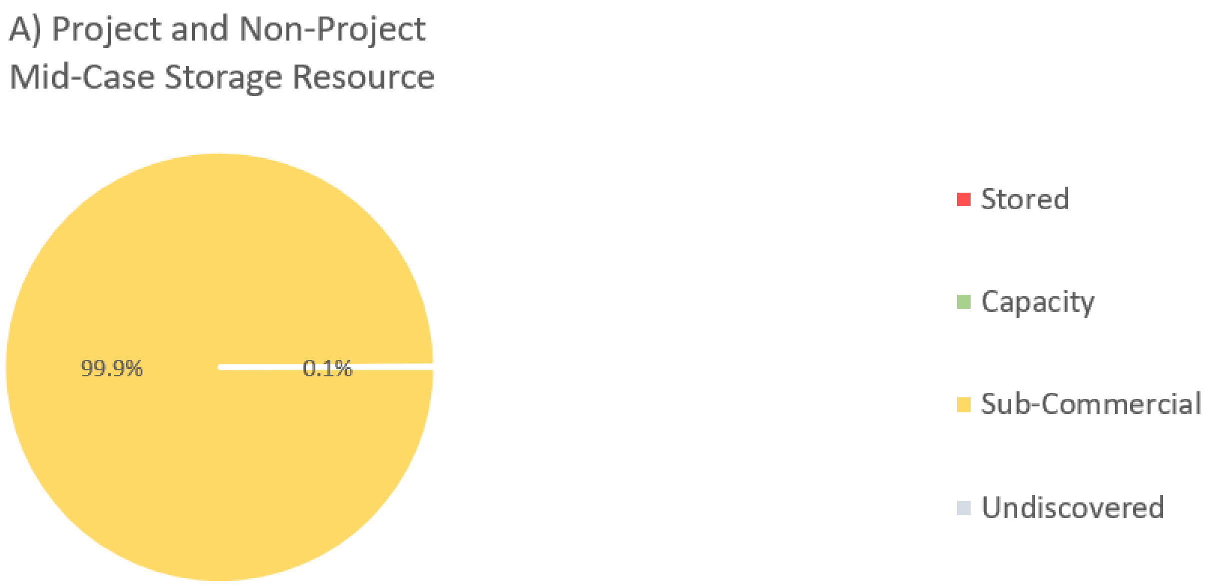
Trinidad and Tobago was assessed during Cycle 5. Moderate data availability shows potential storage for depleted fields. These are classified as Discovered but Inaccessible due to the lack of cassation of production dates, or a CCS specific regulatory and legal framework.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.595	0.000
Undiscovered	0.001	0.000
Aggregated*	0.595	0.000

* 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 Trinidad and Tobago.

Table 25-1: Storage resource classification summary for Trinidad and Tobago.

- Research on Trinidad and Tobago has been mainly academic.
- There are 17 sites in depleted fields with a cumulative storage capacity of 595.5 Mt.
- The main basins for storage site are the onshore and offshore Southern Basin in Trinidad and hydrocarbon fields in the west and east offshore areas Trinidad and offshore west Tobago.
- The University of Trinidad and Tobago and the University of the West Indies have jointly proposed to undertake the development of a national carbon dioxide storage atlas.
- Currently there is no legislation passed or blanket approval for CO_2 storage. However, interest in CO_2 storage is prominent and there is a committee looking into it outlining the rules for more robust legislation.
- Trinidad and Tobago score 22 on the GCCSI CCS Readiness Index.



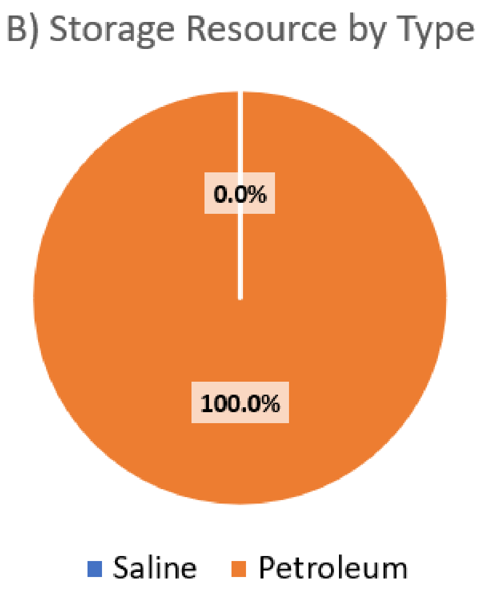


Figure 25-1: Trinidadian and Tobagonian spread of Storage Sites.

A) Spread of storage resource in all Trinidadian and Tobagonian sites across SRMS classifications. B) Split of Trinidadian and Tobagonian storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

