

CO₂ Storage Resource Catalogue

Cycle 5 Report

ASIA

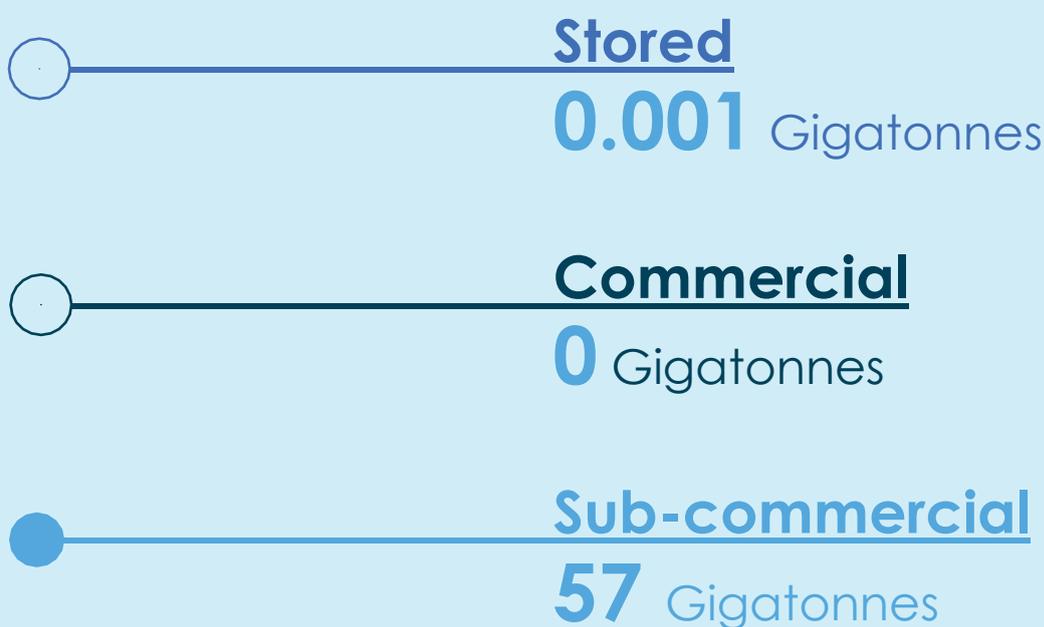
August 2025



HALLIBURTON



Amounts of CO₂



Undiscovered
4332 Gigatonnes

Appendix B: Asia

Afghanistan, Azerbaijan, Armenia, Bangladesh, Brunei, Bhutan, Cambodia, China, Georgia, India, Indonesia, Japan, Kazakhstan, Kyrgyzstan, Laos, Malaysia, Maldives, Mongolia, Philippines, Singapore, South Korea, Timor Leste, Tajikistan, Thailand, Turkmenistan, Uzbekistan and Vietnam.

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1 Armenia

1.1 Summary

Armenia was assessed during Cycle 5. This country is reported as having no current CO₂ geological storage resources.

Classification	CO ₂ storage resource (Gt)	
	Project and no project	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 Armenia.

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

1.2 Evaluation History

Armenia was reviewed during Cycle 5. Armenia is not a hydrocarbon-producing country and as such there will be no future CO₂ storage opportunities in depleted hydrocarbon fields. No CO₂ storage evaluations have been carried out at the federal level. There is only one study in the public domain that evaluated potential storage in Armenia. The outcome was that Armenia has no potential geological storage in either saline aquifers or depleted fields [1].

1.3 Regulatory Framework

Armenia does not currently have any regulatory framework for geological storage of CO₂. Armenia’s climate strategy includes carbon sequestration via nature-based solutions such as an increase reforestation and horticulture [2].

1.4 Future Updates

Armenia is unlikely to pursue geological storage as part of its energy transition plans. However, future updates could investigate to see if any further studies have been conducted in Armenia.

1.5 References

1. United Nations 2021. Geologic CO₂ storage in Eastern Europe, Caucasus and Central Asia: An initial analysis of potential and policy, United Nations, Geneva, [https://unece.org/sites/default/files/2021-04/geologic%20CO₂%20storage%20report_final_en.pdf](https://unece.org/sites/default/files/2021-04/geologic%20CO2%20storage%20report_final_en.pdf)

2. Government of The Republic of Armenia, 2021. Nationally Determined Contribution 2021-2030 of The Republic Of Armenia to the Paris Agreement. <https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20of%20Republic%20of%20Armenia%20%202021-2030.pdf>

2 Azerbaijan

2.1 Summary

Azerbaijan was assessed during Cycle 5. The CSRC has identified no CO₂ storage resources for Azerbaijan.

Classification	CO ₂ storage resource (Gt)	
	Project and no project	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 Azerbaijan.

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

- There's limited literature in the public space regarding CCUS in Azerbaijan. However, a master's thesis from Tallin University of Technology identifies viable storage sites. Also, SOCAR Green, established in 2024, is actively involved in researching CCUS technologies as part of its broader efforts to drive Azerbaijan's energy transition.
- There are no entries in the CRSC for Azerbaijan due to an absence of actual site resources being published. Whilst sites have been identified and presented in the context as options for potential projects, authors of the research do not perform a resource calculation. Three depleted oil and gas fields and one saline formation have been identified.
- The depleted fields include onshore Lokbatan, Mishovdag and Azeri-Chirag-Guneshli (ACG) offshore field. In addition, a saline formation within the Azeri-Chirag-Guneshli (ACG) offshore field has also been identified.
- To date, there are no CCUS projects in Azerbaijan.
- Azerbaijan is yet to put in place a legal framework to permit activities related to CCUS

2.2 Evaluation History

There are ongoing academic and industry studies for geological CO₂ storage and associated CCS infrastructure research in Azerbaijan. Studies from the Department of Materials and Environmental Technology, Tallinn University of Technology have found that almost 90% of existing pipelines are compatible for CO₂ transportation in terms acidity level, pressure limitation of compressed CO₂, and its cost-effectiveness [3]. The report identified options for offshore storage in both depleted fields and saline aquifers but did not perform and resource calculations.

State Oil Company of Azerbaijan Republic founded SOCAR Green in 2024. SOCAR Green is actively involved in the exploration and development of carbon capture, utilization, and storage (CCUS) technologies as part of its broader efforts to drive Azerbaijan's energy transition. As part of its efforts, SOCAR Green is collaborating with international partners to conduct pre-feasibility assessments and research into the most effective CCUS technologies suited for Azerbaijan's energy landscape.

2.3 Resource Review

With a history of an active and successful hydrocarbon industry, Azerbaijan may have promising options for CO₂ storage in both onshore and offshore sites in depleted oil and gas fields, as well as saline aquifers. To date, studies on any potential resource is purely academic.

2.3.1 Major Projects

Currently, there are no major projects of CO₂ storage in Azerbaijan, however Azerbaijan is demonstrating an active strategy for future CCUS enablement by setting up agencies such as SOCAR Green to advance CCUS in the country.

2.3.2 Depleted Oil & Gas Fields

There are three depleted Oil and Gas fields within the country's geological setting that can potentially store CO₂. These include the onshore fields of Lokbatan, Mishovdag and Azeri-Chirag-Guneshli (ACG) offshore fields. Their storage capacities haven't been clearly stated, only estimates for costs of potential CCS projects have been provided.

2.3.3 Saline Aquifers

A saline aquifer within the Azeri-Chirag-Guneshli (ACG) offshore field has been identified for potential CO₂ storage sites. Similarly, the amount of CO₂ it can store hasn't been publicly stated.

2.4 Regulatory Framework

No specific comprehensive legal framework in place in Azerbaijan for CCS.

However, the country pledged to reduce its GHG emission by 35% till 2030, which is an annual reduction of 11.9 Mt CO₂ equivalent. CCUS may need to become part of the efforts to reach this target [1].

2.5 Issues for the Assessment

The assessments to date do not report storage capacities. This has made any resource reporting for the CRSC difficult. In addition, there is very limited academic research on the geological aspects of potential sites. With the initiation of SOCAR Green, future research may become more active.

2.6 Future Updates

2.6.1 Future CRSC Cycles

Future updates to investigate any further research either at an academic or federal level will be valuable for Azerbaijan. The country has shown significant interest in establishing an energy transition group and therefore research will need to be done to help identify how Azerbaijan can seek to achieve its energy transition goals.

2.7 References

1. IEA, Energy Policies Beyond IEA Countries: Eastern Europe, Caucasus, and Central Asia, 2015
2. SOCAR Green, 2025. Renewables. AZ. 'SOCAR Green identifying innovative solutions to reduce carbon emissions across Azerbaijan'. Accessed 07/07/2025
3. Surkhay Mammad-zada, 2020. Carbon capture and storage feasibility in Azerbaijan Department of Materials and Environmental Technology,

3 Bangladesh, India, Pakistan and Sri Lanka

3.1 Summary

Bangladesh, India, Pakistan and Sri Lanka were assessed during Cycle 1. The CSRC has identified CO₂ storage resources for Bangladesh, India, and Pakistan as follows:

Bangladesh

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0	0
Capacity	0	0
Sub-Commercial	1.13	0
Undiscovered	20.0	0
Aggregated*	21.13	0

India

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0	0
Capacity	0	0
Sub-Commercial	0.84	0
Undiscovered	63.3	0
Aggregated*	64.14	0

Pakistan

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0	0
Capacity	0	0
Sub-Commercial	1.7	0
Undiscovered	30.0	0
Aggregated*	31.7	0

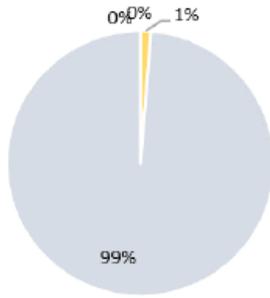
* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Bangladesh, India and Pakistan.

Table 3-1: Storage resource classification summary for Bangladesh, India and Pakistan.

- Bangladesh has 23 sites in the CSRC: 1 saline aquifer (Undiscovered; 20.0 Gt) and 22 gas fields (Discovered; 1.13Gt). India has 15 sites in the CSRC: 11 saline aquifers (Undiscovered; 63.3 Gt) and 4 oil and gas fields (Discovered; 0.84Gt) Pakistan has 17 sites in the CSRC: 2 saline aquifers (Undiscovered; 30 Gt), 14 gas fields and 1 site representing 56 small oilfields (Discovered; summed resource 1.7 Gt).
- No resources in Sri Lanka were reported.
- All sites in Bangladesh, India and Pakistan are classed as “Inaccessible” for both the “Sub-Commercial” oil and gas fields and the “Undiscovered” saline aquifers due to the lack of a CCS regulatory framework in any of these countries. No projects are defined.
- There are no defined storage projects in the region.

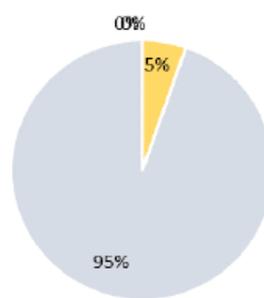
CO₂ Storage Resource Catalogue – Appendix B: Asia

India: Non-Project* Mid-Case Storage Resource



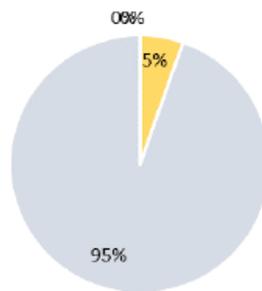
■ Stored ■ Capacity ■ Sub-Commercial ■ Undiscovered

Pakistan: Non-Project* Mid-Case Storage Resource



■ Stored ■ Capacity ■ Sub-Commercial ■ Undiscovered

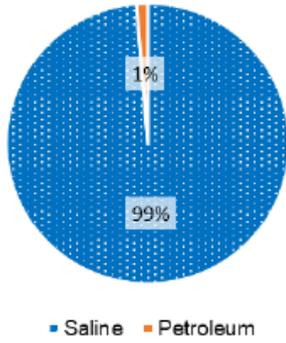
Bangladesh: Non-Project* Mid-Case Storage Resource



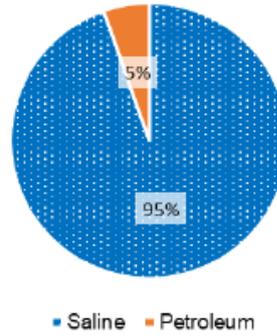
■ Stored ■ Capacity ■ Sub-Commercial ■ Undiscovered

*Note: No sites with a project specified were identified for India, Pakistan and Bangladesh.

India: Saline Aquifer vs Petroleum



Pakistan: Saline Aquifer vs Petroleum



Bangladesh: Saline Aquifer vs Petroleum

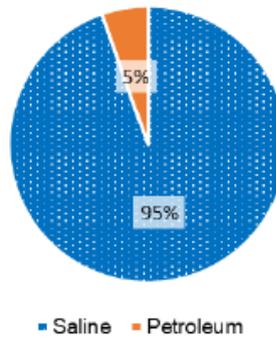


Figure 3-1: India, Pakistan and Bangladesh spread of Storage Sites.

a) Above: Spread of all storage resource across SRMS classifications. Below: Split of storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

3.2 Resource Statement

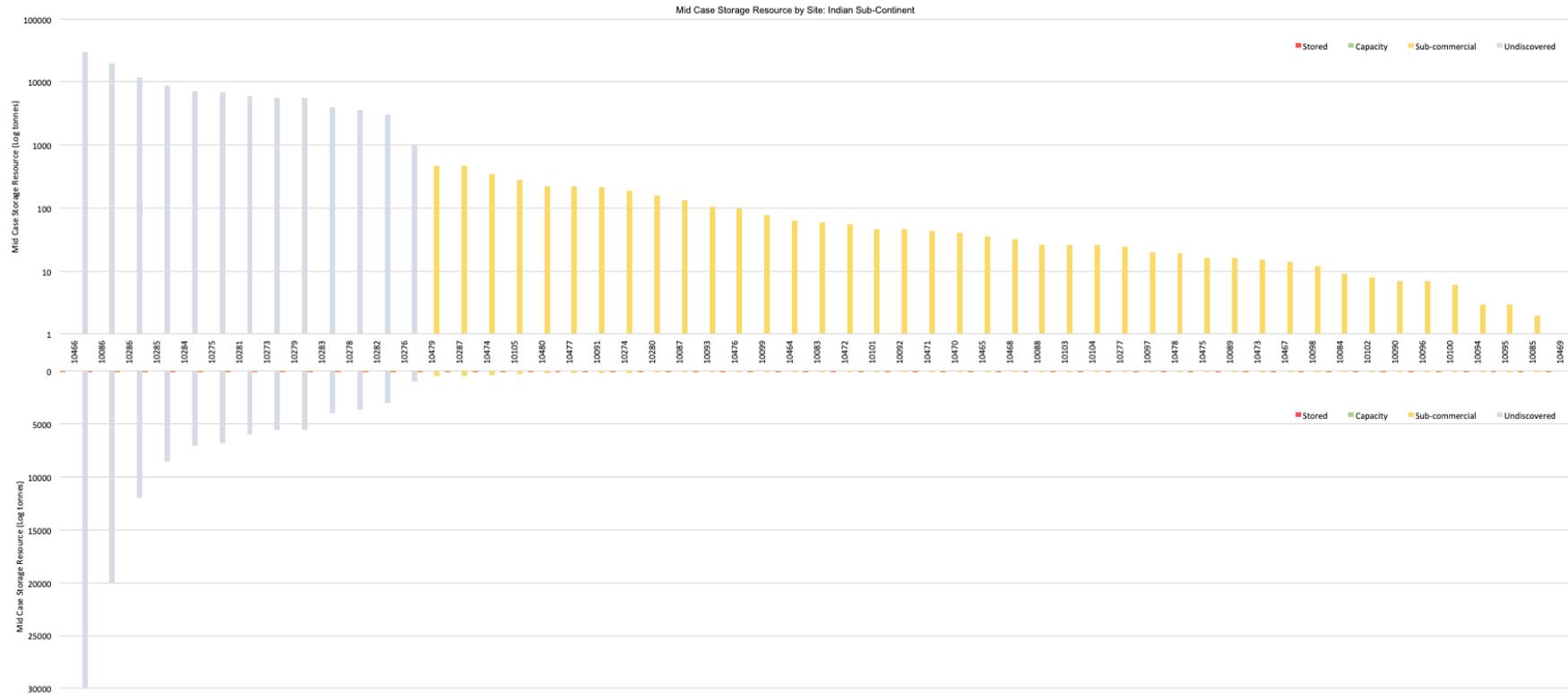


Figure 3-2: Storage resource summary for India, Pakistan & Bangladesh compiled in the CSRC.

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

3.3 Evaluation History

Bangladesh, India, and Pakistan underwent a preliminary assessment as part of the CSRC Cycle 1. A regional evaluation of the CO₂ storage potential of the Indian subcontinent was completed in 2008 by the British Geological Survey (BGS) on behalf of the IEAGHG [1]. Its purpose was an early-stage evaluation to gauge the potential for CO₂ storage in geological reservoirs across the region. It includes a review of all major emissions points of over 1Mt/yr. and considered depleted oil and gas fields, saline aquifers and deep unmineable coal seams. It excludes the potential storage resource within salt caverns and the subcontinent's extensive basalt formations in the Deccan and Raajmahal Traps. The national storage potential of India, Pakistan, and Bangladesh were all evaluated independently. Although there is some evidence for offshore resource potential to the north and west of Sri Lanka, no resource base has been quantified at this time.

The BGS evaluation used the replacement method for calculating storage resource for depleted oil and gas reservoirs, but for India this has been based upon state-by-state petroleum reserves figures (excluding oil already recovered). Elsewhere, many fields had statements of projected ultimate recovery. Further challenges with data availability have resulted in reasonable assumptions having to be made about CO₂ density, water influx, gas production and oil properties. All these factors contribute to the assessment of potential storage resources in depleted oil and gas fields as being both "highly provisional".

For saline aquifer resource estimation, an analogue method has been adopted where it is assumed that the CO₂ storage resource potential could be estimated using the following assumptions:

1. That one or more deep saline aquifers suitable for CO₂ storage were present over 50% of the basin.
2. 0.2 x 10⁶ tonnes CO₂ could be stored per km² of the area above.

This equates the CO₂ storage resource potential in Mt as 10% of the basin area in square kilometres.

3.4 Resource Review

Overall, it is only possible to identify two classes of quantified CO₂ storage resource potential within the region:

- Depleted oil and gas fields - these have been classified as "Discovered" storage resource, but also as "Inaccessible" at this time due to the absence of a CCS regulatory system within any of the countries in the region.
- Saline aquifer systems - these have been classified as "Undiscovered" storage resources, although it is accepted that there will be a small number of wells drilled into these systems

which establish discoveries, the location and details of these wells are not available within the regional assessment. Due to the absence of a CCS regulatory framework, the resources have been classified as “Inaccessible” at the time of assessment.

The regional assessment is an early and indicative assessment of storage resources. Over 95% of the stated resource is held within very poorly defined saline aquifers.

3.5 Regulatory Framework

None of the countries in this region have developed policies or CCS-specific regulatory or legal frameworks and only India has been evaluated under the GCCSI CCS Readiness framework. India is classed as a high opportunity country in that it would benefit from CCS deployment but has no system in place to encourage this. India has a legally nonbinding CO₂ emissions reduction target of 20-25% by 2020. In its Mission Innovation submission India indicated its interest in CO₂ capture and utilization (CCU) beyond EOR but there has been no significant action from the federal government to advance its deployment.

3.5.1 Issues for the Assessment

There is currently little information available to build a true picture of the storage potential of any of the countries in the region. Where data are available, the depth and generally low quality of the information make assessment difficult and so several assumptions have had to be made during resource estimation.

As a result of the low maturity of the resource estimation, there is only a single value provided for each resource. This has been recorded as the 'Mid-Range' estimate of resource potential. As future studies are planned in the region, effort needs to be made to move towards generating probabilistic assessments.

3.6 Brunei Darussalam

3.7 Summary

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

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	0.00	0.00
Undiscovered	0.558	0.558
Aggregated*	0.558	0.558

* 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 Brunei Darussalam.

Table 3-2: Storage resource classification summary for Brunei Darussalam.

- Storage resource potential is present in both saline aquifers and oil and gas fields.
- Storage resource evaluation is very limited in Brunei Darussalam. A single study, evaluating the techno-economic potential across the APEC region identifies only a single formation.
- While potential for CO₂-EOR and EGR are briefly mentioned (the Cycle V formation ranks 6th for CO₂-EOR), only injection into the saline aquifer located below offshore gas discoveries is considered.
- Significant additional technical evaluation will be required to mature the resource potential in Brunei.
- No published CCS-specific regulatory framework or enabling legislation have been published to date. There are currently no well-publicised plans for any future large-scale CCS project in the pipeline.

3.8 Evaluation History

There has been very limited evaluation of CO₂ storage potential in Brunei Darussalam. A single formation was included as part of a 2010 study for the Asia-Pacific Economic Region (APEC) looking at a techno-economic analysis of controlling CO₂ emissions in SE Asia.

3.9 Resource Review

3.9.1 Depleted Oil & Gas Fields

Basin screening was undertaken using a methodology based on that of Shaw and Bachu [2] and identified the Cycle V formation in the Baram Delta B basin in Brunei Darussalam as ranking 6th of 17 formations for CO₂-EOR potential across the region. Potential for enhanced gas recovery using CO₂ injection for re-pressurisation was also discussed but no detailed studies performed.

3.9.2 Saline Aquifers

A high-level techno-economic study of CO₂ storage in saline aquifers co-located with gas fields was carried out.

Simple reservoir simulations, based on reservoir properties from adjacent fields (assumption of 10 km distance from gas discovery), were used to develop a basic storage development plan based on well number and projected injection rates given assumptions of CO₂ volumes and reservoir conditions. Injection of CO₂ (stripped from produced gas) was assumed to take place into a saline aquifer below the gas-producing formation. As such, this evaluation qualifies for inclusion in the Catalogue as it does not represent direct replacement of produced CO₂ in the gas field. CO₂ volumes are based on predicted production and removal from the sales gas while the CO₂ resource is based on the volume of CO₂ injected into the saline aquifer during multiple simulation runs.

The reservoir properties for the injection simulation are provided in the Catalogue database but it should be noted that this is a very high-level study which was focused on providing an indication of the costs of CO₂ capture and storage to allow monetisation of the gas discoveries across the APEC region. The technical evaluation of the actual storage resource is limited; more evaluation will be required to qualify and mature the resource further.

3.10 Regulatory Framework

As of Cycle 3, no CCS-specific regulatory framework exists in Brunei Darussalam. The 2010 review by CO₂CRC [3] as part of the ASEAN assessment identified several laws related to environmental issues and noted that, while there was no specific legal requirement for the development of environmental impact assessments, there was a government requirement for such assessments for heavy industry projects. While it is possible that carbon storage projects could be enabled under existing legislation, particularly that covering the oil and gas industry, this has not yet been tested.

3.11 Issues for the Assessment

The extremely limited information in the public domain has restricted the assessment for Brunei Darussalam. Future development of a pathway to reducing the high per capita CO₂ emissions of the nation may drive further evaluation (see 'Future Updates' below).

3.12 Future Updates

In January 2022 an agreement was signed on a CCS partnership in Brunei Darussalam between Perdana Solutions Sdn Bhd and Asia Pacific Energy Solutions. The partnership is aimed at developing a CCS value chain and an action plan leading to implementation. Future cycles should follow any developments from this partnership.

4 Bhutan, Myanmar, Nepal

4.1 Summary

Bhutan, Myanmar and Nepal were assessed during Cycle 5. These countries are reported as having no current CO₂ geological storage resources.

Classification	CO ₂ storage resource (Gt)	
	Project and no project	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 Bhutan, Myanmar and Nepal.

Table 4-1: Storage resource classification summary for Bhutan, Myanmar and Nepal.

4.2 Bhutan

4.2.1 Evaluation History

Bhutan was reviewed during Cycle 5. Bhutan is not a hydrocarbon-producing country and as such there will be no future CO₂ storage opportunities in depleted hydrocarbon fields. No CO₂ storage evaluations have been carried out at the federal level or at an academic level.

Bhutan is carbon negative country and currently, through its dense forest, absorbs around 7Mt CO₂ annually, whilst it emits around 2Mt. It's constitution mandates that 60% of its land will remain forested for future generations. The country plans to offset any of its CO₂ emissions by exporting hydroelectricity [1,2].

4.2.2 Regulatory Framework

Bhutan does not currently have any regulatory framework for geological storage of CO₂.

4.2.3 Future Updates

Due to Bhutan's plans to offset any CO₂ emissions through methods other than geological CO₂ storage, it is unlikely that future updates to this country will be needed.

4.3 Myanmar

4.3.1 Evaluation History

Myanmar is a signatory to the Paris agreement and has pledged to reduce greenhouse gas emissions. There is limited mention of any CO₂ storage research in Myanmar, however, the

country was included in a review of the ASEAN countries to evaluate opportunities for a CCS industry in the region. Myanmar was not selected as an option for CO₂ storage [3]. The country was also reviewed by the GCCSI in 2024 with a similar conclusion regarding storage potential in the country [4].

There is research to support carbon sequestration through mangrove forestry as a consideration to help achieve net-zero emissions [5].

4.3.2 Regulatory Framework

Myanmar does not currently have any regulatory framework for CCS

4.3.3 Future Updates

Future research is likely to be limited for Myanmar although the country does have an oil and gas industry so may have potential in the future if depleted fields become of interest for CO₂ storage [6].

4.4 Nepal

4.4.1 Evaluation History

Nepal is a mountainous and seismically active country that may pose many challenges for developing a CCS industry. There is research to support that carbon sequestration through forestry as a consideration to help achieve net-zero emissions [7]. However, in its 2021 net-zero emissions strategy report, the Government of Nepal does mention that CCS alternatives beyond forestry may have to be considered but does not provide further details [8].

4.4.2 Regulatory Framework

Nepal does not currently have any regulatory framework for geological storage of CO₂.

4.4.3 Future Updates

Due to Nepal's plans to offset any CO₂ emissions through methods other than geological CO₂ storage, and potential lack of suitable geology it is unlikely that future updates to this country will be needed.

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5 Cambodia

5.1 Summary

Cambodia was assessed during Cycle 5. The CSRC has identified a CO₂ storage resource for Cambodia as follows:

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.047	0.000
Undiscovered	0.085	0.000
Aggregated*	0.132	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 Cambodia.

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

- Academic research by the Cambodian National Petroleum Authority (CNPA) was geared towards identifying suitable aquifers and hydrocarbon reservoirs within the Cambodian subsurface for the geological storage of CO₂.
- Three main formations within saline aquifers were discovered during this research as potential sites (~65 Mt in total). These formations also have hydrocarbon exploration but very little potential storage capacity upon depletion is cited (~5 Mt in total).
- The major saline aquifer sites that have been identified as most promising and most feasible for the geological storage of CO₂ include Khmer Basin, (the most suitable option), followed by the Kampong Saom and Tonle Sap basin.
- No major or pilot projects have been performed in the country as at the time this assessment was made.
- There are currently no laws to explicitly allow or prohibit geological CO₂ storage.

A) Project and Non-Project
Mid-Case Storage Resource



B) Storage Resource by Type

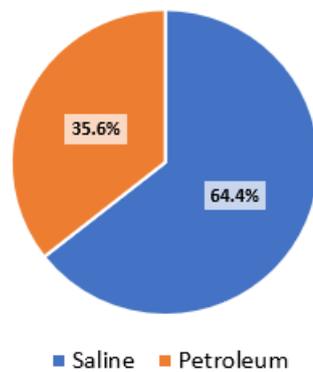


Figure 5-1: Cambodia spread of Storage Sites.

A) Spread of storage resource in all Cambodia sites across SRMS classifications; both project specified and not. B) Split of Cambodian 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.

5.2 Resource Statement



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

The graph above is a log scale, and the graph below is linear.

5.3 Evaluation History

A preliminary study of the viability of CO₂ storage in Cambodia was conducted around 2014. The study was focused on the existence of suitable aquifers and hydrocarbon reservoirs within the Cambodian subsurface for the geological storage of CO₂. This research was conducted via the cooperation of the CNPA (part of the Ministry of Mines and Energy of the Government of Cambodia). [1]

The Khmer Basin emerged as the most feasible for CO₂ storage, followed by Kampong Saom and Tonle Sap Basins respectively.

The present outcome of this study is geared towards helping geologists and CCUS experts gain better understanding of CO₂ storage in Cambodia and suggests that these basins offer the most viable solution for reducing future CO₂ emissions in Cambodia. [1]

5.4 Resource Review

Following initial basin screening and evaluations, a comprehensive assessment of the available pore volume within existing hydrocarbon reserves and aquifers of suitable basins namely the Khmer, offshore Kampong Saom, and Tonle Sap basins were undertaken to determine their possible CO₂ storage capacity [1]

The hydrocarbon reserve and aquifer volumes were converted to volumes of CO₂ that a basin can store, and the outcomes of this conversions states that the hydrocarbon reservoirs have storage capacity of ~5Mt in total for all three basins, and a total of ~85Mt in saline aquifers, making saline aquifers more viable for CO₂ storage in Cambodia.[1]

5.4.1 Major Projects

Currently, there are no major operational storage projects to date in Cambodia.

5.4.2 Depleted Oil & Gas Fields

There are no depleted oil and gas field option in Cambodia.

Research performed by [1] using a storage efficiency factor of 7%, calculated that Cambodia's oil fields collectively have a potential to store approximately 5Mt of CO₂

The offshore Khmer Basin, which contains 45% of the country's total hydrocarbon reserves, is estimated to store 2Mt of CO₂. The Tonle Sap Basin (35% of reserves) also offers 2Mt of storage, while the offshore Kampong Saom Basin (20% of reserves) could store 1Mt upon depletion.

5.4.3 Saline Aquifers

Three major saline aquifer sites have been identified as most promising and most feasible for the geological storage of CO₂ (Khmer Basin which is the most suitable basin, followed by the Kampong Saom and Tonle Sap basin).

The Khmer basin covers an area ~8600km². This basin contains >6000 m of Mesozoic–Cenozoic sediments including ~2000 m of Triassic–Cretaceous basement. Cenozoic sediments within the Khmer Trough are dominated by sandstones interbedded with clays, shale, silts, and coals. The Khmer Basin is an excellent candidate for CO₂ storage, because it is tectonically stable and has limited faulting within reservoir formations. The Khmer basin has a storage capacity of ~22Mt in its saline aquifer.

The offshore Kampong Saom has storage capacity of ~33 Mt in its saline aquifer. The Kampong Saom Basin extends north–south from the southern boundary of the Tonle Sap Basin to the central part of the Gulf of Thailand covering a total area of ~28,000 km² offshore and ~12,000 km² onshore. The Kampong Saom Trough, in the center of the basin, consists of deformed Paleozoic complex basement material and overlying Upper Triassic–Cretaceous orogenic complex sediments [1].

The Tonle Sap basin covers an onshore area of 23, 800 km² in central Cambodia. The Tonle Sap Basin is bordered to the south by the onshore Kampong Saom Basin. The basement of the Tonle Sap Basin is a complex Paleozoic graben that is dominated by metamorphic rocks. This graben may have developed between the late Carboniferous and the Middle Triassic, and is filled with sediments dominated by terrigenous sandstones and carbonates, with a total thickness of >1000 m. The onshore Tonle Sap basin has a storage capacity of ~30 Mt in its saline aquifer. The reservoir intervals have an average porosity of 10% (locally >20%) and an assumed net value of 20%, indicating good CO₂ storage potential. These reservoirs are sealed by Lower Cretaceous evaporites and claystones, both of which would make good cap rocks for CO₂ storage.

5.5 Regulatory Framework

No specific national laws or policies that explicitly define CCS. Limited assessment in relation to Cambodia. However, a comprehensive legal framework is still under development.

5.6 Issues for the Assessment

The resource reported for CO₂ storage should be regarded as preliminary because of the limited available data on which the assessments were based. This is largely due to restricted knowledge of the subsurface geology of Cambodia because of oil and gas exploration policy which limits access to all mineral resource and other subsurface data [1].

Future geological and geophysical data should improve the reliability of the estimates of carbon storage capacity reported here [1].

5.7 Future Updates

5.7.1 Future CRSC Cycles

Future updates would look for any projects or site updates based on more detailed and robust geological and geophysical research and studies.

5.8 References

1. Mao, C., Yamada, Y. and Matsuoka, T. 2014. A preliminary assessment of geological CO₂ storage in Cambodia, *International Journal of Greenhouse Gas Control*, 30, 19-33, DOI:10.1016/j.ijggc.2014.08.016,

6 China

6.1 Summary

China was assessed during Cycle 1 and was updated in Cycle 3. The CSRC has identified a CO₂ storage resource for China as follows:

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.0003	0.0003
Capacity	0.0	0.0
Sub-Commercial	10.5	0.03
Undiscovered	3067	0
Aggregated*	3077	0.03

* 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 China.

Table 6-1: Storage resource classification summary for China.

- There is a total of 72 sites in the CSRC, largely at a regional scale or a high-level evaluation, with only two sites associated with a project. The storage resource is located across a minimum of 21 geological basins, both onshore and offshore.
- China boasts numerous CCUS projects, of which 8 of the key projects currently are, or will reach large-scale operations in the 2020s.
- Government policy has led to numerous pilot- and large-scale CCUS facilities being developed, however, this is largely to support enhanced oil recovery operations (EOR). The lack of CCS-specific legislation means more needs to be done to incentivise geological storage and true decarbonisation.

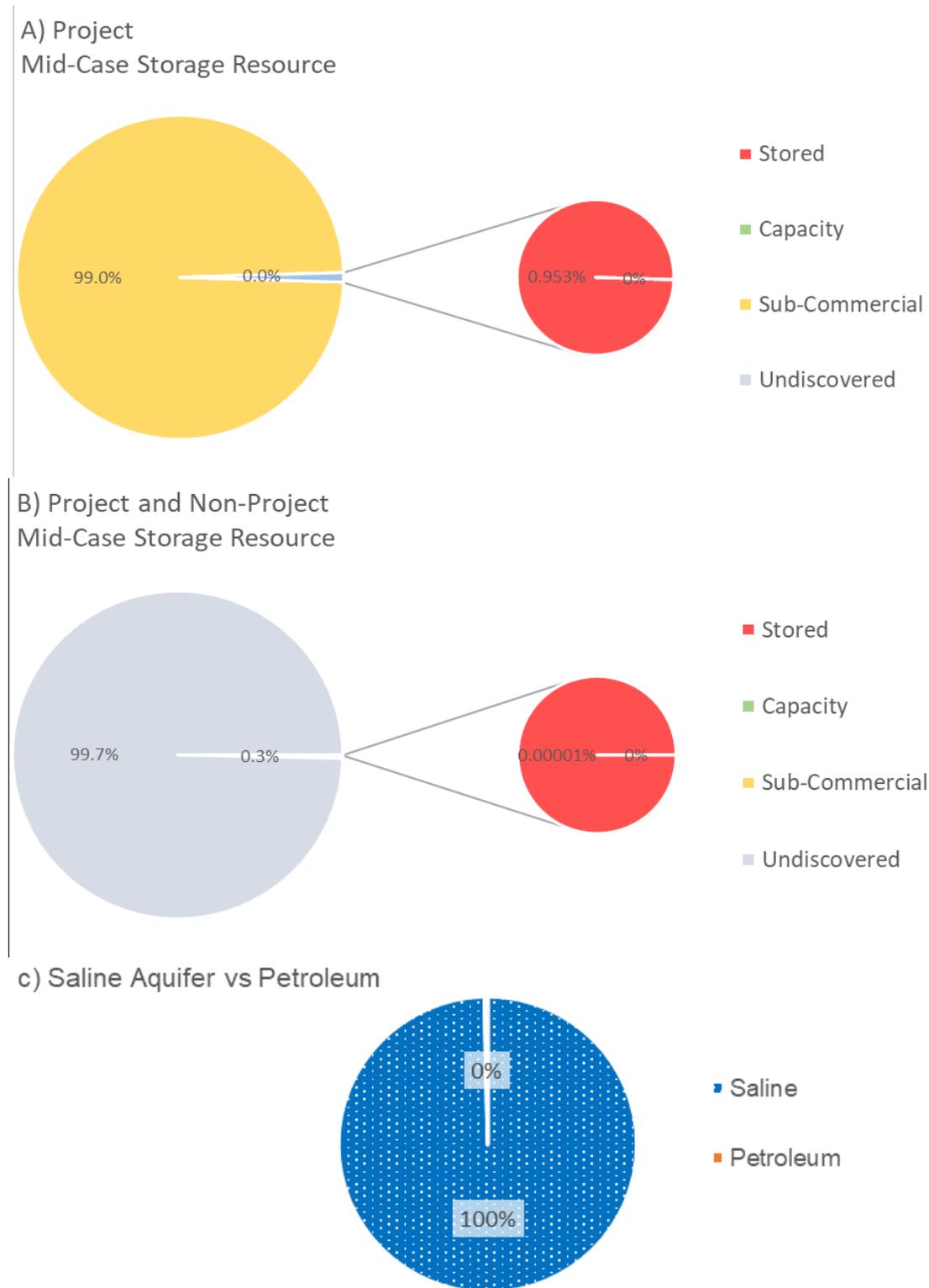


Figure 6-1: China spread of Storage Sites.

A) Spread of storage resource in China sites (72) across SRMS classifications, where a project has been specified. B) Spread of storage resource in all Chinese sites across SRMS classifications; both project specified and not. C) Split of Chinese storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

6.2 Resource Statement

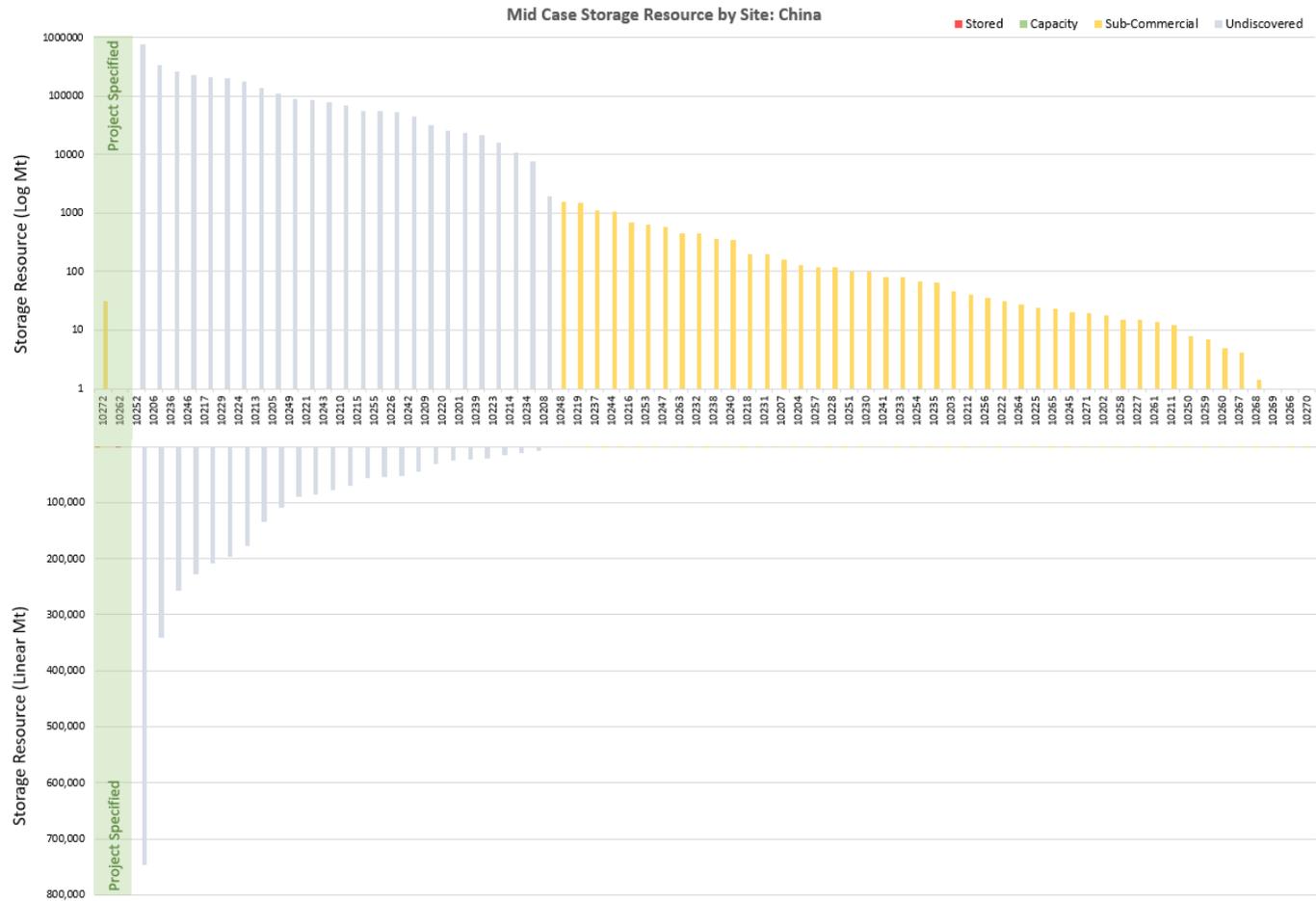


Figure 6-2: Storage resource summary for China compiled in the CSRC.

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

6.3 Evaluation History

The regional evaluation by the Pacific Northwest National Laboratory in 2009 [4], of the potential CO₂ storage resource available within the onshore and offshore territory of China was a first of its kind. It was produced as a collaboration between US and Chinese researchers and was commissioned by the US Department of Energy. The report evaluates a large and diverse geographic portfolio of potential CO₂ storage resource within oil and gas fields, deep saline formations and coal seams. It is only intended to provide a starting point for finer resolution analysis. The majority of the Chinese sites are sourced from this PNNL report.

The estimation of the storage resource within saline aquifers was considered only through theoretical calculation of 100% dissolution of CO₂ within reservoirs deeper than 800-1000m. Whilst acknowledging the clear potential for hydrodynamic and residual trapping, these storage mechanisms are not specifically included within the assessment.