25.2 Resource Statement

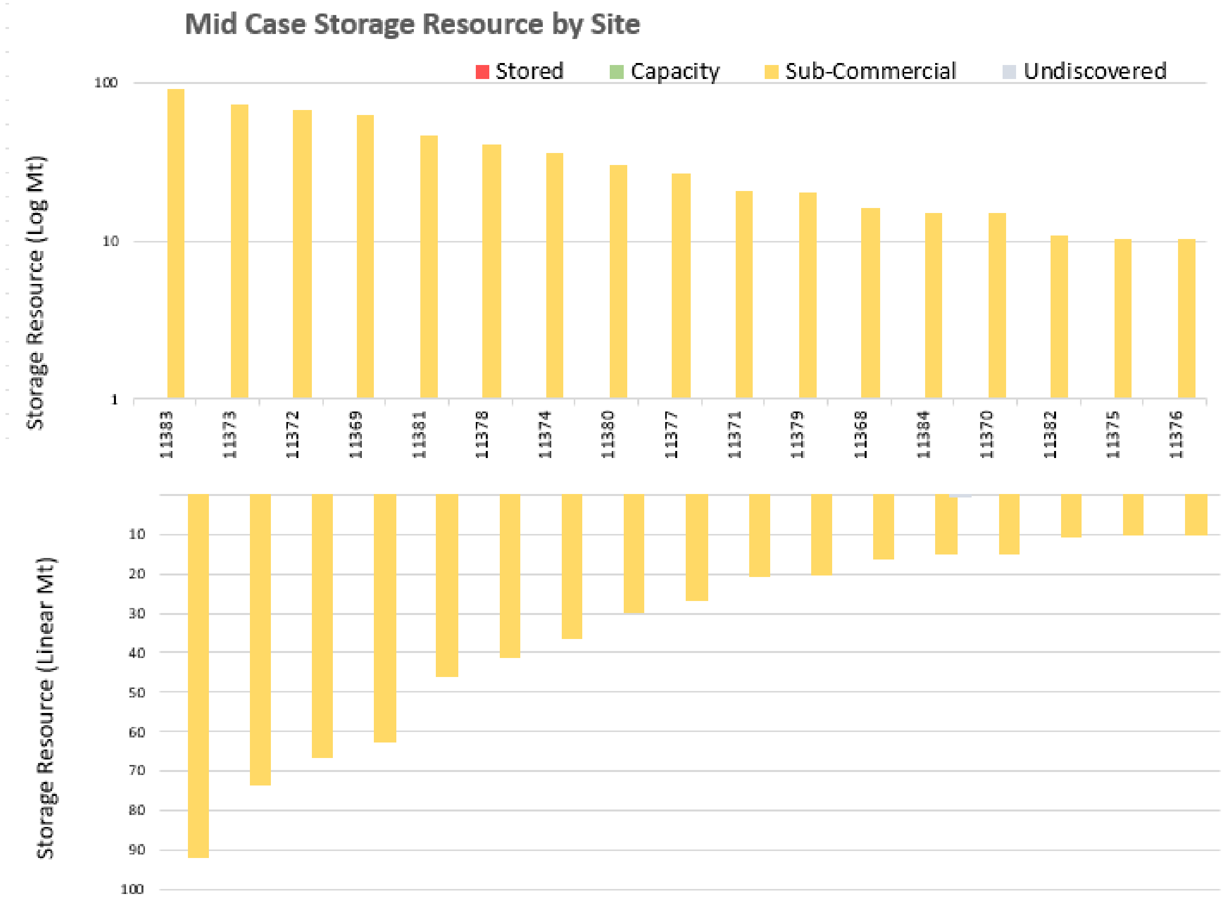


Figure 25-2: Storage resource summary for Trinidad and Tobago compiled in the CSRC.

Graph above is log scale and graph below is linear. No project specified sites were identified.

25.3 Evaluation History

Trinidad and Tobago's storage resources were reviewed, and four sources of information were taken into the catalogue. The first was a 2013 report from the Trinidad & Tobago Ministry of Environment and Water Resources on 'Feasibility of Carbon Capture & Storage Projects in Trinidad & Tobago [1]. In this report, 57 depleted fields were screened, with 36 providing a CO_2 Storage capacity, 12 of which are large enough (>10 Mt) to be recorded in the catalogue. Deep saline aquifers were not considered. Capacity in this study is estimated using the principle that hydrocarbon production from a reservoir is a good estimate of the volume of CO_2 (at reservoir conditions) that can be injected into the depleted reservoir.

Bradshaw-Niles provides two studies on carbon storage potential as part of the Trinidad & Tobago Energy Conference in 2023 [2] and 2024 [4], working jointly with the University of West Indies and the University of Trinidad and Tobago. In the 2023 publication, storage capacity is assessed for several different fields across Trinidad including for the onshore area; Forest Reserve (4.8 Mt), Palo Seco (2.6 Mt across multiple reservoir units), Point Fortin (6.3 Mt) and Grand Ravine (4.6 Mt), and for offshore fields; the Soldado oil fields (90.2 Mt). Only data for the Main Soldado and North Soldado fields and the combined onshore Southern Basin of Trinidad are large enough to be included in the database.

In 2024, Bradshaw-Niles [3] presented values as part of a study focused on the offshore Soldados fields, and onshore Point Fortin, Guapo, Grand Ravine, Forest Reserve and Palo Seco fields all of which are in the Southern Basin and Blocks 1(a) and 1(b) in the Northern Basin.

Alexander et al. [4] published a CO_2 storage capacity assessment including a case study for an onshore block in Trinidad in 2024. The paper focuses on a depleted gas field, providing low, base and high cases for theoretical and effective storage for Field A, Field B, Field C and a combined Block X assessment. In addition, the paper also provides a capacity for the attached saline aquifers of each field and block, within the Upper Cipero Formation.

Additionally, Arjoon et al. [5] published a life cycle analysis of a CO_2 project in Trinidad and Tobago in 2022. This paper aims to determine the net CO_2 emissions from a direct air capture system in tandem with a renewable energy project. A comparison of storage capacities of a saline aquifer and a depleted hydrocarbon reservoir onshore southern basin of Trinidad are shown, however the values are too small (<10 Mt) to be recorded in the database.