The authors PNNL suggest that this approach of ignoring the potential of "free CO₂" phase storage will result in a very conservative resource estimate.

For the evaluation of gas fields, a modified replacement method was adopted which assumes that only 75% of the pore volume once occupied by produced gas could be filled with CO₂. This would seem to make provision for some loss of storage efficiency perhaps resulting from water ingress into the reservoirs from underlying water leg.

Unlike the other regional assessments, the PNNL study only considers the storage in oilfields when linked to enhanced oil recovery. Instead of deploying a simple replacement method for the assessment of storage potential, the regional assessment has considered this potential using guidance and analogues from well-established CO₂ EOR provinces such as the West Texas area of the US. This together with pre-published assessments of initial oil in place for Chinese oilfields has enabled an initial assessment of potential storage resources associated with EOR to be made.

It should be noted that the CO₂ EOR performance of the primary analogues is drawn from an environment where the oil producer must purchase CO₂ from a provider. As a result, the operators have become extremely efficient at using the purchased CO₂ inventory to optimise oil recovery. Of course, this approach also minimises CO₂ storage resource by definition and so this does represent a conservative view of potential storage resource.

The PNNL reported volumes are supplemented by the stored volume at the Shenhua Group CCS Demonstration project [5], plus theoretical storage resource evaluations for hydrocarbon fields within the Dagang oilfield complex [6].

6.4 Resource Review

6.4.1 Major Projects

China hosts a plethora of CCS and CCUS projects, ranging from pilot and demonstration right up to large-scale projects. Many of these projects are not well publicised and as such, this study may be an under-representation of the full scale of commercial and research operations currently being undertaken in China. The GCCSI (2018) recognises 18 key CCUS projects in China, including:

- 10 enhanced oil recovery (EOR) projects; 5 of which are demonstration projects and 5 of which are currently or are developing towards large-scale operations by the 2020s.
- projects capturing carbon dioxide for use in industrial or beverage applications. 2 projects currently under evaluation. There are large-scale facilities with power and coal-to-liquids applications.
- 2 projects currently under evaluation. There are large-scale facilities with power and coal-to-liquids applications.
- projects are dedicated geological storage servicing the power and coal-to-liquids industries. One of these projects came to completion in 2014.

As carbon utilisation is outside the scope of this study, only projects utilising permanent geological storage of CO₂ were considered in the CSRC. These projects include:

Shenhua Group CCS Demonstration project in the Ordos Basin. It was the first deep saline aquifer storage in China. The project started in 2011, injecting 0.1 MtCO₂/yr until completion in 2014, reaching a total of 0.302 Mt CO₂ stored. The full-chain CCS project captured CO₂ from a coal liquefaction plant and injected the CO₂ into a tight carbonate reservoir using fracking to enhance secondary porosity.

China Resources Power (Haifeng) Integrated CCS Demonstration Project, Shanwei. A capture test platform has been running since 2018 capturing 0.025 Mtpa from the power industry, aiming to scale up to large-scale operations (1 Mtpa) in 2020s. Due to the small volumes, this project is not included in the website database.

Guohua Jinjie CCS Full Chain Demonstration, Shaanxi Province. Demonstration-scale operations capturing CO₂ from a coal-to-liquids facility at 0.15 Mtpa since 2017. Due to the small volumes and lack of publicly available literature, this project is not included in the website database.

6.4.2 Depleted Oil & Gas Fields

The natural gas fields represent a small portion of the storage resource in China, with an aggregated storage resource of 5.2 Gt. Similarly, oilfields comprise a more minor component, with an aggregated storage resource of 4.8 Gt for oilfields including EOR. Evaluations for dedicated geological CO₂ storage within oilfields, rather than CO₂ EOR, could only be found for the Dagang Oilfield Complex. This highlights the need for the country-wide evaluation of hydrocarbon fields, to avoid the underestimation of storage resource, as detailed in 3.1.3.

All storage resource within depleted hydrocarbon fields is classified as discovered. As the SRMS classification places a significance on the presence of a CCS regulatory system for classification, the absence of such a system in China currently limits the classification of discovered resources to "Inaccessible". For the oilfields evaluated with EOR operations [4], however, the resource was classified as "Development Not Viable" as CO₂ injection for EOR can take place under existing petroleum regulatory systems.

6.4.3 Saline Aquifers

As in many countries, deep saline formations represent the largest storage target in China, with an Aggregated Storage Resource for Undiscovered sites in the CSRC of 3067 Gt [4]. The PNNL regional evaluation does not present any information regarding the discovery status or the geological formations of the potential CO₂ storage resource. As a result, the entirety of the saline aquifer potential has been classified as Undiscovered Basin Play, even though significant tracts of this potential resource will undoubtedly have been discovered through exploration for petroleum and groundwater resources.

A small volume (0.302 Mt) has been stored in the Shenhua Group CCS Project [5], while 31.4 Mt is classified as Discovered Inaccessible [7], due to the lack of a CCS-specific regulatory system in China. The evaluation by [7], uses simulation modelling to estimate the storage resource of the Donggou Formation, in the Junggar Basin, and represents one of only two sites in this CSRC report with a project specified. In a country where there are numerous CCS and CCUS projects being undertaken, this highlights the lack of detailed published literature on the Chinese CO₂ storage resource.

6.5 Regulatory Framework

China has numerous pilot- and large-scale CCUS facilities supporting the cement, coal-to-liquids and steel industries. These have been developed through state-supported research and development funding. The GCCSI recognise the strong focus on government incentives for EOR activities but encourage a stronger emphasis to be placed to incentivising storage through policy and CCS-specific regulation [8].

6.6 Issues for the Assessment

The calculation of depleted oil fields in the PNNL report was only considered when in EOR applications, which not only contrasts the methodology of other regional reports, but also doesn't provide a true reflection of CO₂ stored, as described in 3.1.3. Indeed, due to these complications, EOR studies are out of the scope for the CSRC, however the values from the PNNL report were included, in the absence of other significant estimations.

6.7 Future Updates

6.7.1 Future evaluations

Further work for evaluators should focus on evaluation at a site or even formation level, to

progress the maturity of the Chinese resource along the SRMS classification system. The current evaluations of Chinese storage provide an under-representation of the storage potential in China.

6.7.2 Future CSRC cycles

In the 2018 GCCSI review of Chinese decarbonisation facilities [9], two key projects are highlighted as planned operations:

- Shanxi International Energy Group CCUS, Shanxi Province. Planned large-scale facility aiming to capture 2 Mtpa in the 2020s from power generation.
- Shenhua Ningxia CTL, Ningxia Province. Another large-scale facility is planned to be operational in the 2020s, aiming to capture 2 Mtpa from the coal-to-liquids industry.

A further two projects are identified by [10] as 'in preparation' for geological storage:

- IGCC Clean Energy pilot-project in Lianyungang. Aims to capture 1 Mtpa using pre-combustion capture.
- Oxy-fuel combustion sequestration in Zhongyan Yingcheng of Hubei. The project aims to capture 0.1 Mtpa for storage in salt rock.

If evaluations for the above projects are published, they should be included in future updates to the CSRC.

A critique is provided in [11], on the status of CCUS policy in China in a recent paper, which could also be included.

7 Georgia

7.1 Summary

Georgia was assessed during Cycle 5. This country is reported as having no current CO₂ geological storage resources.

Classification	CO ₂ storage resource (Gt)	
	Project and no project	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 Georgia.

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

7.2 Evaluation History

There are no conventional CO₂ storage studies available for Georgia and this has placed some uncertainty on the scope of storage resource this country may hold.

Research has been conducted relating to the process of CO₂ mineralization via zeolites in the reservoir. The study commissioned by Block Energy with leading CO₂ storage consultancy OPC is evaluating the potential of a middle Eocene reservoir for the presence and distribution of zeolites. CO₂-water-rock mineral reactions in reservoirs with zeolites can cause much more rapid mineralization of CO₂. Zeolites selectively adsorb CO₂ over other gases. The full research is not yet in the public domain and as such the statements here should be treated with caution until full research is released. Basin wide storage potential is estimated at over 8 gigatons with a reservoir level around 256 Mt via this method. Mineralization is not covered by the SRMS and so the zeolite 'storage' is not included in the database.

The studies indicate that, Block XIB has features that indicate the possibility for a very rapid rate of carbonation: initial calculations show 95% mineralisation of CO₂ within 250 days, compared to 1,000s years in sedimentary systems [1].

7.3 Resource Review

The Patardzeuli Middle Eocene reservoir within the Block XIB/F has been identified as promising storage site.

7.3.1 Major Projects

Block Energy plc, the production and development company focused on Georgia, announced good progress on Phase 2 of its CCS mineralization project, with the key process specific subsurface uncertainties, ahead of the pilot test, having been resolved. Work has shifted to the redesign of existing non-producing wells, and implementation of the pilot injection of CO₂ into the reservoir [2]. Work has been ongoing since November 2024 on Phase 2 of the CCS project. Phase 2 comprises of a desktop study, laboratory and field work, aimed at undertaking a pilot injection into the Patardzueli Middle Eocene reservoir, to prove mineralization and permanent storage of CO₂, and therefore the feasibility of an industrial level sequestration project [2].

A successful water injection test showed that well PAT-92 (an abandoned former production well) and well PAT-49 (currently used for water disposal) are in pressure communication and therefore can be used as injector and monitoring wells (critical for the monitoring and verification plan) for the pilot test [2]. Work is ongoing to finalize the surface facility design at the PAT-49 well site as the monitoring and verification plan to commence injection of CO₂ into the reservoir in mid-2025 [2].

7.4 Regulatory Framework

It has not been clearly stated whether there are comprehensive laws dedicated to CO₂ capture and storage. Georgia is actively pursuing CCS projects, and this may indicate that laws and regulations will be established in the future.

7.5 Issues for the Assessment

The main challenge with the assessment for Georgia has been the lack of studies to support the identification of potential sites. This places some uncertainty on the resources available in the country.

7.6 Future Updates

7.6.1 Future CRSC Cycles

Any future research may also warrant reassessment for potential new studies that could reveal further storage opportunities, particularly those centered around zeolite research. Updates will also be needed if legislative progress are made or finalized.

7.7 References

1. OPC Study Shows Significant CCS Opportunity in Georgia <https://opc.co.uk/news/opc-study-shows-significant-ccs-opportunity-in-georgia/>
2. Block Energy Announces Phase 2 Update on Georgia CCS Project [Block Energy Announces Phase 2 Update on Georgia CCS Project | Carbon Capture Magazine](#)
3. Oelkers, E., Richards, M., 2023 Block Energy Plc, CO₂ Storage & Low-Carbon Gas Opportunities in Georgia Block Energy Plc, Prof. Eric Oelkers & Max Richards

8 Indonesia

8.1 Summary

Indonesia was assessed during Cycle 2. The CSRC has identified a CO₂ storage resource for Indonesia as follows:

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	2.46	0.00
Undiscovered	13.40	4.39
Aggregated*	15.86	4.39

* 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 Indonesia.

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

- Storage resource potential (33 sites) is present in both saline aquifers and oil and gas fields, with saline aquifers accounting for 89% of Indonesia’s storage resource. Six sites are considered ‘projects’.
- Potential storage resource has been identified in 11 sedimentary basins, with published oil and gas storage resource available for seven basins.
- Recent (January 2024) developments in CCS-specific regulations in Indonesia mean that currently Inaccessible storage resources can be commercially matured.
- The only discovered resource for Indonesia is in oil and gas fields.
- One known pilot project, the Gundih CCS Pilot, has support through state research and development funding and from the state-owned company Pertamina. It is yet to undergo the design and construction phase. This shows that the government clearly has an interest in potentially growing the CCS industry.
- Indonesia has several high CO₂ gas fields, many of which were studied in the CO₂CRC (2010) [3] report, with their associated saline aquifers proposed for CO₂ injection sites. Please see Section 3.6.4 in the main report for a discussion on high CO₂ fields.

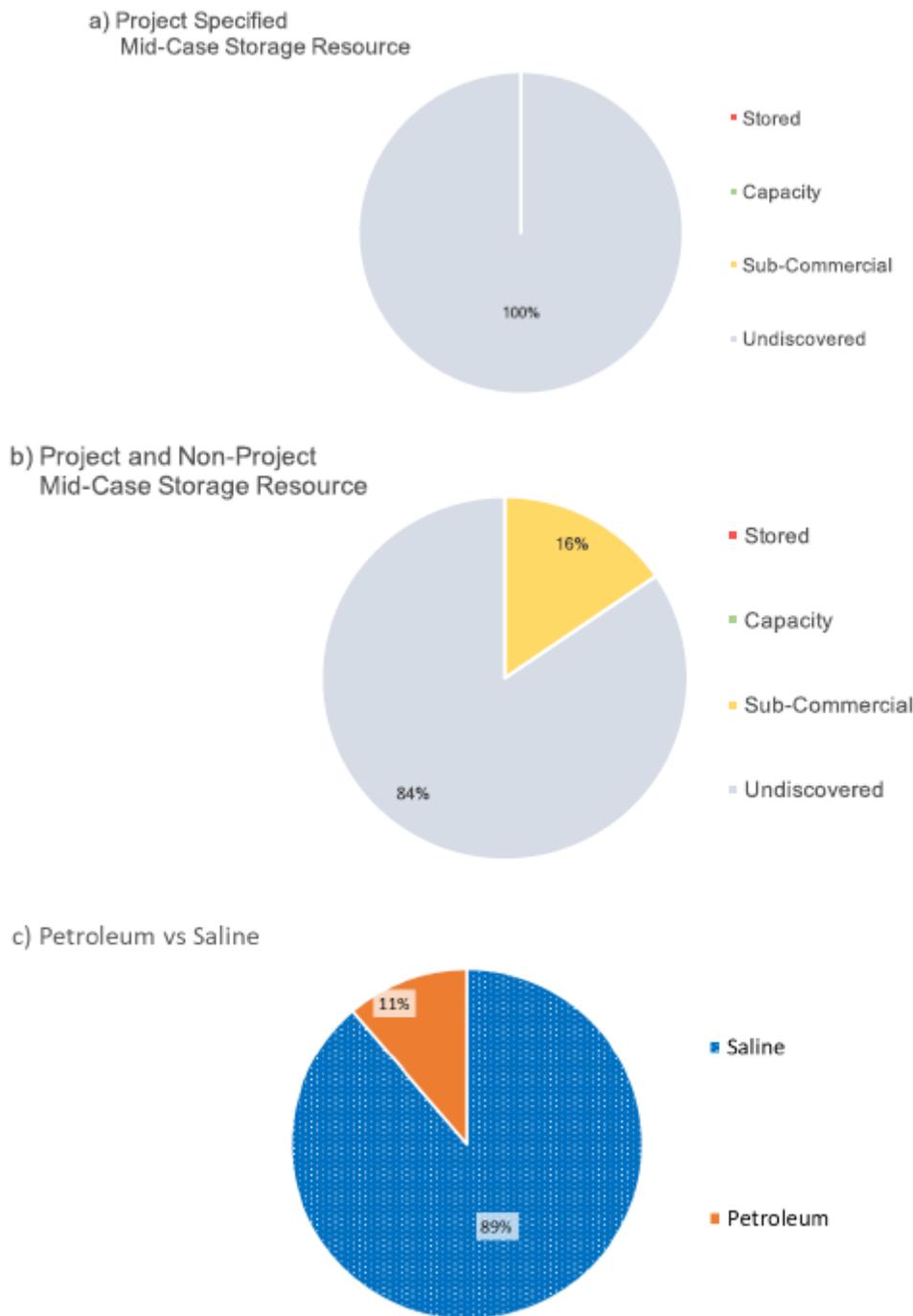


Figure 8-1: Indonesia spread of Storage Sites.

a) Spread of storage resource in Indonesia. Sites (33) across SRMS classifications, where a project has been specified. b) Spread of storage resource in all Indonesia sites across SRMS classifications; both project specified and not. c) Split of Indonesia storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

8.2 Resource Statement

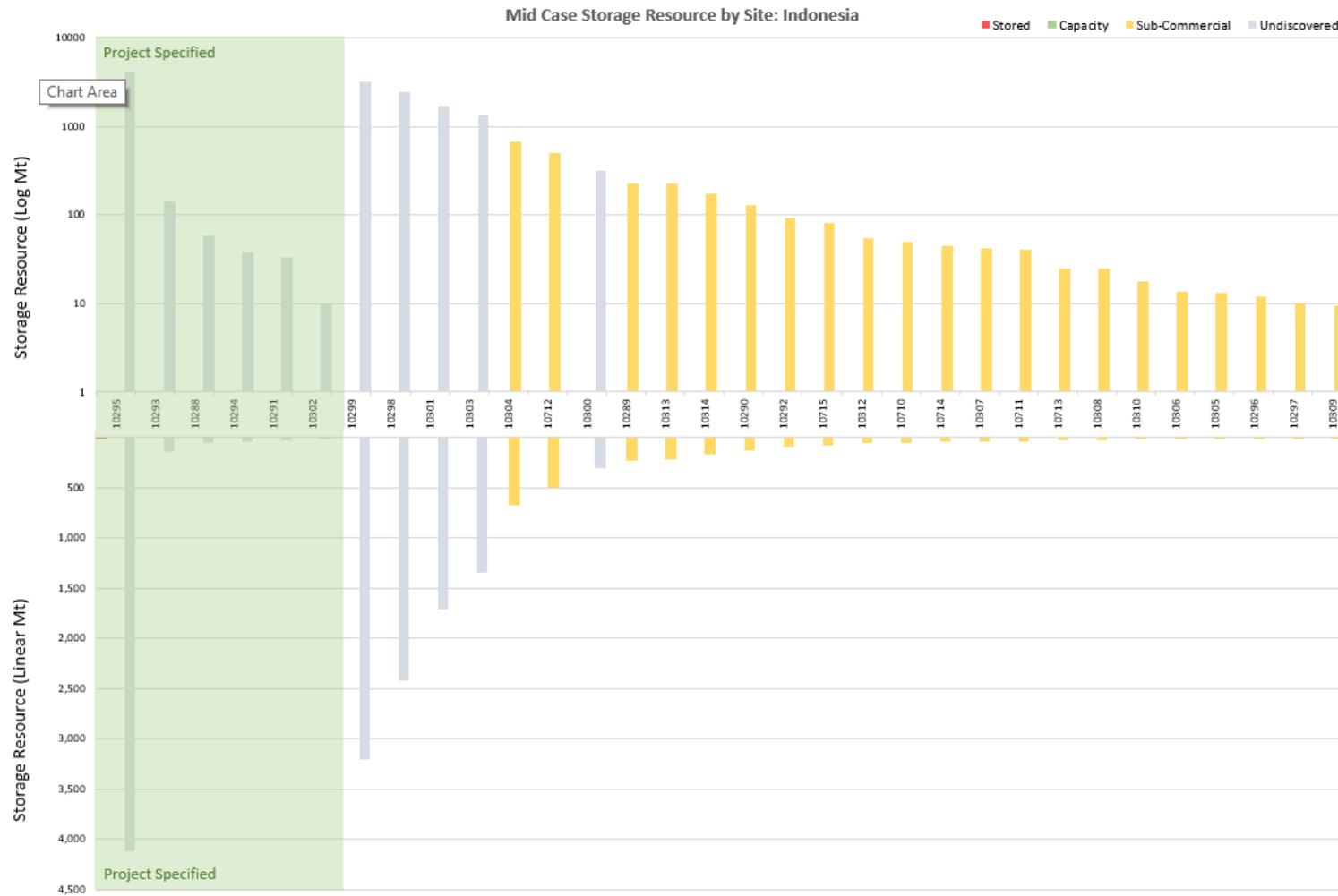


Figure 8-2: Storage resource summary for indonesia compiled in the CSRC.

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 Cycle 2 storage resource assessment was based on five papers: Hedriana et al (2017) [12], World Bank (2015) [13], Iskandar et al (2013) [14], Asian Development Bank (2013) [15] and CO₂CRC (2010) [3]. All additional papers that were reviewed either provided no storage resource value, had been superseded by later studies, were based on CO₂-EOR or referred to the Gundih CCS Pilot, which is not included as a site in the CSRC as it is below the minimum threshold of 10 Mt.

Hedriana et al (2017) [12] built on the World Bank (2015) [13] study and both used equivalent approaches for calculating saline aquifer resource. The Hedriana et al (2017) [12] paper is more recent and uses a more realistic value for storage efficiency factor, therefore the saline aquifer resource from this paper was used in the CSRC.

The Asian Development Bank (2013) [15] report looked at a broad range of gas field resources in South Sumatra, which were split down to individual fields with attached resource numbers, and locations shown on a map. The World Bank (2015) [13] paper also includes a list of gas field resources in South Sumatra. The individual gas fields identified in the report have different names and resource numbers than the Asian Development Bank (2013) [15] report and do not appear to be duplicates so are included in the CSRC.

The CO₂CRC (2010) study for the Asia-Pacific Economic Cooperation [3] looked at high CO₂ gas fields and produced development plans for the saline aquifers associated with these fields. The resource values were included in the CSRC as projects.