25.4 Resource Review

Trinidad and Tobago has zero saline aquifer storage sites and 17 depleted field sites.

25.4.1 Major Projects

The University of Trinidad and Tobago and the University of the West Indies have jointly proposed to undertake the development of a national carbon dioxide storage atlas [6]. The atlas is a key component of the programme that is intended to develop full-scale carbon capture and CO_2 enhanced oil recovery deployment. No information has been publicly shared for inclusion in the database.

25.4.2 Depleted Oil & Gas Fields

The results of the 2013 Ministry study [1] suggest that the most prospective CO_2 storage opportunities are: on the East Coast – Osprey (26.9 Mt), Amherstia (16.2 Mt), Mahogany (10.2 Mt) and Dolphin (66.8 Mt) gas fields; on the North Coast – Charconia (20.7 Mt), Hibiscus (73.5 Mt) and Poinsettia (41.3 Mt); and onshore – Carapal Ridge oil field in the Central Block (9.2 Mt). The other fields reported in the study are Cassra-1 (62.6 Mt), Cassra-2 (15 Mt), Iguana 1 (36.5 Mt), Iris (10.2 Mt) and Sancoche (20.5 Mt). It is not specifically stated why these fields were ruled out during the screening process.

A substantial assumption is made by the report to classify Block 1a and Block 1b oilfields offshore to the west of Point Lisas as sufficient capacity and suitability for CO_2 storage to support a CCS development program. However, no data is provided, and therefore the site has been excluded from the catalogue.

In Bradshaw-Niles (2023) [2] CO_2 storage capacity has been provided in the paper as theoretical and effective storage; however, no details are provided for how the effective storage was calculated. Values are given as P90, and what is inferred as P50, which is included for theoretical capacity in the database. These are stated as 29.9 Mt for the Main Soldado Field, 46.3 Mt for the North Soldado Field, and 10.9 Mt for the onshore Southern Basin.

In Bradshaw-Niles (2024) [3] the theoretical storage capacity was estimated to be 126.5 Mt, with the effective storage capacity being 92.1 Mt. No definition of the calculation from theoretical to effective storage capacity has been provided.

Alexander et al. study [4] provides a base case effective storage capacity for Field A as 15.1 Mt, Field B as 1.4 Mt and Field C as 0.4 Mt, giving a combined storage potential for Block X as 16.9 Mt.

The values for all studies are classified as Discovered but Inaccessible in an absence of any regulatory information that permits CO_2 storage.

25.4.3 Saline Aquifers

There is limited information reported on Trinidad and Tobago's potential saline aquifers for CO_2 storage. However, this may change if there is a regulatory shift to permit CO_2 storage in Trinidad and Tobago.

The Alexander et al. [4] study shows an attached saline aquifer for Field A recorded as Undiscovered at 0.7 Mt. The combined CO_2 storage capacity in saline aquifers of each field amount to 0.7 Mt, with Field A accounting for approximately 90% of the total volume that could potentially be stored in 'Block X'. This can be attributed to the size of the field and its maximum injection pressure parameter in comparison to the other fields. The values are classified as Inaccessible in an absence of any regulatory information that permits CO_2 storage.

25.5 Regulatory Framework

There has also been growing interest in the storage aspect of carbon management within Trinidad and Tobago. At the Commonwealth Heads of Government meeting in 2009, the South Chamber of Industry and Commerce (now the Energy Chamber) delivered a presentation entitled 'Carbon Capture and Storage: The T&T Landscape'. This presentation inspired the formation of the Carbon Reduction Strategy Task Force (CRSTF) in April of 2010 [6]. The Ministry of Planning and Development's August 2015 'Strategy for Reduction of Carbon Emissions in Trinidad and Tobago to 2040' identified the development of a carbon capture and storage map with possible locations for CCS sites, as a proposed measure in its action plan for the mitigation of greenhouse gas [6]. In 2020, the Ministry of Energy and Energy Industries publicly released the guidance document 'Guidelines to Operators for the Approval of a CO_2 Injection Project by the Resource Management Division' [7] which focuses on enhanced oil recovery, followed in 2021 by the establishment of a Carbon Capture and Carbon dioxide Enhanced Oil Recovery Steering Committee to manage the implementation of a large-scale CO_2 EOR projects.

Currently there is no legislation passed or blanket approval for CO_2 storage. However, interest in CO_2 storage is prominent and there is a committee looking into it outlining the rules for more robust legislation.

25.5.1 Issues for the Assessment

Across all studies, containment is assumed competent due to the sites being depleted fields and having held hydrocarbons, however the number of wells in the fields are unknown.

The Alexander et al. [4] study has ambiguity in the location of the site as the literature does not specific report the name of the field, however via Hugget and Burley (2008) [8], we have identified this as the Carapal Ridge Field. Although the source reference names the fields within 'Block X' as A, B and C, cross referencing of other literature suggests that these are the Carapal Ridge, Baraka and Corosan fields, the largest field being the Carapal Ridge field in the onshore Southern Basin.

25.6 Future Updates

25.6.1 Future evaluations

Future evaluations should address any legislation updates and if more refined storage assessments or any sites that have become of interest for a project.

26 United States of America

26.1 Summary

The CSRC Cycle 1 assessment identified the CO_2 storage resource for the United States of America as shown in the table below. This was not updated in Cycle 2 but was in Cycle 3.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.008	0.008
Capacity	0.000	0.000
Sub-Commercial	257.979	55.289
Undiscovered	7803.826	15.000
Aggregated*	8061.813	70.297

* 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 United States of America.

Table 26-1: Storage resource classification summary for United States of America.

- Storage resource potential is present in both saline aquifers and oil and gas fields.
- Potential storage resources have been identified in 36 US States with 12 projects and 14 regional studies included in the Cycle 1 Assessment. High level, state-wide estimates are also provided by the DOE Atlas V, but these have no detail in terms of individual resource location or estimate attached.
- As of December 2019, 4.36 Mt of CO_2 has been reported injected and stored or permitted for injection by 4 CCS projects operating in the USA: Illinois Basin Decatur project (1Mt), Illinois: ICCS (5 Mt), the Citronelle Project (0.1 Mt), and the Michigan Basin Niagaran Pinnacle Reef Trend project (0.14 Mt). A significant volume of CO_2 has also been injected into oilfields via EOR operations, but this figure is not included in the SRMS.
- While the US storage resource is distributed across the Lower 48, the regional saline aquifer studies are dominated by the northern states within the Williston, Michigan, Illinois, Powder River, and Denver basins. Future assessments should focus on updating with the vast potential in other parts of the country, including California, the southern states, the Gulf of Mexico region, and the Federal Offshore.
- The current regulatory system is positive to CCS with recent changes to the tax system (45Q) to incentivise both CO_2-EOR and geological storage. California leads the way with state-level credit-based systems. Permitting for existing CCS projects provides a way forward for future projects.
- The DOE-funded CarbonSAFE initiative is currently funding thirteen Phase I 'Pre-Feasibility'

studies and six Phase II 'Feasibility' programs with the aim of identifying several saline aquifer sites with proven potential to store at least 50 Mt/site with an anticipated injection start-date of 2026.

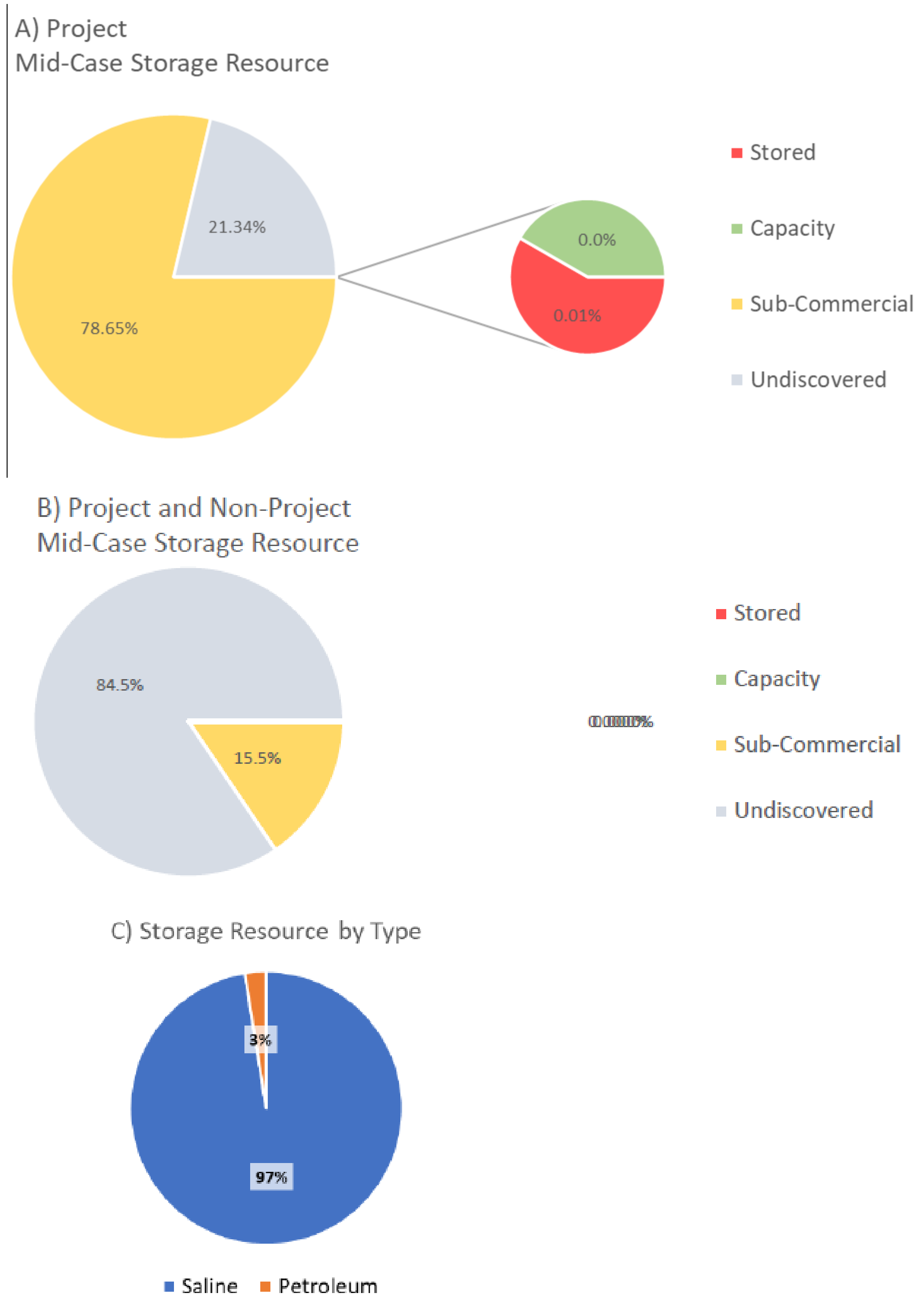


Figure 26-1: United States of America spread of Storage Sites.