8.4 Resource Review

8.4.1 Introduction

The only known pilot project in Indonesia is the Gundih CCS Pilot located in Blora district, Central Java province. Key players include Indonesia's state-owned oil and gas company Pertamina, the Ministry of Energy and Mineral Resources and the Asian Development Bank among others. The development plan is to capture CO₂ from the Gundih gas field and inject this into an uneconomic oil field at a rate of 30 tonnes per day. A total of 20 kt is to be injected during the two years of the project. According to the Global CCS Institute's database for pilot plants [16], the design and construction phase of the project is due to begin by the early 2020s.

8.4.2 Depleted Oil & Gas Fields

The only discovered storage resource in Indonesia are depleted oil and gas fields. The data coverage ranges from resources associated with individual fields to cumulative resources for entire basins. The South Sumatra Basin has resource values for 13 individual gas fields, which could be located on a map. The total resource between all 13 fields is 875 Mt, which is greater than any cumulative South Sumatra data that has been assessed. All together, these fields represent 49% of the discovered resource throughout the entire country.

Resource for the West Java Basin is divided into offshore and onshore fields and totals 395 Mt, representing 22% of the discovered resource.

All other basins do not have individual field values, the only subdivisions present are between cumulative oil fields and gas fields. Other basins with depleted oil field resource are: East Kalimantan, North Sumatra, South Sumatra and Barito. Other basins with depleted gas field resource: Salawati and North East Java. All these other basins hold a total resource of 528 Mt, 29% of Indonesia's discovered resource.

All oil and gas fields are classified as discovered, but inaccessible as the country has no regulatory framework present for CCS activities.

8.4.3 Saline Aquifers

As mentioned in the introduction, Indonesia has a small range of basin-wide saline aquifer data. All basin-wide storage resources exist within the South Sumatra and West Java basins – this is because they were included in multiple studies that aimed to identify sites for storage of CO₂ emissions from coal power stations in the area. Overall, three published values for each basin-wide resource were assessed, but only the resources from Hedriana et al. (2017) [12] were included as they were most recent, and in the case of south Sumatra, the values were more refined. The other two studies considered were a 2015 study by the World Bank [13] and a 2013 study by the Asian Development Bank [15]. There is a null entry in the storage assessment database to represent this.

The small saline aquifer sites mentioned above are associated with nearby high CO₂ fields [3] and represent 31% of the undiscovered resource. They are spread over five basins compared to just two for basin-wide resources. It should be noted that these sequence plays were only assessed based on their potential to store CO₂ from nearby high CO₂ gas fields. Therefore, they may not be in a good location, nor have the desirable properties for injection of anthropogenic CO₂ from power stations.

All saline aquifers are classed as undiscovered and inaccessible as the country has no regulatory framework present for CCS activities. If a regulatory framework became available, these resources would be promoted to the Basin Play and Sequence play maturity classes.

8.5 Regulatory Framework

Although Indonesia has a petroleum industry, laws specific to CCS were lacking until early 2024. On 30 January 2024, the President of Indonesia enacted a regulation for "Implementation of Carbon Capture and Storage (CCS) Activities". This establishes a robust legal framework for development of CCS projects.

Due to the pre-Cycle 4 lack of regulatory framework for CCS, all storage resources for Indonesia were classified as Inaccessible under the SRMS. Under the new framework, these resources can be re-classified and become available for commercial maturation.

The Gundih pilot project is yet to undergo the design and construction phase, but it has support through state research and development funding and from the state-owned company Pertamina. This shows that the government clearly has an interest in potentially growing the CCS industry. The Global CCS Institute's CCS Readiness Index also ranks Indonesia within the top 5 countries for inherent CCS interest, meaning that it has a high fossil fuel dependency and therefore will need CCS projects to meet future climate goals. Currently, interest in EOR projects appears to be greater than that for storage, since they provide financial incentives. The government needs to incentivise CO₂ storage through policy and the new CCS-specific regulations.

8.6 Issues for the Assessment

8.6.1 Saline Aquifers

The most recent data for gas fields in South Sumatra and West Java are given as cumulative basin numbers by Hedriana et al. (2017) [12], however the data in the CSRC are from World Bank 2015 [13] and Asian Development Bank (2013) [15] as these sources presented data for individual fields that could be located on a map. Therefore, the gas field data presented here is not the most recent but is the most refined.

The depleted oilfield storage that is given by Iskander et al. (2013) [14] does represent CO₂ storage as opposed to CO₂-EOR. However, due to the high incentives for EOR activities in the region, this can't be ruled out in any of these fields.

8.6.2 Saline Aquifers

To calculate the resource for the West Java Basin saline aquifer, the methodology presented in the World Bank 2015 report [13] used volumetric data from 15 gas fields before scaling up by a factor of 3 to represent the full extent of the basin. This is a different method than that which is used to calculate resource for most other saline aquifers.

In the CO₂CRC (2010) study for APEC [3], saline aquifers associated with high CO₂ fields were the planned CO₂ injection sites, and therefore included as storage resource in the CSRC. For each of these sites, a simple simulation was conducted to determine the maximum rate of CO₂ that could be injected over the injection period without the pressure in the reservoir exceeding its fracture pressure. Sensitivities were carried out on the number of wells required. Due to the sites having development plans, they have been included as projects in the CSRC.

8.7 Future Updates

8.7.1 Future Updates for Evaluators

- There is good detail on storage resource for depleted gas fields within the South Sumatra Basin, however the low resolution of the map images in the reports makes the field names challenging to read. For future evaluations, providing higher resolution map images is recommended.

- In other basins out with South Sumatra, acquiring, analysing and publishing new resource data that would divide up the cumulative depleted gas and oil field resource into individual field values with an attached location would be a good next step to mature the storage resource in Indonesia.
- For the West Natuna Basin, no data was uncovered in this cycle. The Natuna gas field and associated saline aquifer storage is East of Natuna Island and so not located within the West Natuna basin.
- The only basin wide saline aquifer data assessed in this cycle came from the West Java Basin, Java Sea Basin and the South Sumatra Basin. Future assessments should look to uncover basin wide saline aquifer resource data from other basins.
- A re-assessment of Indonesia's storage resource should be undertaken in future cycles to reflect the recent CCS regulatory developments.

9 Japan

9.1 Summary

Japan was assessed during Cycle 2 and updated in Cycle 3. The CSRC has identified a CO₂ storage resource for Japan:

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.0003	0.0003
Capacity	0.00	0.00
Sub-Commercial	36.23	0.03
Undiscovered	116.04	0.01
Aggregated*	152.27	0.04

* 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 Japan.

Table 9-1: Storage resource classification summary for Japan.

- Although storage resource is reported as being present in both saline aquifers and oil and gas fields, the greatest potential lies in saline aquifers.
- Evaluation of potential storage sites began in the late 1990's. Japan has developed one pilot project (10,000t) and one demonstration project (300,000 t) to date.
- Early studies reviewed sites using available data from hydrocarbon exploration ('Mission 1' study), follow-up evaluation of saline aquifers close to emissions sources ('Mission 2 study) indicate significant storage potential, but the data are not readily available in the published literature.
- 25 sites with storage potential were identified in the Cycle 2 assessment, however only 13 have a storage resource estimate attached to it due to the difficulty in accessing data.
- The demonstration project, Tomakomai, is the first project in which CO₂ injection wells are directionally drilled from onshore to an offshore (subsea completion) injection point. Additional resource potential is available at the project site.
- Japan has no current CCS-specific current regulatory system, but CCS is embedded in its long-term Low Emissions Development strategy. The Tomakomai demonstration project was permitted using existing laws.

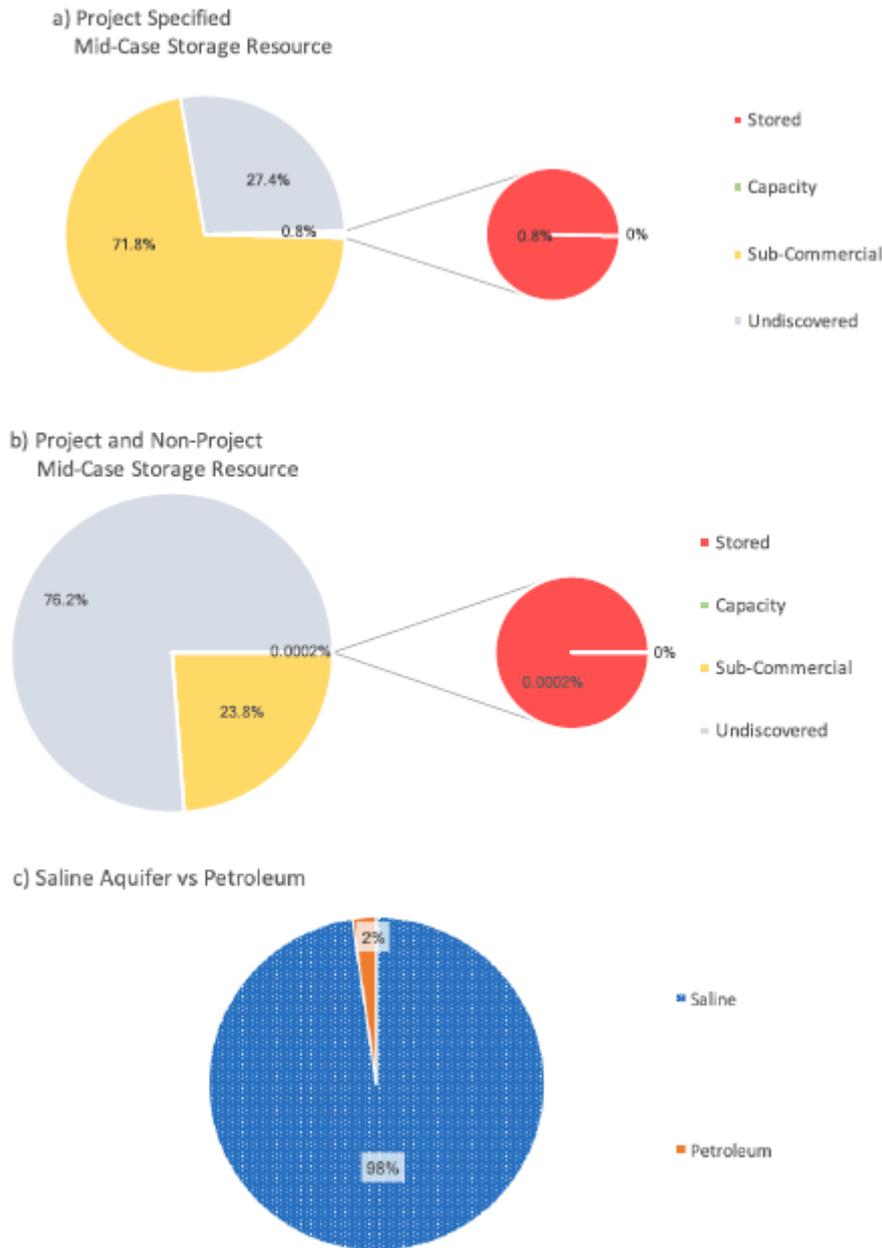


Figure 9-1: Japan spread of Storage Sites.

a) Spread of storage resource in Japan (25) across SRMS classifications, where a project has been specified. b) Spread of storage resource in all Japan sites across SRMS classifications; both project specified and not. c) Split of Japan storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

9.2 Resource Statement



Figure 9-2: Storage resource summary for Japan compiled in the CSRC.

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

9.3 Evaluation History

Evaluation of potential storage resources in Japan began in the mid-nineties with an initial review of the storage opportunity using available hydrocarbon exploration and field data. All identified sites were subdivided by trapping style, data availability, and whether injected CO₂ could be 100% dissolved. A volumetric -based estimate of 91.5 Gt storage resource was published [17]. This initial review was followed by a 5-year national R&D project, 'Underground Storage of CO₂', which was then extended in 2005 to cover site selection for large-scale demonstration projects and future commercial projects. 'Mission 1' of the national project involved the Research Institute of Innovation Technology for the Earth (RITE) and the Engineering Advancement Association of Japan (ENAA) publishing a review of the 1995 data and an updated (volumetric) storage resource of 146.1 Gt [18], although the storage efficiency factors used are considered high (25% for structural traps; 12.5% for stratigraphic traps and open aquifers). 'Mission 2' studies continued the storage review work but focused on non-hydrocarbon-bearing basins close to major CO₂ emission sources (areas not covered by the Mission 1 studies). This work was used to build a database of 'promising areas' [19]. This Japanese language database is not readily available in the public domain, although attempts have been made to access the data during this 2020 Cycle (see 'Future Work'). Ogawa et al. [20] describe 27 candidate storage aquifers of which between 14 and 17 were down selected for detailed (although still at a regional level) study. In the absence of access to the Mission 2 database, estimates of storage potential in this assessment cycle are derived from a published bubble plot [20].

In 2008 [21] a comprehensive evaluation of potential storage sites identified 3 candidate sites: Nakoso-Iwaki Oki, a depleted gas reservoir 40km off the east coast of Honshu; Kitakyushu, a saline (open, no structure) aquifer; and Tomakomai, a pair of saline aquifers with some closure. Following the Great East Japan Earthquake, the Iwaki-Oki site was no longer considered as a candidate site. The Kitakyushu site was under a very early stage of evaluation having only limited 2D seismic data available. The more data-rich (3D seismic and 2 survey wells available) Tomakomai site was selected as Japan's first CCS Demonstration project.

In 2017, Japan CCS Co. Ltd. was commissioned by the Ministry of Environment (MOE) and the Ministry of Economy, Trade and Industry (METI) to conduct an 'Investigation of Potential CO₂ Storage Sites' with the aim of selecting prospective sites by around 2021. At the Miakawa project (coal or biomass-fired power station), the search is underway to identify and evaluate potential transport and storage options for the project. The JCCS project is thought to be linked to this effort.

First deployment of CCS occurred at the pilot Nagaoka Project (2003 – 2005 where 10,400t CO₂ was injected into an onshore saline aquifer. This was followed by a successful demonstration scale project at Tomakomai.

As of 2020, Japan has a GCCSI Indicator score of 71/100 [22], an evaluation of a country's

geological storage potential, maturity of their storage assessments and progress in the deployment of CO₂ injection sites.

Additional studies which provide discussion and storage estimates for microbubble CO₂ storage in Japan have not been included in this assessment cycle on the basis that they represent a more unconventional and untested approach to storage.

9.4 Resource Review

Although there is some identified storage potential in depleted fields in Japan (3.5 Gt), most of the storage resource potential lies in saline aquifers in the Neocene section of the subsurface; the older, deeper geological section is considered too structurally complex for CO₂ storage [23] [24]. unknown.

9.4.1 Major Projects

Following the success of the pilot Nagaoka project, the Tomakomai Demonstration Project, operated by Japan CCS Co. Ltd., commenced in 2012 and ran until late 2020. Tomakomai and Nagaoka remain the only projects in Japan to have injected CO₂ for storage purposes.

At Tomakomai (Hokkaido Prefecture), gaseous CO₂ (99% purity) sourced from a hydrogen production unit (pressure swing adsorption off-gas) at an oil refinery near the port area is injected 3-4 km offshore into 2 offshore saline aquifers via 2 reservoir-dedicated, deviated injection wells. Between April 2016 and November 2019 300,110 tonnes CO₂ (approximately 100,000t/year) was injected for permanent storage. Extensive post-injection monitoring will continue. The majority (300,012t) of the CO₂ has been injected into the higher permeability Moebetsu Formation (1.1km subsea), with only 98t injected into volcanic rocks of the Takinoue Formation (2.7km). CO₂ injection was not impacted by the 2018 Hokkaido Eastern Iburi Earthquake. Current dynamic models indicate that up to 5.73 Mt CO₂ may be injected into the Moebetsu Formation using the existing injection well, while the Greater Moebetsu Formation is calculated (volumetric method) to hold a storage resource in the region of 486 Mt (P50; [24]). Future development plans include looking at the potential for using Tomakomai as a storage reservoir for CO₂ from other emission sources across Japan (Tanaka, pers.comm.).

A new pilot project, the Miakwa Pilot, broke ground in 2018. The Miakwa Power Plant is a biomass fed plant where over 500t CO₂/day will be captured and stored (making it carbon negative). The storage site for the pilot has yet to be determined but potential sites are being reviewed, including those involving transport of the captured CO₂ to distant locations.

9.4.2 Depleted Oil & Gas Fields

No detailed review of storage potential in depleted oil and gas fields is available in the public domain. Both Tanaka [17] and Takahashi et al [18] used data derived from hydrocarbon activities, which included oil and gas exploration data, with Takahashi et al. reporting 3.5 Gt total storage potential in 13 unnamed oil and gas fields. The offshore Iwaki-Oki depleted gas

field (ceased production in 2007) was a candidate site for a demonstration project [21] with a numerically simulated 20Mt potential resource (at an injection rate of 1 Mt/year), but further evaluation and consideration was discontinued following the 'Great East Japan Earthquake', in 2011. Other technical issues including low reservoir pressure and legacy wells were also considered problematic. An additional 27.5 Gt is reported in onshore dissolved gas fields by the same authors. The large (368 BCM) Southern Kanto gas field is included in this resource, but no further breakdown of these storage resources is available in the public domain.

9.4.3 Saline Aquifers

Both Mission 1 and Mission 2 evaluated the storage potential on non-hydrocarbon bearing saline aquifers across Japan. The Mission 2 study (as reported in Ogawa et al. [20] focussed on areas close to major emission sources, with particular focus on Tokyo Bay, Ise Bay, Osaka Bay and Northern Kyushu. Of these, a more detailed evaluation of Osaka Bay and, to a more limited extent, Tokyo Bay are published, but are still on a regional scale. In addition to these areas an additional 10 or 11 areas (out of the total 27 areas reviewed) were reviewed to assess the accuracy of the volumetric estimate of storage. Analyses of data availability and quality were made but unfortunately actual target formations and calculated resource estimates are only provided for 3 areas. All other estimates have had to be derived from a 'bubble' plot which limits the accuracy of the Catalogue data entries.

The volumetric resource calculation methodology uses a 'storage factor' derived from the ratio of immiscible CO₂ plume volume to total plume volume which, when multiplied by a value for the supercritical CO₂ gas phase volume fraction of the injected plume is considered to equate to the US DOE [25] 'storage efficiency factor'. However, in the examples published, the storage efficiency equivalent factor was an optimistic 12.5%, almost certainly resulting in an overestimation of the storage resource estimate (US DOE, [25] P50 confidence interval storage efficiency factor for clastic reservoirs is 2.0%.

The estimated resource total for these Mission 2 aquifers is in the region of 23.9 Gt but care should be taken with this figure for the reasons described above. If a 2% storage efficiency factor were used the total resource estimate would be closer to 4Gt.

9.5 Regulatory Framework

According In the 2018 GCCSI CCS Readiness Index [8], Japan ranked as a 'Progressive Nation', or one which is actively advancing deployment of CCS in the country but still has some 'gaps in legislation policy and/or storage resource development which must be addressed before widespread deployment can proceed'. As of 2020, Japan has no CCS-specific regulatory system. However, it has continued to be a leader in future clean energy development. Japan is one of 15 countries which includes CCS in a long term low GHG emission development (LED) strategy under the UN Framework Convention on Climate Change (UNFCCC) [22]. CCS is embedded in the countries 2020 Environmental Innovation Strategy with an expectation that CCS will contribute 14% of cumulative CO₂ reduction by 2060. Japan also has the stated aim of being

carbon neutral by 2050. Regulatory precedent is held through the CO₂ stored by the Nagaoka (pilot) and Tomakomai (demonstration) projects under the current regulatory system. To permit the Tomakomai project Japan amended a domestic law reflecting the London Protocol (1996) and awarded a 5-year permit allowing offshore storage of CO₂ but required an accompanying marine environment survey plan [26].

9.6 Issues for the Assessment

Lack of ready access to site-specific data was the main issue for this assessment cycle. Since 1995 Japan has undertaken several country-wide evaluations of storage potential however much of the detail of these is not in the accessible public domain. This means that the Catalogue risks an underestimation, or at a minimum a poor representation, of the details of the available resource.

9.7 Future Updates

9.7.1 Future CSRC cycles

Should any further development at the Tomakomai storage system occur, this should be reviewed on an annual basis to ensure the Global Storage Catalogue is up to date.

The RITE/ENAA storage resource database could provide additional, in-depth resource summaries which are currently not readily available in the public domain. If Japan CCS Co. Ltd. publish the results of their 2017 study 'Investigation of Potential CO₂ Storage Sites', any new sites should be added to the Catalogue.

10 Kazakhstan

10.1 Summary

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

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	1.17	0.00
Undiscovered	581.71	0.00
Aggregated*	582.88	0.00

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

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

- Storage Kazakhstan has no identified CCS projects but has 20 storage sites in the CSRC.
- Oil and gas fields were assessed for CO₂ storage and are determined to be “Discovered: inaccessible” because the fields are assumed to be discovered with drilled wells and no regulatory framework for CCS exists in Kazakhstan.
- Saline aquifers were assessed for CO₂ storage and are determined to be “Undiscovered: inaccessible” because no information was provided regarding drilled discovery of the aquifer resources and no regulatory framework for CCS exists in Kazakhstan.
- Kazakhstan currently has no defined CCS projects.