A) Spread of storage resource in U.S. sites (132) across SRMS classifications, where a project has been specified. B) Spread of storage resource in all U.S. sites across SRMS classifications; both project specified and not. C) Split of U.S. storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

26.2 Resource Statement

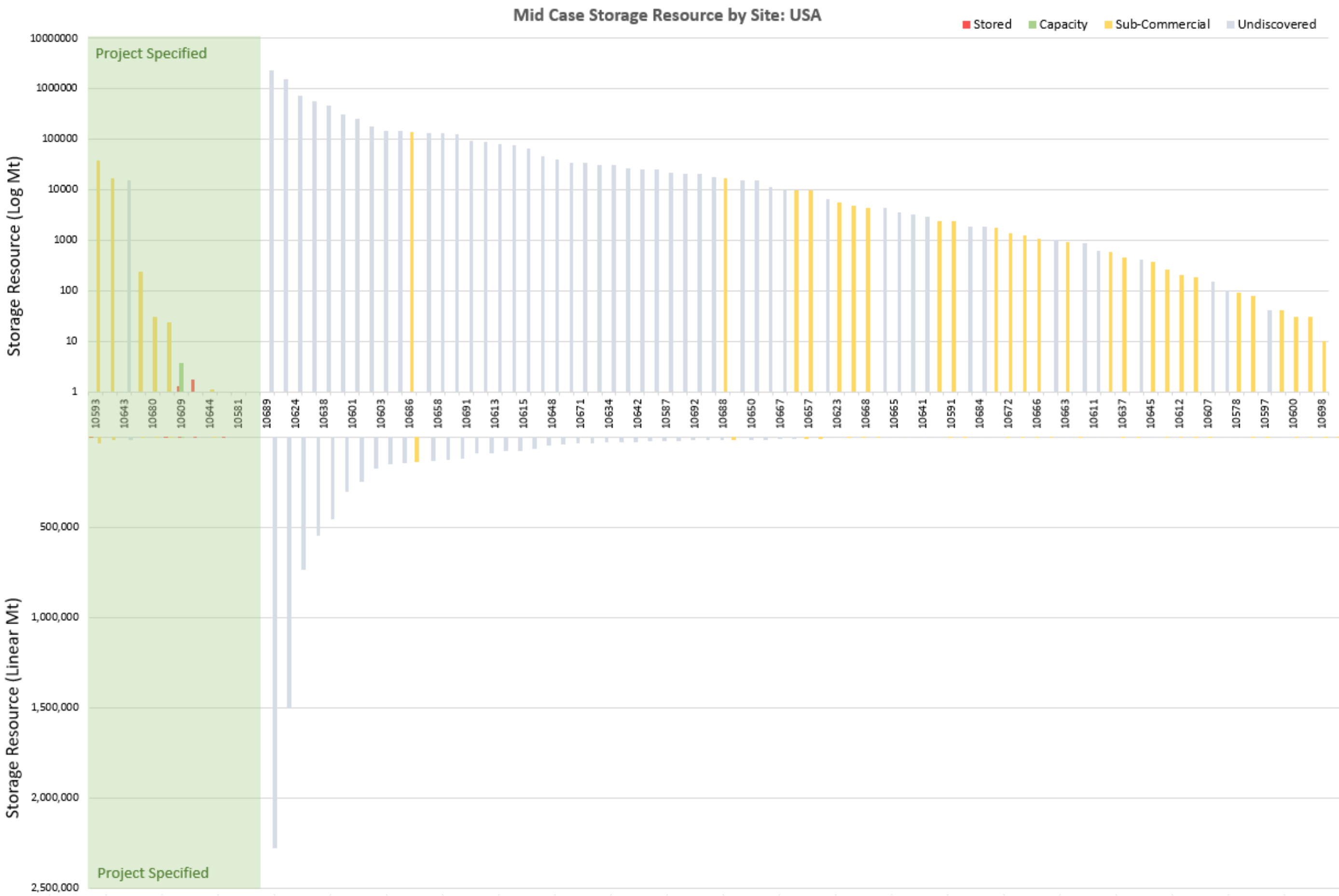


Figure 26-2: Storage resource summary for U.S. compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

26.3 Evaluation History

The initial basis for the Cycle 1 Assessment was the 2015 US and North America Carbon Storage Atlas - fifth edition produced by the National Energy Technology Laboratory and commissioned by the US DOE Office of Fossil Energy. The storage information in Atlas V was developed to provide a high-level overview of the immense CO_2 storage potential of the North America region and was intended to provide developers with a starting point for further investigation. The Atlas considers a full range of sequestration options including oil and natural gas reservoirs (with or without EOR), saline aquifers, deep unmineable coal seams, unconventional organic rich shales, and basalt formations. Data and information in the Atlas are based on input from the DOE-funded Regional Sequestration Partnerships, research groups delivering evaluations of sequestration potential across the USA and parts of Canada. The Atlas V provides a state-by-state breakdown of potential CO_2 storage resources available in both saline formations, and oil and gas fields. These are referred to as 'State-wide Evaluations' for both saline aquifers and petroleum fields to highlight the fact that little is known about the origin and geographic location of the data presented. In addition, the Atlas delivers short case studies on the major evaluation and demonstration projects taking place across North America between 2005 and 2015 which points to the detail that is available but remains unpublished.

The State-wide saline aquifer evaluations have been further broken down into regional studies carried out by the Regional Partnerships. These are generally presented as estimates of storage resource potential at the sequence play level for a geological basin and, as such often cross state or as in the case of the Cambro-Ord Basal Sand, national boundaries. In such cases, it has been assumed that the regional studies by the partnerships represent the summed resource reported at the state level by the Atlas V and so the State-wide evaluation for those states is nulled.

In the Cycle 1 Assessment, the demonstration project sites identified from the Atlas V were reviewed and updated, where possible, to populate the SRMS database. The nature of the Atlas V has presented some challenges for the storage resource classification due to its extensive scope, but high-level overview approach; the data collated by the Cycle 1 Assessment is in no way intended as a substitute for site-specific characterisation, testing and assessment.

The calculation methods used to assess resource potential are essentially volumetric methodologies for the Statewide assessments, with local variations at the local/Project-scale provided where information is available.

For oil and gas fields, Potential CO_2 Storage Resources have been estimated by the replacement method where suitable records are available and the volumetric method where production and injection records are unavailable.

26.4 Resource Review

Despite the volume, quality, and progression of CO_2 storage in North America, the current classification of potential storage resource is significantly limited due to the mismatch between the lack of detail available and the very large resource base, particularly for saline aquifers. The approach taken here is to adopt a minimum maturity level approach to classification and only elevate resources to more mature classes when there is both evidence and quantification available. This has led to an understatement of the maturity of the resource potential with 97% held within the Undiscovered: Prospective maturity class; the USA represents a strong candidate for re-classification.

The Sub-Commercial resource class contains both the oil and gas fields (203 Gt, classified as 'Inaccessible' at this stage due a lack of knowledge on field accessibility dates), and those storage projects (55 Gt), classified as 'Development Not Viable) for which detailed data are not published, or where their current activity status is on-hold, cancelled, or unknown.

26.4.1 Major Projects

The USA has amassed a huge amount of information through the Regional Carbon Sequestration Partnerships. These have informed the location and potential scale of storage through high level screening studies through to the selection of pilot projects. The US DOE is now developing the next generation of large-scale, integrated CCS projects: the CarbonSAFE Initiative.

At the time of assessment, the only projects reporting stored CO_2 in the subsurface (non-CO_2 EOR) are the Alabama Citronelle Project (0.114 Mt), the Illinois IBDP, injecting 1Mt over 3 years, and the IL: ICCS project, injecting up to 5Mt over 3 years.

26.4.2 Depleted Oil & Gas Fields

While there is a large inventory of CO_2 injection into commercial oil properties for enhanced oil recovery, there are very few studies which have evaluated the injection of CO_2 into depleted oil and gas fields for carbon storage without an uplift in hydrocarbon production. The DOE Atlas V does however report large resource estimates in oil and gas fields for some states, e.g., Texas: 17180 Mt, West Virginia: 9840 Mt, New Mexico: 9710 Mt, Louisiana: 5700 Mt, and California: 4850 Mt, but the source evaluations for these figures are unknown. The National Energy Technology Laboratory (NETL) has indicated that an additional demand of 10 to 45 Gt CO_2 for enhanced oil recovery operations may exist across the Lower 48 states, Alaska and Offshore Gulf of Mexico. This could significantly increase the available storage potential of depleted oil fields but a more detailed breakdown of where and which fields could be targets for CO_2 storage is needed, and a mechanism for including this resource into the SRMS.

26.4.3 Saline Aquifers

The storage resource in the USA is currently dominated by the state-wide (Basin Play) saline aquifer resource estimates provided by the DOE Atlas (7803 Gt), and regional studies (e.g., COSS (Basal Sand), and the Lower Cretaceous and Mississippian aquifers; 416 Gt) reported by the DOE Regional Partnerships. These regional estimates are assigned Undiscovered: Sequence

Play status due to the immense scale of the aquifers and the lack of published detail which would move them into the Discovered resource category. The scale of this resource suggests that the USA Discovered portfolio is heavily under-estimated.

The Cycle 1 Assessment focused the PCOR partnership studies which cover Montana, North and South Dakota, NW Nebraska, and NE Wyoming and focus on the Williston, Powder River and Denver basins. As discussed earlier (Section 6.3.4.2: Application of SRMS to North America), this region has required some careful treatment to avoid double counting. Those states wholly covered by the PCOR study area (MT, ND, SD) have had the State-wide saline aquifer evaluation nulled in the database to avoid double counting, however, there is a mismatch between the summed state-wide evaluations for these three states, and the summed regional sequence play resource estimates reported.

This is likely to be at least partly a result of re-calculation using a different storage efficiency factor by the DOE before incorporation into the Atlas, making direct comparison of reported data difficult.

The state-wide saline aquifer evaluations in other areas of the USA point to extremely large, gigatonne-scale, potential storage resources, for example, Texas: 1505.8 Gt, California: 1311.1 Gt, Louisiana: 734.6 Gt, Wyoming: 550.3 Gt, Mississippi: 459.2 Gt, and Alabama: 304.1 Gt. These regions require further evaluation to breakdown the resource for proper assessment against the SRMS. Future evaluations should also work towards validating, if appropriate, such large resource estimates.