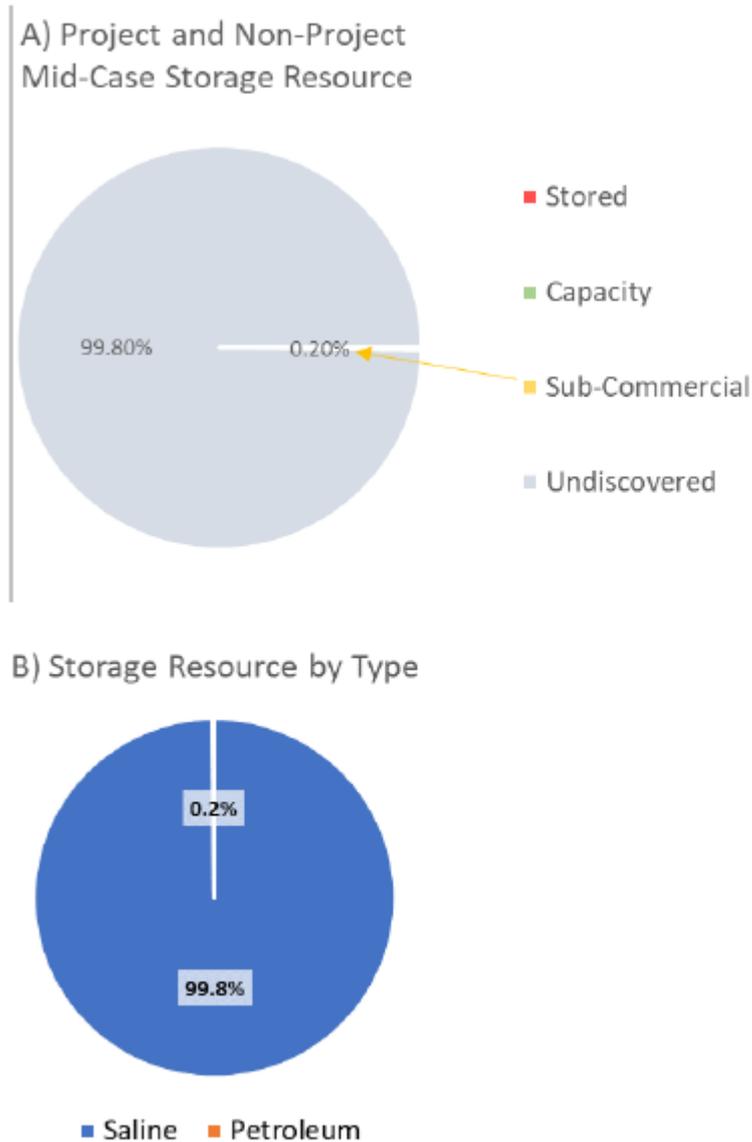


Figure 10-1: Kazakhstan spread of Storage Sites.

A) Spread of storage resource in Kazakhstan (20) across SRMS classifications; both project specified and not. B) Split of Kazakhstan storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

10.2 Resource Statement

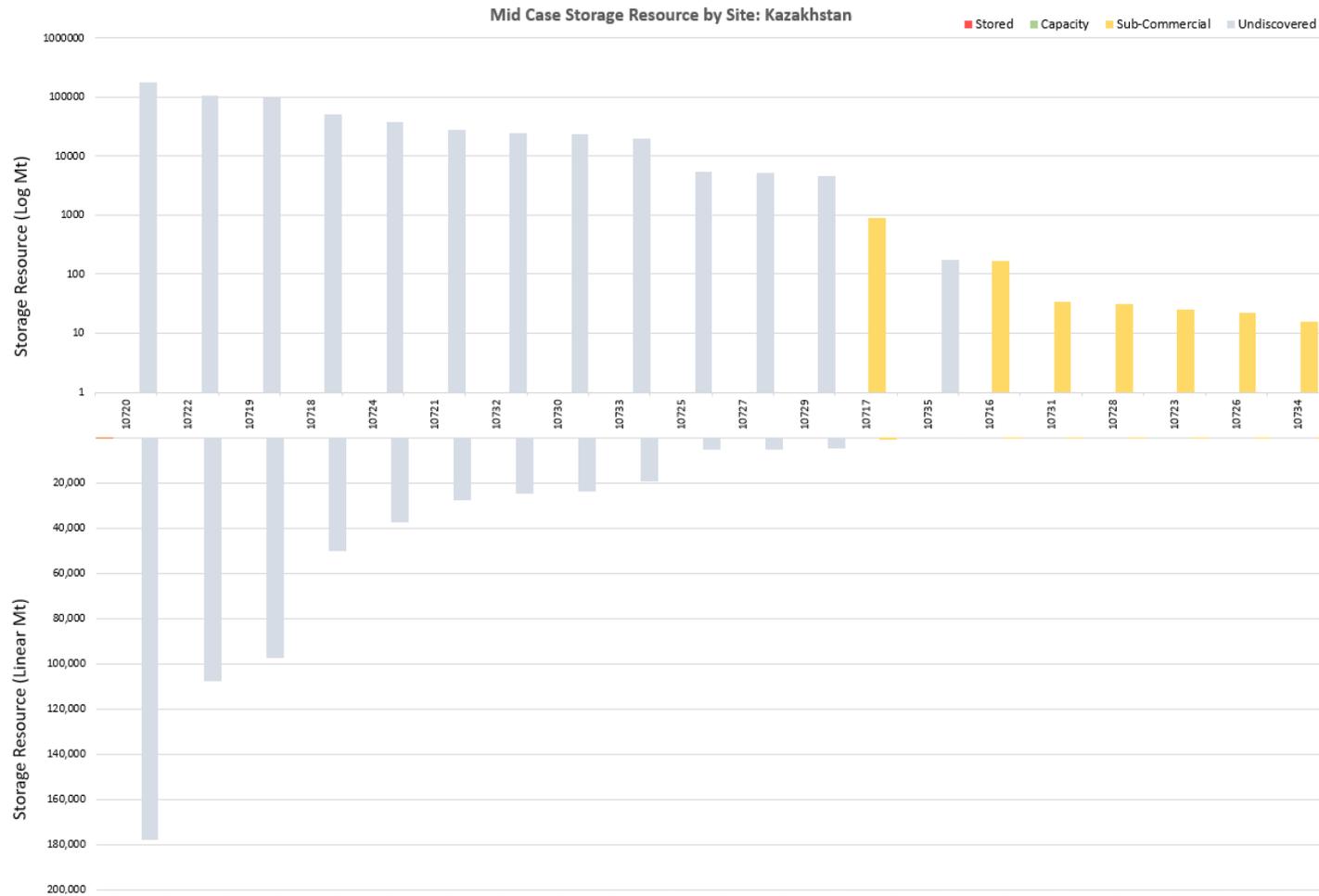


Figure 10-2: Storage resource summary for Kazakhstan compiled in the CSRC.

Graph above is log scale and graph below is linear.

10.3 Evaluation History

Kazakhstan has significant oil and gas resources, on the order of 30 billion barrels – similar in scale to those of Libya and Nigeria [27]. Abuov et al. [28] considered both depleted oil and gas field storage resources and saline aquifer storage resources in their recent characterization of Kazakhstan’s six most suitable sedimentary basins. While their resource characterization is high-level and regional in scale, the significant volume of subsurface geological data and discovered hydrocarbon resources in Kazakhstan provides a preliminary picture of the country’s substantial geologic storage resource base.

Apart from this study, very little has been published on Kazakhstan’s geologic storage resources.

10.4 Resource Review

10.4.1 Major Projects

Kazakhstan has no announced CCS projects of any size.

10.4.2 Depleted Oil & Gas Fields

Abuov et al. [28] estimate storage resources in Kazakhstan’s depleted oil and gas fields utilizing the Carbon Sequestration Leadership Forum (CSLF) approach, which assumes that volumes previously occupied by hydrocarbons will be available for CO₂ storage. Basin-level storage parameters used in the authors’ calculations were provided in the appendices to their paper. Only basins exceeding 10 Mt of storage resources are included in the CSRC. Results of this study show the Precaspian Basin is evaluated as containing – by a significant amount – the largest amount of storage resources in depleted oil and gas fields in the country. The Precaspian basin is assessed at 875 Mt. The authors did not present formation-level analysis for depleted oil and gas fields.

10.4.3 Saline Aquifers

Abuov et al. [28] estimate storage resources in Kazakhstan’s saline aquifers utilizing the US Department of Energy (USDOE) approach, which employs a storage efficiency factor accounting for the fraction of the total pore space with which the injected CO₂ will come into contact. Compared to their study of resources in depleted oil and gas fields, the authors take a more detailed approach in assessing the country’s saline aquifers, partitioning calculations by geologic age at the sequence-level.

According to these authors, the Precaspian Basin has, by far, the largest saline storage resources available in the country – approximately 460 Gt. These resources are distributed amongst five reservoir intervals ranging from the Carboniferous to the Cretaceous, in both clastic and carbonate lithologies. Saline aquifer storage resources in the other evaluated basins are an order of magnitude lower, ranging from ~44,000 Mt in the Mangyshlak Basin, down to just 176 Mt in the Zaysan Basin. The Zaysan basin situated on a transform continental boundary, is seismically unstable, and is therefore not considered suitable for storage.

The Precaspian basin has the largest storage resource base in Kazakhstan, across both depleted oil and gas fields and saline aquifers. It is unclear at this time if this is the case due to favorable geological characteristics or if this is simply an artefact of data density and availability for this basin relative to the other Kazakhstan basins evaluated by Abuov et al. [28].

10.5 Regulatory Framework

While Kazakhstan has ratified both the Kyoto Protocol, the UNFCCC Paris Agreement, and established an emissions trading scheme (ETS), the government has not yet established a CCS-specific regulatory or legal framework which would enable storage of CO₂ or encourage private investment in CCS projects.

10.6 Issues for the Assessment

Very little subsurface data is publicly available for Kazakhstan, so although the CO₂ storage potential in the country is likely high (indicated by this evaluation by Abuov et al. [28] and implied by its significant hydrocarbon resources), a comprehensive picture of Kazakhstan's CO₂ storage resources remains unclear.

The resources assessed in this cycle provided very little or no information about CCS projects, individual storage sites, or storage formation parameters. Reported masses of CO₂ (as presented by Abuov et al. [28]) for oil and gas fields are classified as discovered resources but we assume those fields have been penetrated by drilled wells. These resources will remain classified as Discovered: Inaccessible until the country establishes a legal regulatory framework for CCS projects. Due to the lack of published subsurface detail, saline aquifers are assumed to have not been defined by drilling and are therefore classified as Undiscovered resources. To mature these saline aquifer assessments into the Discovered classification, more information is required, such as locations of well control.

10.7 Future Updates

10.7.1 Future evaluations

More detailed analysis is required to mature Kazakhstan's storage resources toward commerciality, for both saline aquifers and depleted oil and gas fields. Geologic models including simulation of injection projects should be completed for proposed storage sites utilizing well and seismic data to constrain model dimensions and subsurface architecture. In order to fully understand the CO₂ storage resources of Kazakhstan, all possible sites need to be characterized and assessed.

10.7.2 Future CRSC cycles

Updates to this Cycle 3 assessment should be completed if additional studies on Kazakhstan's storage resources become available.

11 Afghanistan, Kyrgyzstan, Tajikistan and Turkmenistan

11.1 Summary

Afghanistan, Kyrgyzstan, Tajikistan and Turkmenistan were assessed during Cycle 5. These countries are reported as having no current CO₂ geological storage resources.

Classification	CO ₂ storage resource (Gt)	
	Project and no project	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 Afghanistan, Kyrgyzstan, Tajikistan and Turkmenistan.

Table 11-1: Storage resource classification summary for Afghanistan, Kyrgyzstan, Tajikistan and Turkmenistan.

11.2 Afghanistan

11.2.1 Evaluation History

Afghanistan was reviewed during Cycle 5. No CO₂ storage evaluations have been carried out at the federal or academic level. Afghanistan is not currently a hydrocarbon-producing country despite having significant resources in the north of the country in the Amu Darya and Afghan-Tajik basins. The likelihood of any depleted reservoir for CO₂ storage therefore will be in the very distant future. A report in 2020 called 'Technology Needs Assessment Report Mitigation' by the Government of the Islamic Republic of Afghanistan's National Environmental Protection Agency discussed CCS as key technology to be addressing climate change mitigation needs of the country. There were no further details published other than what CCS is. Due to political changes in the country, it is unclear if climate mitigation technology is still under consideration. [1].

11.2.2 Regulatory Framework

Afghanistan does not currently have any regulatory framework for geological storage of CO₂.

11.2.3 Future Updates

The future of any climate imitation plans are unclear in Afghanistan and hence future updates are unlikely to be necessary.

11.3 Kyrgyzstan

11.3.1 Evaluation History

Kyrgyzstan has a very small hydrocarbon-producing industry, however, to date no CO₂ storage opportunities have been reported in depleted hydrocarbon fields. Further to this, no CO₂ storage evaluations have been carried out at the federal level. There is only one study in the public domain that evaluated potential storage in Kyrgyzstan with the outcome being that Kyrgyzstan has no potential geological storage in either saline aquifers or depleted fields [1].

11.3.2 Regulatory Framework

Kyrgyzstan does not currently have any regulatory framework for geological storage of CO₂.

11.3.3 Future Updates

Kyrgyzstan is unlikely to pursue geological storage as part of its energy transition plans. However, future updates could investigate to see if any further studies have been conducted in the country.

11.4 Tajikistan

11.4.1 Evaluation History

There are no published reports or research to support that Tajikistan has areas suitable for geological storage of CO₂. The country is reported as having nominal capacity through Advanced EOR of around 10 Mt [3]. Tajikistan has one of the lowest GHG emissions in Central Asia. Its climate strategy includes carbon sequestration via nature-based solutions such as an increase reforestation [4].

11.4.2 Depleted Oil & Gas Fields

There are no reported resources in Tajikistan. It's very small hydrocarbon industry may not be viable for future CO₂ storage.

11.4.3 Regulatory Framework

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

11.4.4 Future Updates

Tajikistan is unlikely to pursue geological storage as part of its energy transition plans. However, future updates could investigate to see if any further studies have been conducted in the country or it is part on an updated regional assessment.

11.5 Turkmenistan

11.5.1 Evaluation History

There are no published reports or research to support that Turkmenistan has areas suitable for geological storage of CO₂. However, the country is reported as having some capacity through Advanced EOR of around 122 Mt [5]. Turkmenistan has a climate strategy that includes carbon

sequestration via nature-based solutions such as an increase reforestation [6].

11.5.2 Depleted Oil & Gas Fields

There are no reported resources in Turkmenistan. However, Turkmenistan does have significant hydrocarbon resources producing both oil and gas and hence may have future depleted fields that could be repurposed for CO₂ storage.

11.5.3 Regulatory Framework

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

11.5.4 Future Updates

Since Turkmenistan is part of the Caspian Basin and with a significant hydrocarbon industry, future updates should look to see if there is any regional advancement of CCS studies that include Turkmenistan for using depleted oil and gas fields.

11.6 References

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12 Laos

12.1 Summary

Lao was assessed during Cycle 5. This country is reported as having no current CO₂ geological storage resources.

Classification	CO ₂ storage resource (Gt)	
	Project and no project	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 Laos.

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

12.2 Evaluation History

There are no published reports or research to support that Laos has areas suitable for geological storage of CO₂. Laos does have several sedimentary basins and most are currently exploited for mineral resources including coal, limestone, metals and gems. One basin, (the Khorat Plateau Basin, which covers most of neighboring NE Thailand), has undergone some initial exploration for hydrocarbons and may have potential suitable formations for CO₂ storage, but this requires further research. As yet the country is not focused on investigating CCS as part of its climate strategy and prefers options that include carbon sequestration via improving agricultural and forestry practices. [1].

12.3 Regulatory Framework

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

12.4 Future Updates

Due to a preference to nature-based CO₂ sequestration, Laos will not need future updates

12.5 References

1. Lao People's Democratic Republic, 2021. Nationally Determined Contribution (NDC). <https://unfccc.int/sites/default/files/NDC/2022-06/NDC%202020%20of%20Lao%20PDR%20%28English%29%2C%2009%20April%2021%20%281%29.pdf>

13 Malaysia

13.1 Summary

Malaysia was assessed during Cycle 2. The CSRC has identified a CO₂ storage resource for Malaysia as follows:

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.0	0.0
Capacity	0.0	0.0
Sub-Commercial	0.0	0.0
Undiscovered	149.6	0.1
Aggregated*	149.6	0.1

* 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 Malaysia.

Table 13-1: Storage resource classification summary for Malaysia.

- Malaysia has six sites in the Cycle 2 Assessment: two basin scale saline aquifers (undiscovered) and one project where the resource will be used to store CO₂ that is co-produced with natural gas (undiscovered).
- All sites are undiscovered as there is no published information on wells that may have been drilled in the formation.
- In the absence of any CCS-specific regulatory system, all resources are currently classified as 'Inaccessible'.

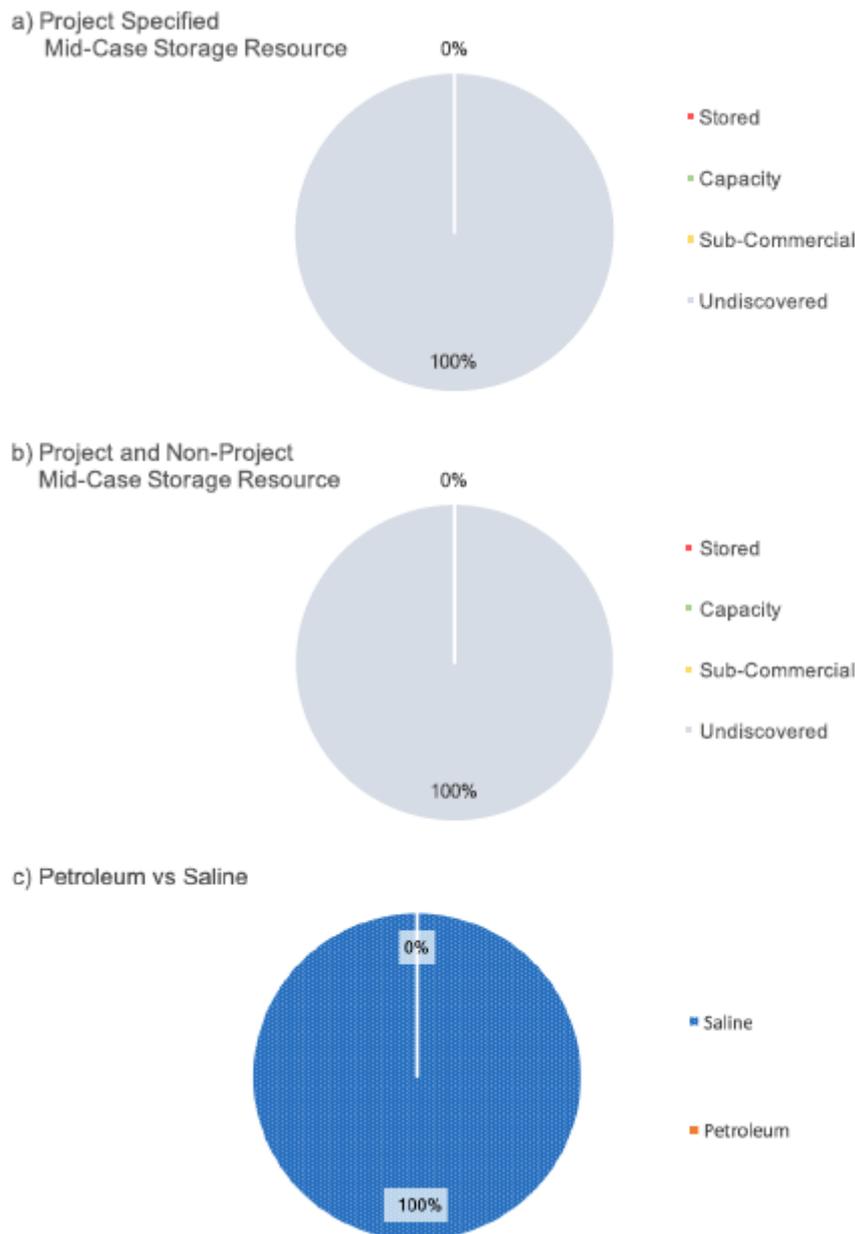


Figure 13-1: Malaysia spread of Storage Sites.

a) Spread of storage resource in Malaysia sites (6) across SRMS classifications, where a project has been specified. b) Spread of storage resource in all Malaysia sites across SRMS classifications; both project specified and not. c) Split of Malaysia storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