26.5 Regulatory Framework

According to the GCCSI CCS Readiness Index 2018 (GCSSI, 2018), the USA ranks in the highest category, second only to Canada, indicating that, as a country the USA is well placed to enable CCS deployment, though long-term investment and commitment to CCS. Positive regulatory developments include a 2018 revision to the 45Q CCS tax incentive increasing the tax credit for dedicated geological storage to $22.66/ton (increasing linearly to $50/ton by 2026), and incorporation of a CCS Protocol into the California Low Carbon Fuel Standard (LCFS; a credit-based emissions reduction system). LCFS can also be stacked with 45Q. The final rules and a 2 year extension of 45Q was passed in December 2020. Several US states are looking to simplify CCS guidelines and provide regulatory clarity to help enable CCS deployment (Beck, 2019). The USA does, however, score maximum points on the GCCSI Inherent CCS Interest as a nation which relies heavily on fossil fuels and therefore is most likely to have a need for a robust CCS policy to achieve any future deep emissions reduction targets.

26.6 Issues for the Assessment

The Cycle 1 Assessment recognises that the resource statement significantly understates the Sub-Commercial storage resource within the USA saline aquifer systems due to the lack of detail on discovery status. The expectation is that there are large tracts of saline aquifer that should be considered as Discovered resource. Sub-Commercial storage resources are classified at this time as Development Not Viable due to the lack of information on this portfolio. The classification status of the commercial and active projects could also be improved through achieving more clarity regarding the progression and status of pilot projects with many projects only reporting very limited consents for injection at this time.

Several large, commercial-scale carbon capture facilities have either captured anthropogenic CO_2, or have commenced operations, however most are delivering to EOR operations. Large-scale capture and geological storage operations have not yet started-up in the USA. Future opportunities exist with the CarbonSAFE Initiative – see 'Future Updates' below.

26.7 Future Updates

26.7.1 Future assessments

The USA is expected to deliver several projects into the CCS pipeline in the next 5 years:

- IL: ICCS Project: this project follows (but is administratively separate to) the pilot IBDP project in Decatur, Illinois. CO_2 injection and monitoring continues through 2020. The final injection volume needs to be updated when it becomes available.

- CarbonSAFE Initiative (the Carbon Storage Assurance Facility Enterprise) is a DOE-funded program focused on the development of geological storage sites with the potential to store at least 50 Mt CO_2. The timeframe for deployment is 2025-2035. Currently there are 13 projects at the 'pre-feasibility' stage and 6 being funded to better establish the 'feasibility' of a project. The funding cycle for many of these ends in during 2020-2021 and so results should be available for update in the next two assessment cycles. It is anticipated that the projects which succeed at the 'Feasibility' stage will be the major projects with the best chance of progressing to the FEED study stage and onward to project commerciality.

- Gulf Coast Offshore opportunity: a key area which is under-represented in the current SRMS database is the offshore zone and the offshore Gulf Coast. The region is represented by two Pre-Feasibility CarbonSAFE projects, but any future country update should include published reviews of the offshore potential.

27 Uruguay

27.1 Summary

Uruguay was assessed during Cycle 5. This country is reported as having no current CO_2 geological storage resources.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

* 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 Uruguay.

Table 27-1: Storage resource classification summary for Uruguay.

27.2 Evaluation History

There are no published reports or research to support that Uruguay has been investigating storage of CO_2. As part of it NDC's Uruguay's main efforts with respect to CO_2 reduction is to protect its native forest and prevent deforestation.

Uruguay does not have an active hydrocarbon industry at present but has been searching for oil and gas resources since the 1950s. With the discovery of oil off the coast of Namibia then Uruguay's interest in offshore petroleum increase. Whilst not applicable now to CO_2 storage opportunities, this may mean depleted oil and gas fields could be available in the distant future.

27.3 Regulatory Framework

Uruguay does not currently have any regulatory framework for geological CCS.

27.4 Future Updates

Future updates are unlikely to be necessary in the near future however any depleted fields may hold some potential, but this will not be for many years yet.

28 Venezuela

28.1 Summary

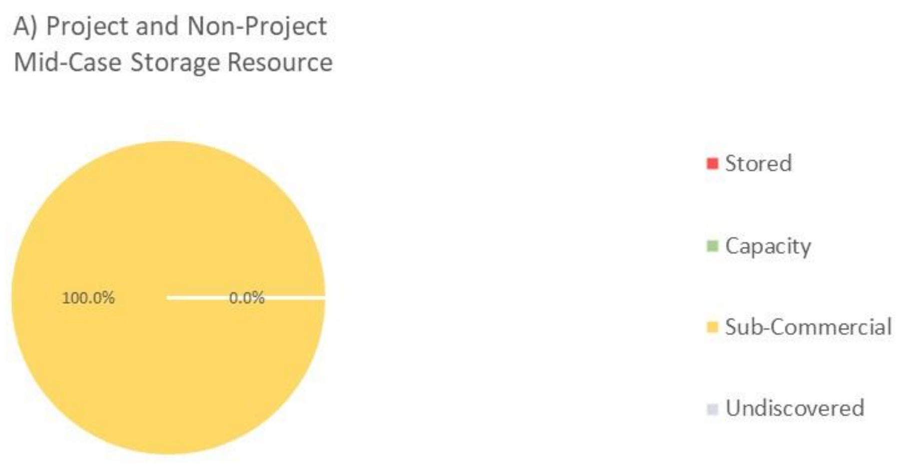
Venezuela was assessed during Cycle 5. The assessment identified the CO_2 storage resource for Venezuela as shown in the table below.