13.2 Resource Statement

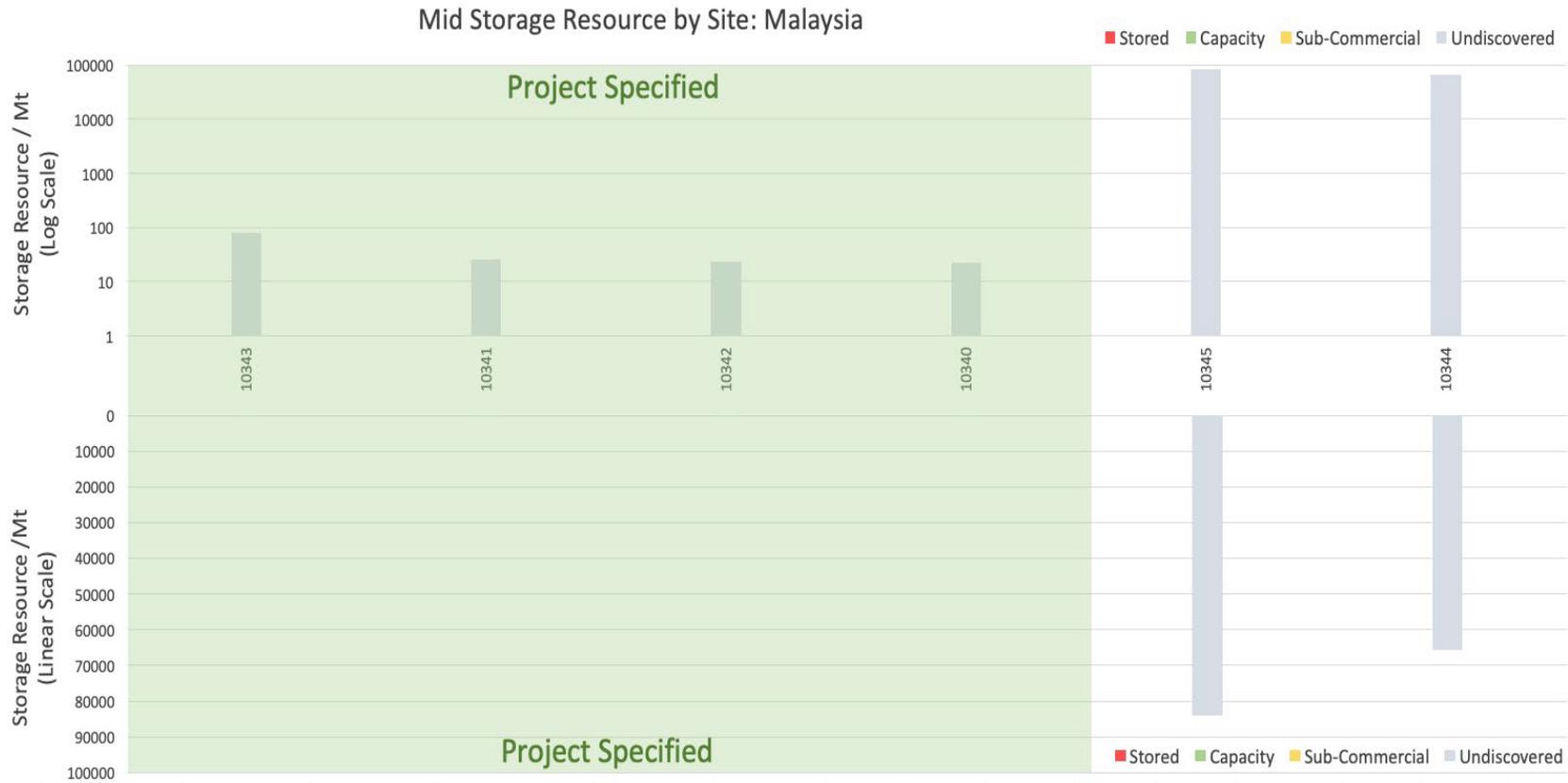


Figure 13-2: Storage resource summary for Malaysia compiled in the CSRC.

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

13.3 Evaluation History

The oldest evaluation of Malaysia's carbon storage potential was carried out by the Asia-Pacific Economic Cooperation in partnership with CO₂CRC. This assessment solely focused on storage of CO₂ co-produced with natural gas in south east Asia using a case study on CO₂ capture and storage from the cumulative gas stream of the undeveloped Tangga Barat cluster, Malay basin, although all estimates appear to have been generated using a simple volumetric methodology.

A regional study was undertaken by Junin and Hasbollah. [29], in which a dynamic spreadsheet (using geological and economic inputs) was used to assess 14 of Malaysia's sedimentary basins on their potential for carbon storage. This spreadsheet down selected to just two basins that are most suitable for CO₂ storage. The assessment criteria did not include proximity of the resource to large CO₂ emissions sources. The storage resource was calculated by the US-DOE [30]volumetric method for the two "high scoring" basins, these numbers are given as part of the 2020 Assessment. Junin and Hasbollah. [29] carried out this study in recognition of the fact that Malaysia's CO₂ emissions have been increasing by 1.9% per year since 1990, and if not acted on will continue to rise as Malaysia undergoes rapid economic growth.

Both of the above studies calculate storage resource using basic volumetric calculations. Based on lithology and depositional environment, all reservoirs presented will have a large variation in properties resulting in the resource estimates having low confidence.

13.4 Resource Review

All storage resources assessed in this region are saline aquifers, however they can be subdivided into two different classes:

- Storage of CO₂ co-produced with natural gas: sites selected because of their close proximity to undeveloped natural gas fields with high percentage CO₂ content. These were classified as undiscovered as, although there are hydrocarbon exploration wells in the area, there is no direct mention of wells within the formation nor any indication of proximity to the storage resource site.

Basin wide storage resource – these have been classified as undiscovered as, although the basins have an active hydrocarbon exploration and production, there is no mention or location of any wells within the basins. Potential storage sites are mapped onto cross-sections, but these are not geographically co-located.

13.5 Regulatory Framework

Malaysia has been evaluated under the 2018 GCCSI CCS readiness index [8]. However, there are no CCS-specific regulatory or legal frameworks that could directly assist a project in Malaysia. The readiness index gives Malaysia a high score for inherent interest; this means that based on the nation's economic dependence on fossil fuels, it would benefit from implementing CCS as a carbon emissions reduction strategy. However, the index shows that law and policy

changes are needed to give more incentives for CCS project development.

An APEC (2010) study outlines a range of incentives that Malaysia has in place for environmental management, some of these may be relevant for CO₂ transport and storage practices. Incentives include: varying tax exemptions for companies providing energy conservation services; facilities to store, treat and dispose of toxic waste; or companies using environmental protection equipment. While CO₂ transport and storage practices do not currently qualify for these, it would be possible to make a case for their inclusion.

Malaysia has committed to reduce its emissions intensity by 40% by 2020 and 45% (relative to 2005 emissions) by 2030 as part of the Paris Agreement (UNFCCC, 2015). By 2011 they had already reduced emissions by 33% and, a recent announcement from the Malaysian state-owned energy company Petronas, states their aim of becoming a net zero emitter of greenhouse gases by 2050.

13.6 Issues for the Assessment

The biggest issue with classifying all the Malaysia storage resources, was a lack of detail on data availability and location; no well numbers or locations were given despite some sites being in or near areas with significant ongoing petroleum exploration. This means that most of the resources have had their maturity downgraded.

Accuracy of resource estimates for most sites is limited by both the volumetric methodology used and the assumption of one set of reservoir properties for all estimates at all sites.

For all but one of the storage resources presented, there is only a single value for resource estimation. In cases where the resource estimation only reflects the volume of emissions over lifetime of project, the resource estimate has been recorded as the 'Low-Range' value. In all other cases the resource estimation has been recorded as the 'Mid-Range' value.

13.7 Future Updates

13.7.1 Future CSRC cycles

- Any updates on current potential storage sites should align with SRMS approach and methods to allow progress (maturation) up the classification system.
- Updates should be made if Petronas and other petroleum's companies release any well location data for the area's which contain storage resources in the Malay Basin and Greater Sarawak Basin. This would promote several storage resources from undiscovered to discovered.

14 Maldives

14.1 Summary

Maldives was assessed during Cycle 5. This country is reported as having no current CO₂ geological storage resources.

Classification	CO ₂ storage resource (Gt)	
	Project and no project	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 Maldives.

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

14.2 Evaluation History

There are no published reports or research at a federal or academic level to support that The Maldives has sites suitable for geological storage of CO₂. As a low-lying volcanic atoll with a very small land area (115 km²), a population of ~500,000 and no heavy industry, geological carbon storage is unlikely to be considered in the Maldives.

14.3 Regulatory Framework

Maldives does not currently have any regulatory framework for geological storage of CO₂.

14.4 Future Updates

Due to a lack of suitable geology and low emissions the Maldives will unlikely need future updates.

15 Mongolia

15.1 Summary

Mongolia was assessed during Cycle 5. There are currently no identified CO₂ storage resources for Mongolia.

Classification	CO ₂ storage resource (Gt)	
	Project and no project	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 Mongolia.

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

15.2 Evaluation History

There is no research at a federal or academic level for CO₂ storage potential in Mongolia. However, reports in China do suggest that suitable formations for storing CO₂ have been identified in China may also extend into Mongolia. They include formations in the Eren basin, Ordos basin (including Hetao basin), Bohai Bay basin and Junggar basin [1]. Geological research indicates the Eren basin, to be the most viable candidate for CO₂ storage. This site is a saline aquifer with favorable features that are still under study for establishing its potential for long term CO₂ retention.

While geological CCS is acknowledged to mitigate carbon emissions, the country lays more emphasis on natural climate solutions due to large rangeland and vegetation and the considerable carbon sequestration potential which can be achieved by other environmental efforts such as afforestation and effective land and soil management (soil organic carbon), which Mongolia deems more cost effective.

15.3 Regulatory Framework

There are no clear legal frameworks relating to Capture and Storage (CCS) in Mongolia.

15.4 Issues for the Assessment

Lack of geological research, lack of data and absence of regulatory frameworks are the main issues for this Cycle 5 assessment of Mongolia.

15.5 Future Updates

15.5.1 Future CRSC Cycles

Since Mongolia possesses geological characteristics for CO₂ storage and has recognized it as a means to achieve net zero emissions, future cycles could seek form any progress with research studies.

15.6 References

Zeng, Rongshu; Vincent, Ceri Jayne; Tian, Xingyou; Stephenson, Mike H.; Wang, Shu; Xu, Wendong. 2013. New potential carbon emission reduction enterprises in China: deep geological storage of CO₂ emitted through industrial usage of coal in China. *Greenhouse Gases: Science and Technology*, 3 (2). 106-115. 10.1002/ghg.1314

16 Philippines

16.1 Summary

The Philippines was assessed during Cycle 5. The CSRC has identified a CO₂ storage resource for Philippines as follows:

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.318	0.000
Undiscovered	23.000	0.000
Aggregated*	23.318	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 the Philippines.

Table 16-1: Storage resource classification summary for the Philippines.

- The Asian Development Bank is looking into technologies such as CCS to reduce emissions and limit global warming in Southeast Asia and the Philippines was included in this regional research.
- All reported Philippines hydrocarbon field storage resources were hosted in one unidentified field, (estimated storage capacity of about 251 Mt CO₂), one near-depleted gas field (estimated storage capacity of about 67.2 Mt), and two saline aquifers of about 23 Gt storage capacity in total.
- The identified sites include the Malampaya gas field, the Cagayan and Central Luzon Basins (saline aquifers).
- To date, there are no ongoing projects in Philippines for CO₂ storage.
- There is no comprehensive legal framework to permit CO₂ storage related activities.
- Research on Philippines CO₂ capacity is preliminary with lack of detailed geological research on identified sites.

A) Project and Non-Project
Mid-Case Storage Resource



B) Storage Resource by Type

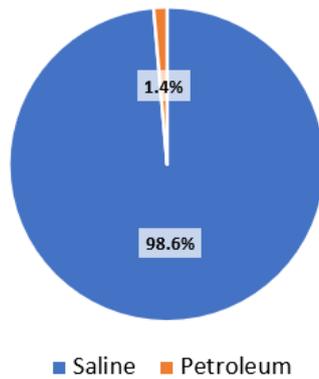


Figure 16-1: Philippine spread of Storage Sites.

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

16.2 Resource Statement



Figure 16-2: Storage resource summary for Philippines compiled in the CSRC.

The graph above is a log scale, and the graph below is linear.

16.3 Evaluation History

There is limited research for the Philippines in the public domain and it is largely restricted to two regional assessment reports from the Asian Development Bank and the GCCSI & ERIA

The Asian Development Bank (ADB) launched a regional technical assistance project to assess CCS potential in countries like Indonesia, the Philippines, Thailand and Vietnam. This was completed in 2013. The research reviewed potential for CO₂ storage in the Philippines from a source to sink perspective. Both hydrocarbon fields and aquifers were identified but with very limited technical details. In addition, it was also cited that the Philippines has ophiolite complexes that could provide an unconventional CO₂ sink.

The GCCSI and ERIA reviewed the ASEAN countries for storage, value chain, policy and regulations in 2024. Similar results were reported in terms of CO₂ resources since the ADB assessment was used.

16.4 Resource Review

The Philippines has an oil and gas industry and some potential for storage with one field identified as have promising CO₂ potential. Additionally, two saline aquifers have been cited as potential options for storage [2].

16.4.1 Major Projects

Currently, there haven't been any announcements about CCS facilities being built in the Philippines [1].

There are no carbon capture projects in industrial processes or in operating power generation facilities in the Philippines primarily due to the many challenges surrounding the use of CCS technology such as technical, cost-competitiveness, concern for environmental and public health risks, and the absence of policies mandating reductions in carbon emissions or specific laws for the purpose [3].

16.4.2 Depleted Oil & Gas Fields

There is great uncertainty on the resource in any depleted oil and gas fields in the Philippines.

According to the GCCSI & ERIA report in 2024 [1], the storage resource assessment of the Philippines is limited to a single gas field (Malampaya gas field) in the North Palawan Basin. The current study found that the Malampaya Gas Field had a potential estimated storage resource of 67.2 Mt CO₂, with 57.1 Mt CO₂ currently available today for injection. The field is comprised of Oligocene to Miocene carbonate build-ups of the Nido Formation and sealed by mudstones of the overlying Pagasa Formation. Porosity ranges from 5 to 30 %, and permeabilities range from 0.01 to 1,000 mD.

The ADB (2013) [3] also concluded that collectively hydrocarbon field storage resources were hosted in one unidentified field, 251 Mt CO₂ (total of 307 Mt CO₂). This is included in the CRSC

as a country wide entry. Caution should be applied to these resource estimates since it is possibly a collation of many small fields, that individually do not have sufficient resources to develop.

16.4.3 Saline Aquifers

The Cagayan and Central Luzon Basins have sufficient data for initial CO₂ storage screening. With its proximity to the Calabarzon (the basin lies within 50km of the Calabarzon) and relatively absent of major faults, the Central Luzon Basins was assessed first as a possible storage site. According to the ADB report [3], the storage resources in saline formations of the Luzon and Cagayan basins (both underlying Luzon Island) were estimated. It cites a theoretical storage of 23 Gt.

16.5 Regulatory Framework

The Philippines lacks a CCS-specific legal and regulatory framework and CCS-specific domestic policies or incentives [1].

The Philippines has several laws and regulations that could potentially be used to regulate CCS projects. Environmental laws could cover provisions for ongoing liability for negligence or intentional misconduct in carrying out a CCS project. Nevertheless, specific provisions of law are needed to address, among others, ownership and long-term steward of injected CO₂ on State land, containment structures, and monitoring, measurement and verification requirements [2].

16.6 Issues for the Assessment

The resource reported for CO₂ storage should be regarded as preliminary because of the limited available data on which the assessments were based. This is largely due to very limited research into CO₂ storage in the country.

16.7 Future Updates

16.7.1 Future CRSC Cycles

Future updates would look for any projects or site updates that may have evolved from installing storage atlas mapping of formations to give more insights on storage potential of onshore and offshore saline formations.

16.8 References

1. Global CCS Institute and Economic Research Institute for ASEAN and East Asia (ERIA). 2024. *Comprehensive CCUS Research Report: Storage, Value Chain, Policy & Regulation and Financing*. ERIA Research Project Report No. 16. Jakarta: ERIA
2. Philippines Department of Energy. Philippine Presentation On Carbon Capture And Storage, http://www.ccop.or.th/eppm/projects/42/docs/Philippines_CCS_presentation_CCOP.pdf

3. ADB, Global CCS Institute, Department of Energy & Climate Change. 2013. Prospects for Carbon Capture and Storage in Southeast Asia. ISBN 978-92-9254-290-0 (Print), 978-92-9254-291-7 (PDF) Publication Stock No. RPT135683-2

17 Singapore

17.1 Summary

Singapore was assessed during Cycle 5. This country is reported as having no current CO₂ geological storage resources.

Classification	CO ₂ storage resource (Gt)	
	Project and no project	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 Singapore.

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

17.2 Evaluation History

The geology of Singapore is not suitable for geological storage of CO₂. As such, there are no assessments in the public domain that have reviewed storage site potential.

17.3 Major Projects

Although there are no CO₂ storage projects in the country, Singapore is proactive in its engagement with other countries to develop a CCUS industry [1,2]:

- In 2020 Australia and Singapore signed a memorandum of to advance cooperation on low-emission technologies which indicated that CCUS is a key solution.
- In 2022, Singapore is also started working with, Chevron and Mitsui O.S.K. Lines, Ltd. on the feasibility of transporting liquified CO₂ from Singapore to permanent storage locations offshore Australia.
- In 2023, The UK and Singapore signed a MoU to establish a bilateral Green Economy Framework which will facilitate cooperation in the policy, regulatory and technical aspects of CCUS.
- In 2024 Singapore signed a Letter of Intent with Indonesia to collaborate on cross-border CCS. Also in 2024, the country selected ExxonMobil and Shell to form the S-Hub Consortium to develop a cross-border CCS project.

- Singapore's Energy Market Authority is a member of the Asia CCUS Network

17.4 Regulatory Framework

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

17.5 Future Updates

Future updates could report on any further developments Singapore has as part of regional storage projects.

17.6 References

1. Seah, S., 2024. Carbon Capture, Utilisation and Storage (CCUS): A Singapore Perspective. Accessed 23/05/2025. <https://www.twobirds.com/en/insights/2024/singapore/carbon-capture-utilisation-and-storage-ccus-a-singapore-perspective#:~:text=To%20work%20around%20Singapore's%20geographical,tonnes%20of%20CO2%20storage%20potential.>
2. Srivastav, P., Schenkel, M., Goher Ur Rehman Mir, Berg, T., and Staats, M. Carbon Capture, Utilisation and Storage, (CCUS): Decarbonisation Pathways for Singapore's Energy and Chemicals Sectors <https://file.go.gov.sg/carbon-capture-utilisation-and-storage-decarbonisation-pathway-for-singapore-energy-and-chemical-sectors-pdf.pdf>

18 South Korea

18.1 Summary

South Korea was assessed during Cycle 2. The CSRC has identified a CO₂ storage resource for South Korea as follows:

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.0	0.0
Capacity	0.0	0.0
Sub-Commercial	0.02	0.02
Undiscovered	203.3	0.0
Aggregated*	203.4	0.02

* 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 South Korea.

Table 18-1: Storage resource classification summary for South Korea.

- Storage resource potential is dominated by Undiscovered resource in saline aquifers in offshore basins. Only one gas field has been evaluated (Donghae-1).
- Potential storage resource has been identified in three offshore basins marginal to the Korean peninsula. Limited resource potential may exist in onshore basins, but these are generally too shallow and tight for large scale storage.
- As of February 2021, 203.4 Gt of potential resource has been reported from nine sites however all but one site is a basin-scale play and resource number should be flagged as carrying low confidence. No projects have been identified.
- The Ulleung Basin (East Sea) is considered to have the greatest commercial potential due to its location near the SE coast, however the Jeju Basin (northern East China Sea) holds greater resource potential. Data to support the resource statements is lacking.
- No current regulatory system exists with respect to CCS however South Korea has stated an ambitious Intended National Contribution (2015) and a Draft Korean CCS Act has been circulated.