Classification	CO_2 storage resource (Gt) Project and no project	CO_2 storage resource (Gt) Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	2.700	0.000
Undiscovered	0.000	0.000
Aggregated*	2.700	0.000

* 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 Venezuela.

Table 28-1: Storage resource classification summary for Venezuela.

- Very limited research exists for storage sites in Venezuela. High level research estimates there may be around 2.7 Gt of storage resources in Lake Maracaibo oil and gas fields.
- To date there are no existing regulations in the country for CO_2 storage.
- Venezuela has been investigating opportunities for CO_2-EOR but there is limited information on this.



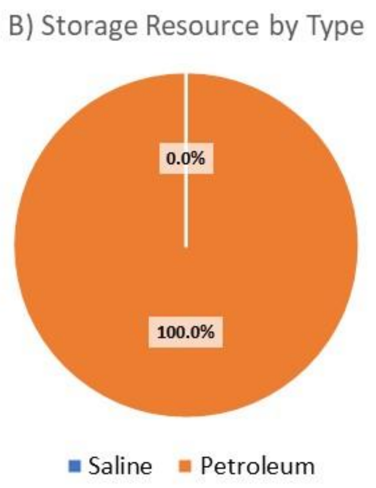


Figure 28-1: Venezuelan spread of Storage Sites.

A) Spread of storage resource Venezuelan site across SRMS classifications, where a project has been specified and not. B) Split of Venezuelan storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

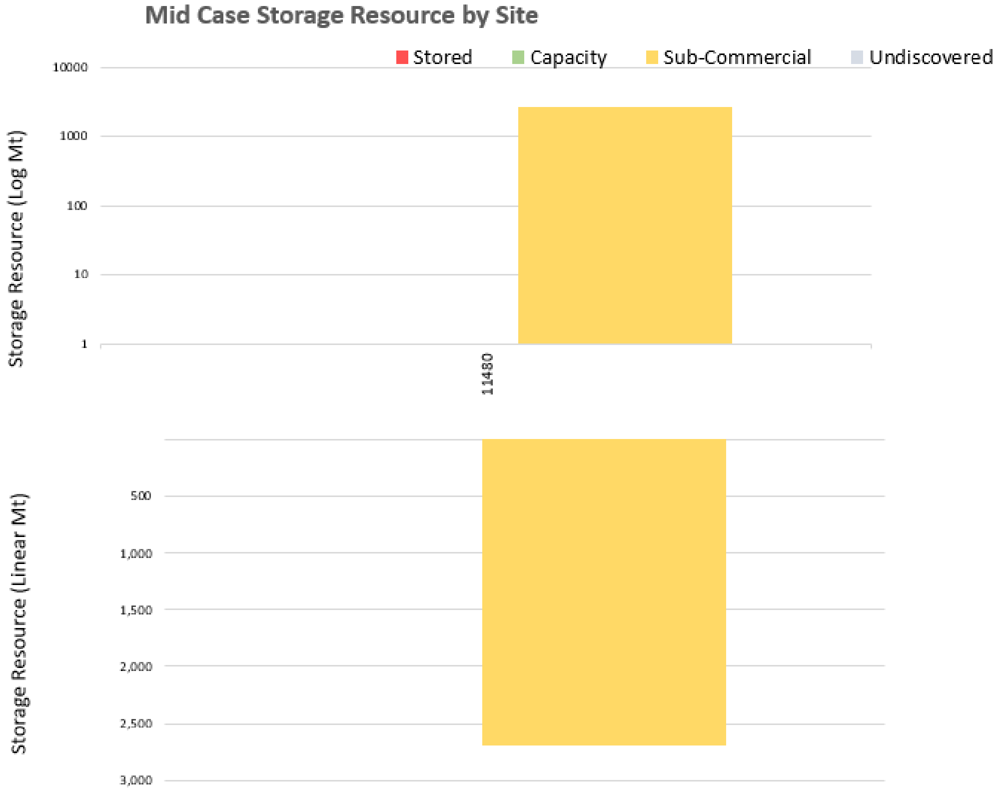


Figure 28-2: Storage resource summary for U.S. compiled in the CSRC.

Graph above is log scale and graph below is linear

28.2 Evaluation History

There is very limited literature and research in the public domain for CO_2 storage in Venezuela and this places great uncertainty on the resource estimates. One study that exists was performed in 2004 [1,2], where Venezuela was reviewed as part of a global source to sink study by Bradshaw and Dance. This high-level study reported that the majority of the potential CO_2 storage capacity is in the eastern offshore areas and in Lake Maracaibo. The research, although highly theoretical, estimates 2.7 Gt of resources in the lake's oil and gas fields. This is the only site entered into the CSRC and due to the lack of research and limited information on methodology. This resource estimate should be treated with caution. The Venezuelan national oil and gas company (PDVSA) has embarked on an EOR screening projects for a number of maturing fields [3].

28.3 Regulatory Framework

At the time of cycle 5, there is no information on any establishment for regulatory frameworks in Venezuela for CO_2 storage.

28.4 Future Updates

Venezuela may hold some significant CO_2 resources based on its history as a major oil and gas producer. Saline basins may also exist but there is no research published on them to date. Future updates may be better placed to see if the country is investigating CO_2-EOR and if these projects will later migrate into dedicated storage projects.

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