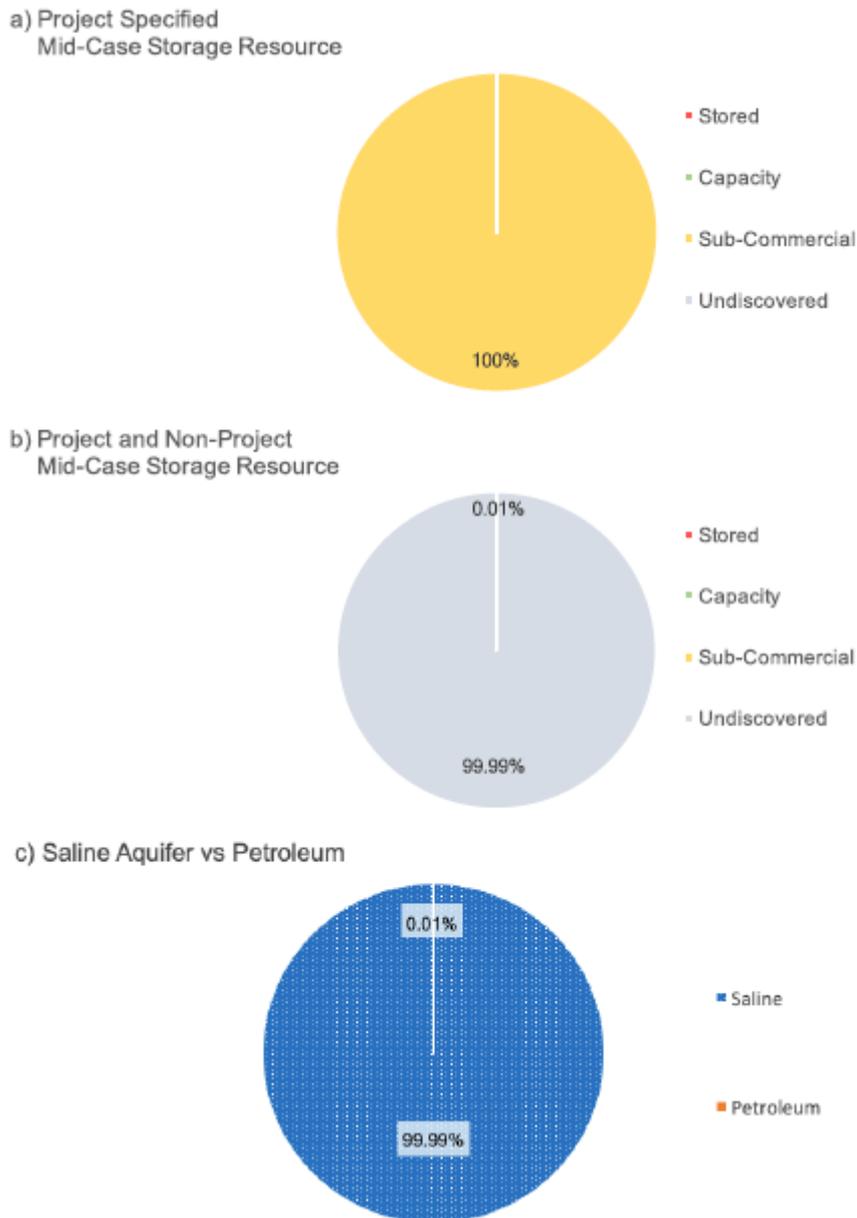


Figure 18-1: South Korea spread of Storage Sites.

a) Spread of storage resource in South Korea (9) across SRMS classifications, where a project has been specified. b) Spread of storage resource in all South Korea sites across SRMS classifications; both project specified and not. c) Split of South Korea storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

18.2 Resource Statement

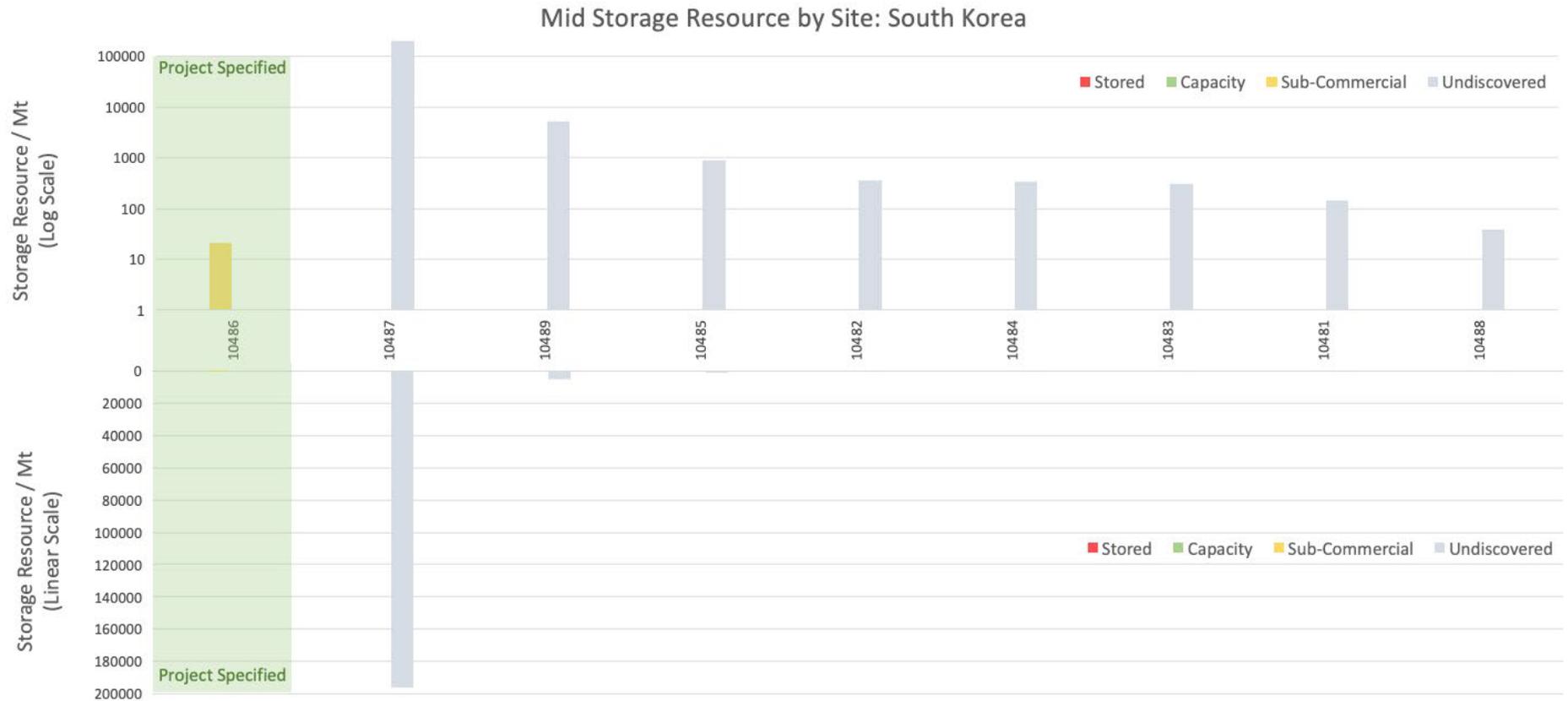


Figure 18-2: Storage resource summary for South Korea compiled in the CSRC.

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

18.3 Evaluation History

In general, the onshore geology of South Korea is considered unsuitable for commercial-scale CO₂ storage. According to Park et al. [31], Kim et al. ([32], Lee et al [33], and Huh and Yoo [34] the onshore basin geology is unfavourable for CO₂ injection and storage, being too shallow with low permeability. Saline aquifer storage is considered to hold the most potential due to the lack of a local hydrocarbon industry [32]. In addition, a 2017 5.4 magnitude earthquake in Pohang City (in the largest onshore basin) caused cessation of all fluid injection activities (both CO₂ and geothermal). Post-event analysis suggests the earthquake was induced by water-injection in an enhanced geothermal system [35].

Studies have been undertaken in both the onshore and offshore areas in South Korea. Of the three offshore basins (the Ulleung basin in the East Sea, the Jeju basin in the East China Sea to the south of the peninsula, and the Kunsan basin in the Yellow Sea to the west). The Ulleung basin has been considered the most feasible due to the presence of gas-bearing structures [36] [35] and closer proximity to major emissions sources. Further developments made be possible as KNOC and Woodside began exploration in the Ulleung Basin in 2019 and new drilling contract (awarded February 2021) for the area may lead to further data availability. The data availability in the Yellow Sea (6 wells, plus 2D and limited 3D) and the Jeju Basin (14 wells plus 2D and some 3D surveys) is more restricted.

The calculation methods used to assess resource potential are essentially volumetric methodologies using the DOE/NETL [37] approach. No projects have been identified which meet the Global catalogue threshold of 10 Mt for inclusion.

18.4 Resource Review

The current classification of potential storage resource in South Korea is significantly limited due to the lack of robust data sets for evaluating the saline aquifers. The approach taken here is to adopt a minimum maturity level approach to classification; resources can progress to more mature classes when there is both evidence and quantification available. The stated resource for South Korea is considered an overestimation as it represents a theoretical value based on limited data.

All resource entries (both saline aquifer and the single gas field) are classified as 'Inaccessible' at this stage due the lack of a regulatory system for CCS and any knowledge on gas field accessibility dates).

18.4.1 Major Projects

No major storage projects have been announced by South Korea. The Korea 2020 project was a major national plan controlling technology development, R & D, and promotion of CCS facilities. Although the projects identified are heavily focused on carbon capture the project did carry the goal of selecting a storage site suitable for the injection of 10,000 t CO₂. Two potential sites are discussed in the literature, the Yeong-Il Bay site in the offshore Pohang Basin and the

Noeseongsan block in the onshore Janggi Basin. Although start-up of injection was due to be in 2016-2017, no mention of these pilot projects was found in the public literature or on the Korea 2020 website. Simulation of injection at the Yeong-Il Bay site indicated a maximum injection volume of between 40,000 t [38] and <1 Mt [39] before maximum allowable pressures were reached.

18.4.2 Depleted Oil & Gas Fields

The Ulleung Basin (East Sea) contains the only identified gas-bearing structures and the only active hydrocarbon field in South Korea. The Donghae-1 gas field (Gorae structure) and the attached aquifer has been evaluated for a range of injection scenarios, with post-depletion CO₂ injection with brine extraction giving the most optimistic resource (24.3 Mt; [36]). Additional gas-bearing structures in the Ulleung Basin (e.g., Dolgorae) may hold potential but no evaluations are available to this cycle of assessment.

18.4.3 Saline Aquifers

The storage resource in South Korea is dominated by the basin-scale saline aquifer resource estimates. Few publications provide sufficient back-up detail to support the published resource estimates, for example, the Taebaek Basin (onshore) has a published resource estimate of 3 Mt (sandstones; [40]) but presentations by the KCCSA [41] quote 180 Mt. In the absence of supporting information for this estimate, the Taebaek Basin resource is not included in the Cycle 2 Assessment. The greatest onshore resource potential is held in the Gyeongsang (Kyoungsang) Basin in which up to 1 Gt resource [42] was calculated in sandstones units from 3 separate locations. The highest potential, 535 Mt, was identified in channel sandstones from these locations. An alternative estimate of 680 Mt for the basin are given by KCCSA [41] but with no supporting data. In the absence of more detailed analysis, these sites may warrant further evaluation. In the south east of the peninsula, the onshore Janggi Basin was evaluated as a potential pilot project location with emphasis on the Janggi Conglomerate and the clastic Seondongri Formation, both of which show significant theoretical resource estimates (142 Mt and 26 Mt respectively [38]; [43] but probabilistic estimates of the effective resource (fluid phase) do not meet the Catalogue threshold (1 Mt and 0.2 Mt respectively).

Three offshore basins have undergone evaluation of their storage resource. The most advanced is the Ulleung Basin where subsurface data (seismic and well) is available. The Jeju Basin to the south has been evaluated but used a simplistic approach dividing the study area into a layer model (cross-cutting geological/lithological boundaries). The estimated resource range of 24 – 690 Gt (average: 196 Gt) is considered a significant overestimation. To the west, the Gunsan (Kunsan) Basin was evaluated by MEST (2008; in Korean) with a reported 254 Mt resource, although this has also been linked to EOR [32] and as such is not currently included in the Catalogue.

18.5 Regulatory Framework

Following an initial GHG reduction goal of 30% (243 Mt) of 2020 BAU emission (813 Mt), with

2Mt of the total to be achieved through CCS, the South Korean government announced an Intended Nationally Determined Contribution (INDC) of a reduction of 37% of GHG emissions compared to 2030 BAU. CCS is seen as a key technology to achieve low carbon growth [44] but currently has no CCS-specific regulatory system, although a Draft Korean CCS Act has been circulated. As a result, all resource entries in the Global Catalogue are currently sitting in the Inaccessible category. This may be changed as soon as any legal and regulatory system is adopted. South Korea did test an emissions trading scheme (started in 2010), with the goal of the scheme taking effect in 2015.

18.6 Issues for the Assessment

While South Korea has been proactive at setting up national plans (e.g., Korea 2020) for R&D and technology development, most of the focus to date has been capture technology. The proposed 10,000t storage pilot has not been reported on in the literature although this may relate to cessation of activities following the 2017 Pohang earthquake.

Current published evaluations of storage resource potential are high level, basin scale estimates with no projects (except for the Yeong-Il Bay pilot study which is <1Mt) available for inclusion in the Global Catalogue.

18.7 Future Updates

18.7.1 Future CSRC cycles

There is limited information on future carbon storage development in South Korea, however it is anticipated that this may change if the country looks to CCS to help meet its current INDC. Future assessment cycles should check for developments.

19 Timor-Leste

19.1 Summary

Timor-Leste was assessed during Cycle 5. The CSRC has identified a CO₂ storage resource for Timor-Leste as follows:

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.250	0.000
Undiscovered	0.000	0.000
Aggregated*	0.250	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 Timor-Leste.

Table 19-1: Storage resource classification summary for Timor-Leste.

- The Government of Timor-Leste has been exploring the option of carbon capture and storage in the country to meet the Paris Agreement commitments and identified the depleting Bayu-Undan reservoir as a viable option.
- The recently depleted Bayu-Undan field in the Timor Sea is the promising option for carbon storage. There is no published report on saline aquifer storage options.
- There is advance development on Bayu-Undan carbon capture and storage (CCS) project with stakeholders such as Santos (main operator) and other partners.
- Timor-Leste is currently developing regulatory and fiscal frameworks for CCS activities.

A) Project and Non-Project Mid-Case Storage Resource



B) Storage Resource by Type

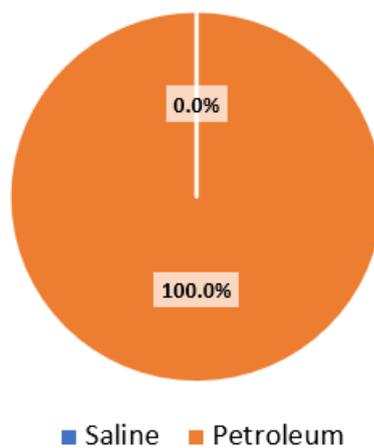


Figure 19-1: Timor-Leste spread of Storage Sites.

A) Spread of storage resource in all Timor-Leste sites across SRMS classifications; both project specified and not. B) Split of Timor-Leste 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.

19.2 Resource Statement

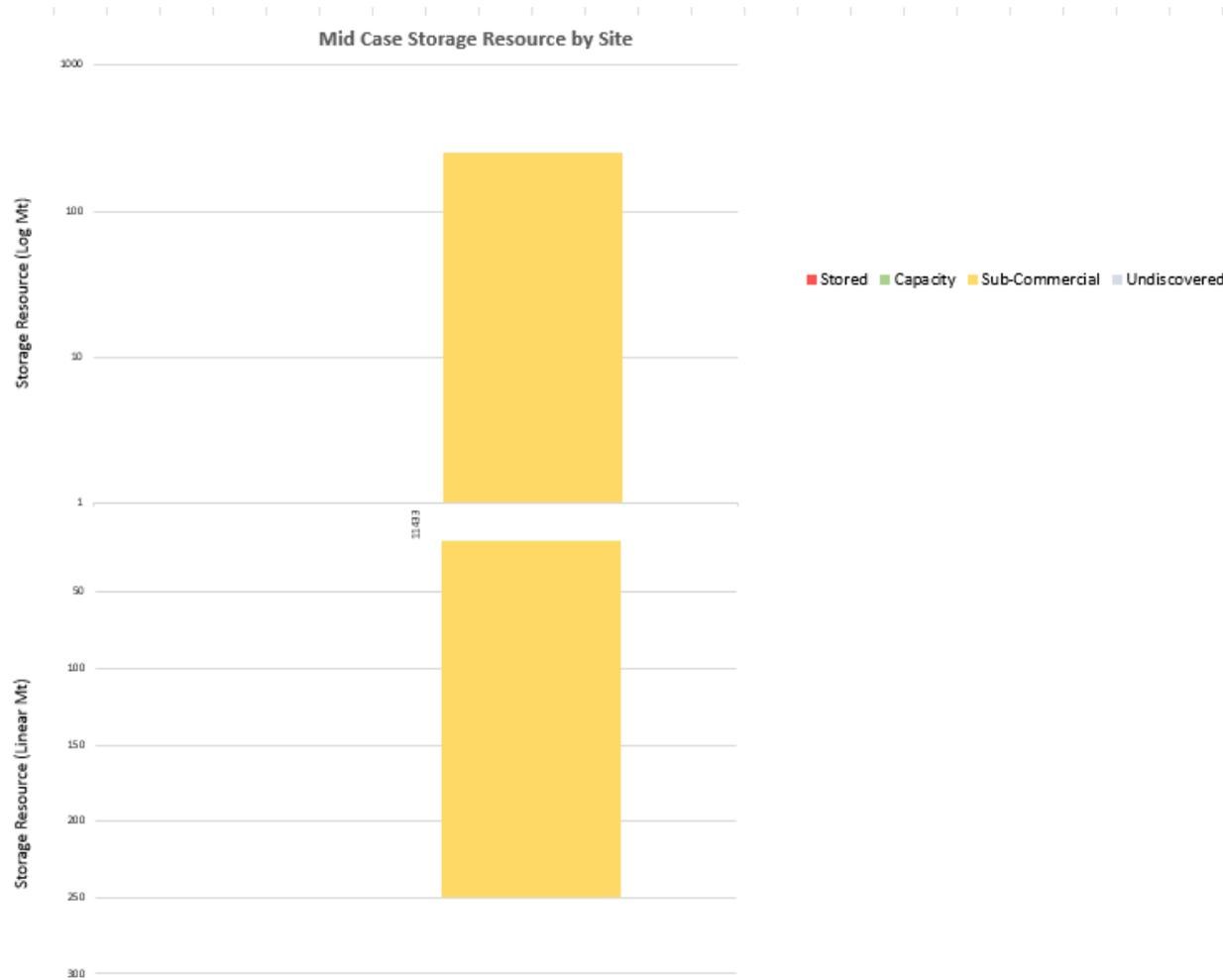


Figure 19-2: Storage resource summary for Timor-Leste compiled in the CSRC.

The graph above is a log scale, and the graph below is linear.

19.3 Evaluation History

A published presentation by the National Authority for Petroleum and Minerals on CCS in Timor-Leste indicates that the Government of Timor-Leste (GoTL) has been evaluating the development of a CCS hub facility at the depleting Bayu-Undan reservoir, a mature gas and condensate field located in the Timor Sea which has been in production since 2004.

The proposed Bayu-Undan CCS reflects GoTL's commitment towards accelerating decarbonization and meeting the Paris Agreement commitments.

19.4 Resource Review

According to available literature, Timor-Leste's main CO₂ storage potential lies within the depleted Bayu-Undan field in the Timor Sea. Very limited research and studies exist for saline aquifers.

19.4.1 Major Projects

In March 2022, the Bayu-Undan offshore gas production facility in Timor-Leste entered the front-end engineering and design (FEED) phase for the proposed Bayu-Undan CCS. The project has the potential to be the largest CCS project in the world and one of the many that will be critical to help the world meet its climate goals [3].

In 2023, Santos and its Bayu-Undan joint venture partners signed a Memorandum of Understanding (MoU) with Timor-Leste's national oil company, TIMOR GAP to explore partnership opportunities for the proposed Bayu-Undan CCS project [2]. Santos has 43.4% operated interest in Bayu-Undan. The remaining interest is held by SK E&S (25%), INPEX (11.4%), Eni (11%), and Tokyo Sea Resources (9.2%). The Bayu-Undan CCS project is part of Santos' three-hub CCS strategy that includes the Moomba's CCS project (Australia), now 70 per cent complete and on track to store up to 1.7Mt of CO₂ per year commencing in 2024.

19.4.2 Depleted Oil & Gas Fields

The recently depleted Bayu-Undan field has been identified and secured for CCS project. The field has estimated storage capacity of >250Mt CO₂, with potential for >10Mtpa. This field has 20 years of storage modelled, with potential for additional upside [1]. The Bayu-Undan field has proven reservoir seal and high injectivity [1].

19.4.3 Saline Aquifers

There is an absence of any literature in the public domain that reports on Timor-Leste's saline aquifer storage.

19.5 Regulatory Framework

Based on available literature, Timor-Leste is exploring the regulatory and fiscal frameworks for Bayu-Undan TL CCS Hub [1].

The International Finance Corporation (IFC) will provide technical assistance to the Ministry of

Petroleum and Mineral Resources in Timor-Leste, contributing to the formulation of legal and commercial frameworks [2]. Santos is also working closely with the Timor-Leste regulator, ANPM, towards the necessary agreements and regulatory framework that will be required for the Bayu-Undan CCS project [3].

19.6 Issues for the Assessment

There is limited literature in the public domain or Timor Leste. However, with an active and significant project underway, research may not expand further through the country as the Bayu-Undan project will remain a core focus for any CCS activities.

19.7 Future Updates

19.7.1 Future CRSC Cycles

Since Timor-Leste is in the process of developing regulatory and fiscal frameworks, future evaluations should address legislation updates, and any new update to the Bayu-Undan project.

19.8 References

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3. Globally Significant Carbon Capture and Storage Project a Step Closer Globally significant carbon capture and storage project a step closer | Santos

20 Thailand

20.1 Summary

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

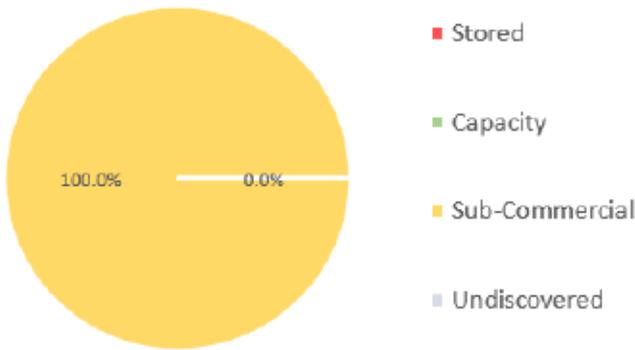
Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	1.571	0.011
Undiscovered	8.9	0.070
Aggregated*	10.471	0.011

* 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 Thailand.

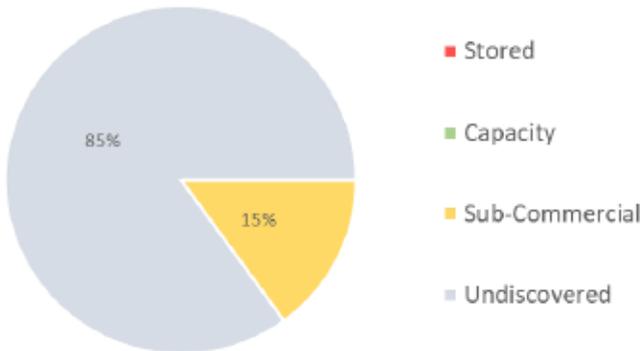
Table 20-1: Storage resource classification summary for Thailand.

- There are currently 39 sites at both local and regional scale, located across a minimum of 10 basins both onshore and offshore
- One of these evaluations has a project defined
- Only two sites in the country are saline aquifers, the remaining 37 are all petroleum
- There are no active CCS projects in Thailand
- The Thai Government have not yet developed a CCS specific regulatory framework.

Mid-Case Storage Resource



B) Project and Non-Project Mid-Case Storage Resource



C) Storage Resource by Type

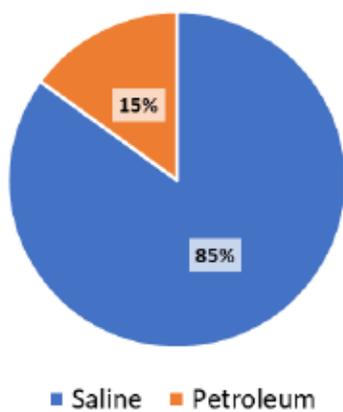


Figure 20-1: Thailand spread of Storage Sites.

A) Spread of storage resource in Thailand sites (39) across SRMS classifications, where a project has been specified. B) Spread of storage resource in all Thailand sites across SRMS classifications; both project specified and not. C) Split of Thailand storage resource between saline aquifers and hydrocarbon fields, both project specified and not.

20.2 Resource Statement

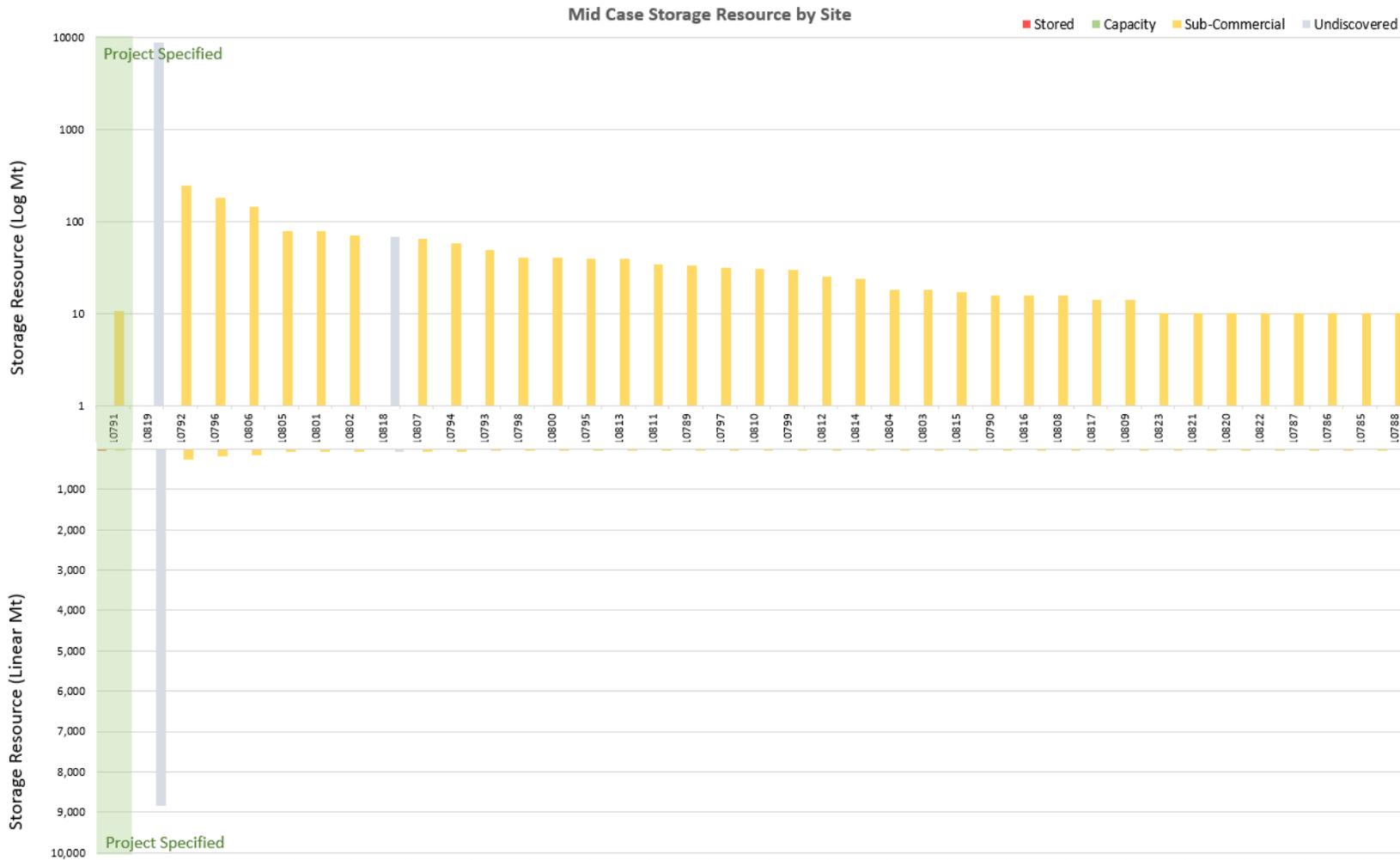


Figure 20-2: Storage resource summary for Thailand compiled in the CSRC.

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

20.3 Evaluation History

Several storage resource evaluation studies have been carried out on potential opportunities in Thailand. Most of these focus on offshore depleted hydrocarbon fields:

- The earliest published evaluation of Thailand's carbon storage potential was carried out by the Asia-Pacific Economic Cooperation in partnership with CO₂CRC [3]. This evaluation is solely focused on storage of CO₂ co-produced with natural gas in southeast Asia. Only a single site with 70Mt resource is presented in this publication for Thailand. For all resources presented, a simple simulation was conducted to determine the maximum rate of CO₂ that can be injected over the injection period without the pressure in the reservoir exceeding its fracture pressure.
- A country-wide storage resource screening study for Thailand was carried out by the Asian Development Bank in 2013 [15]. Here, qualifying criteria were used to screen all sedimentary basins in the country for both saline aquifer and petroleum resource. This study gives resource estimates for individual depleted oil and gas fields and a cumulative resource for all saline aquifers deeper than 1000m in the country. Almost 70% of the gas fields studied are located in the Pattani Basin with the remainder in the Greater Thai, Malay, Greater Chao Phraya, Phitsanulok, and Greater Khorat basins. The screening criteria used to select and score each of the potential petroleum storage sites included the following attributes: Capacity, Injection rate, depth, seal integrity, and absence of active faulting. Site scores also evaluated the number of production/ injection and abandoned wells and economic criteria (e.g., existing infrastructure, willingness of operator etc.). Replacement volume calculations were used to calculate depleted field storage resources and were based on cumulative production data for oil, gas and water and reserve estimates. Saline aquifer resource was estimated using rough pore volumes of all formations.
- Choomkong 2017 [45] presents an updated evaluation of Thailand's country wide depleted petroleum resource. The results are presented as cumulative values per basin and sub-basin. This study does not use any screening criteria therefore each basin resource will include some resource that is not commercially viable. To calculate storage resources, oil and gas STP values were converted to equivalent CO₂ tonnage stored using a standard conversion for all fields included. This assumes constant pressure and temperature gradients as well as permeability throughout. This paper also considers CO₂ sources, as the storage resource results are presented next to their closest emitters. This study was in response to Thailand's Alternative Energy Development Plan (2015-2036) which was developed in response to increased electricity demand that is expected in order to keep pace with the economic growth of the ASEAN Economic Community. This study evaluates depleted field storage within the same basins as ADB 2013 but applies no screening criteria and does not give resource values for individual fields, therefore it has been decided to include the depleted field resources from ADB 2013 in the CSRC instead of those from this study).

- Maneeintr 2017 [46] presents a dynamic simulation of CO₂ injection for the Fang Oilfield – Thailand's northern most resource. Reservoir information was derived from the Defense Energy Department, Northern Petroleum Development Centre, and CMG's GEM software package was used to simulate CO₂ injection into this reservoir. The three Injection rates simulated were based on CO₂ streams coming from the Mae Moh Power plant. These rates were: 1000, 2000 and 4000 tons/day over periods of 35, 17, and 9 years.
- Choomkong 2020 [47] is the most recent study evaluated in the CSRC and focuses on the Bua-Ban oilfield in the Songkhla basin, which sits close to shore near the border with Malaysia. A block geo-model was created for two intervals within this AOI, the lower Oligocene and the lower Miocene. The lower Miocene interval was only simulated with total injected CO₂ of 2.71Mt so has not been included in the CSRC. The Simulation was run on Eclipse 2017, Injection rates and total volume in the model were programmed to match CO₂ streams from the Chana powerplant in the period from 2015 to 2017. The static model was created on Petrel using data from 164 wells in the area and a local geophysical survey.
- Two depleted gas field studies, located in the Malay basin were also reviewed but did not meet the CSRC 10 Mt storage resource threshold. Rawangphai 2018 [48] reported a resource of maximum 2Mt, while Maneeintr 2018 [49] reported a total resource of 6Mt for a different field. Both studies simulated injection using GEM software package.

20.4 Resource Review

20.4.1 Introduction

The majority of resource sits in the petroleum category, with most located offshore in gulf of Thailand Basins. Only two studies are listed for saline aquifer resource, and these have a significant lack of accompanying data.

20.4.2 Pilot Projects

No pilot projects have been announced by Thailand.

20.4.3 Depleted Oil & Gas Fields

Most reported storage sites sit within depleted oil and gas fields. The offshore Pattani and Malay basins contain 75% of these sites but all have limited geographic and geological data for each individual field. Onshore depleted petroleum resources are minimal. The potential 16 Mt resource in the Fang Oil field near the border with Myanmar is situated near the large stationary emissions of the Mae Moh power plant and benefits from a more detailed study including estimates of dynamic capacity and injectivity. An in-depth study to evaluate potential storage in the Songkhla basin, has identified a 10.8Mt storage site located close to the onshore stationary emissions of Songkhla province. Other onshore resources that sit close to emissions hubs include the Phu Horm and Nam Phong fields (Greater Khorat basin), and the Kamphaeng Saen and Suphanburi fields (Greater Chao Phraya basin), as well as the cumulative depleted petroleum resource of the Phitsanulok basin in NW Thailand.

20.4.4 Saline Aquifers

Storage potential in saline aquifers is currently limited in Thailand. A study by Asian Development Bank [15] reviewed aquifer resource potential in 94 basins & sub-basins across the country however only 10 basins were sufficiently well understood to generate a storage resource estimate for formations sitting below a 1000m depth cut-off. The 84 basins that did not make the cut lacked sufficient data to make the resource calculation.

A saline aquifer was evaluated as a potential storage target for CO₂ in produced gas from a high CO₂ field in the Pattani Basin. A simple injection simulation in to the aquifer (located approximately 20 km from the field) injected 70 Mt over a 20-year period without exceeding the formations fracture pressure.

20.5 Regulatory Framework

As of 2017, the baseline annual emissions used for the country was 300Mt/ year, but these emissions rates have been dramatically increasing in line with economic growth. Thailand has committed, under UNFCCC 2015, to reduce emissions by 20-25% below BAU levels by 2030. This means that the country will need to cut emissions by 110-140 Mt-CO₂e within the next 9 years to meet this target. The Thai Government has developed several action plans to achieve this goal. These plans include: the National Economic and Social Development Plan, the Climate Change Master Plan (2015-2050), the Power Development plan (2015-2036), the Alternative Energy Development Plan (2015-2036), amongst others. The Power Development plan focuses on reduction of CO₂ emissions from the power sector and may be able to offer incentives for CCS in Thailand. Currently however, the country has no CCS specific regulatory system [8], therefore all resource entries in the CSRC (Cycle 3) sit in the Inaccessible category, however, a presentation at ASEAN Clean Energy Forum 2020 by the Ministry of Energy states that the “definition of principles for Thailand’s CCS regulations within international context” has been partially completed and the country is on route to creating CCS specific regulations.

20.6 Issues for the Assessment

The only storage atlas for Thailand is the Asian Development Bank (ADB) 2013 report [15]. This presents the majority of Thailand’s storage resource estimate in the CSRC to date but, due to limited accompanying data, the overall maturity of the resource assessment is low. Although the ADB study report gives individual storage resource estimates for all gas fields greater than 10Mt, these figures cannot be linked to geographic location as the map does not display field names. If this location data existed, it would help avoid the likely double accounting issues between ADB 2013 and Choomkong 2017 [45].

The only project site entry in the CSRC is the Bua-Ban field [47]; this would also be assessed at a higher SRMS maturity class if Thailand developed a CCS regulatory framework. The standout issue with this project entry, however, is clarity on existing versus virtual well data utilised for the static modelling effort. Although 164 well are displayed on the block model, it is

unclear if some of these wells are virtual wells based on offset wells in the greater Songkhla basin, or if all these wells physically exist within the model bounds. For the purpose of this assessment, however, the AOI has sufficient wells to make the area 100% discovered under the SRMS.

20.7 Future Updates

Any evaluations that further interrogate the countries saline aquifer resource would be valuable in building a more complete picture of the potential storage resource in Thailand. Indeed, future studies should focus on assessing aquifers that are linked to the many depleted gas fields available for storage, such as those in the Pattani, Greater Chao Phraya, and Greater Khorat basins. These areas will have a large amount of geological data accessible from the Department of Mineral Fuels.

Also, the CSRC would benefit from studies that present more robust data (both geographic and subsurface) for depleted petroleum fields in the Pattani, Greater Chao Phraya and Greater Khorat basins.

21 Uzbekistan

21.1 Summary

Uzbekistan was assessed during Cycle 5. The CSRC has identified a CO₂ storage resource for Uzbekistan as follows:

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	34.594	0.000
Aggregated*	34.594	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 Uzbekistan.

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

- Uzbekistan being an active member of the Paris agreement, conducted a regional study to assess the country’s feasibility for CCUS
- Six sedimentary basins with saline aquifers have been identified as most viable CO₂ storage options. The locations of these storage sites are Amu-Darya, Fergana, Surkhandarya, East Aral, Ustyurt and Mangyshlak sedimentary basins.
- To date, no major or operational CCS project have been announced in Uzbekistan
- Uzbekistan recently established a legal framework to implement green projects.

A) Project and Non-Project Mid-Case Storage Resource



B) Storage Resource by Type

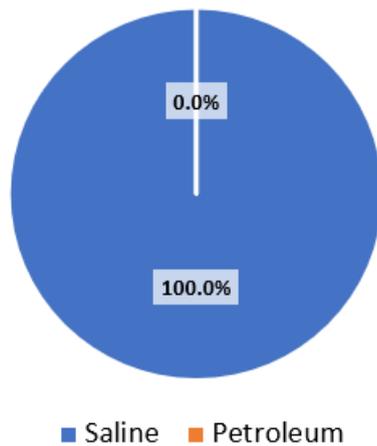


Figure 21-1: Uzbekistan spread of Storage Sites.

A) Spread of storage resource in all Uzbekistan sites across SRMS classifications; both project specified and not. B) Split of Uzbekistan storage resources between saline aquifers and hydrocarbon fields, (include bith 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.

21.2 Resource Statement

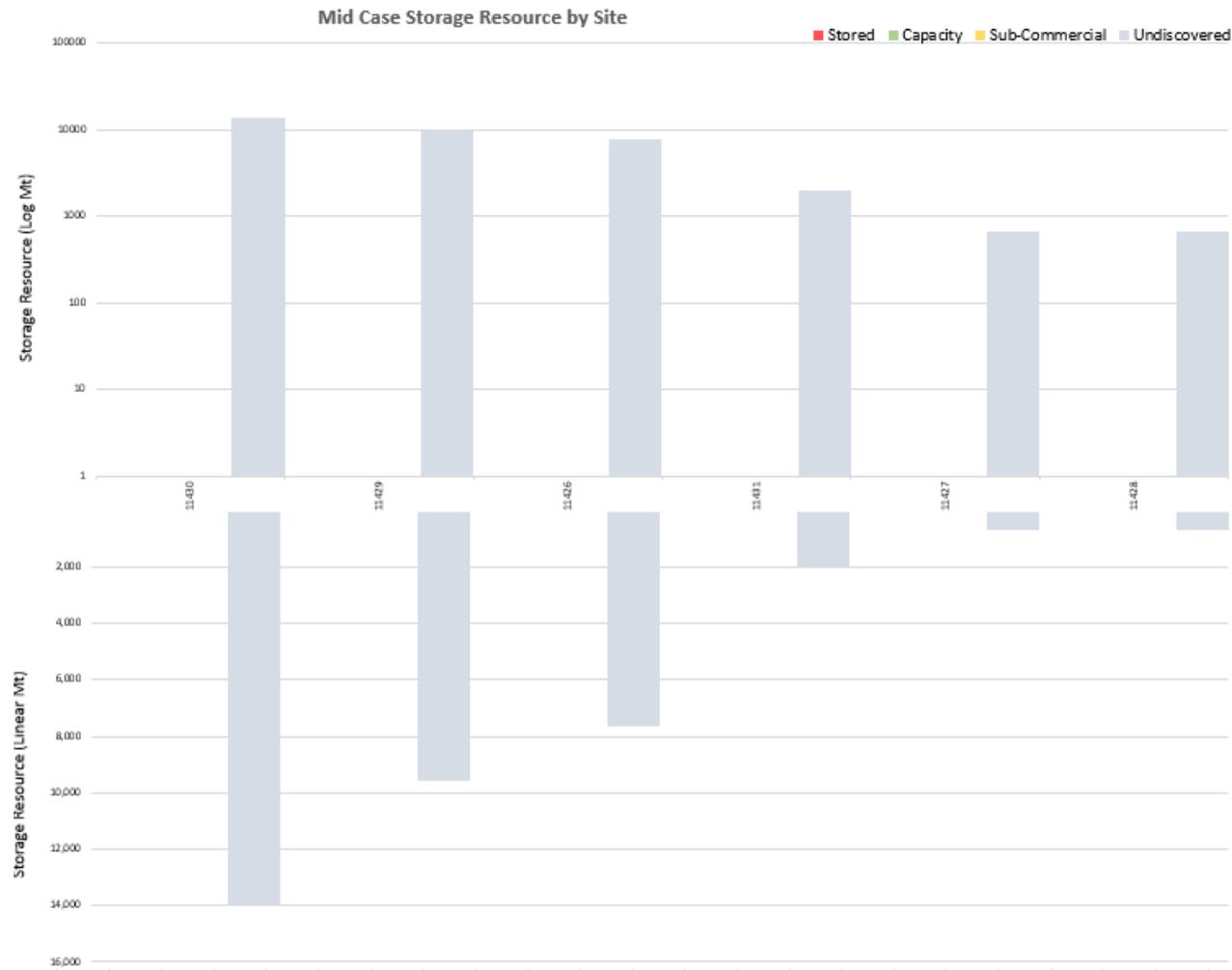


Figure 21-2: Storage resource summary for Uzbekistan compiled in the CSRC.

The graph above is a log scale, and the graph below is linear.

21.3 Evaluation History

Preliminary academic regional research was conducted in Uzbekistan in 2024 for CO₂ storage to help address increase threats of climate change. There is little other research in the public domain for this country.

Uzbekistan being a member of the Paris Agreement is exploring options for sustainable development by reducing greenhouse gas emissions and promoting renewable energy.

The country is still new to CCS technology, and is actively evaluating its potential for achieving net-zero emissions in short- and mid-term

21.4 Resource Review

In Uzbekistan, six onshore sedimentary basins have been identified as most promising for CO₂ storage.

21.4.1 Major Projects

Although Uzbekistan is actively conducting feasibility studies on this subject, to date there have not been any publicly reported large-scale, operational geological CO₂ storage projects in the country.

21.4.2 Depleted Oil & Gas Fields

There are no depleted oil and gas fields for explicitly storing CO₂. All resource fields mentioned in the literature focus on CO₂ storage for enhanced oil and gas recovery.

21.4.3 Saline Aquifers

Deep saline aquifers are a significant focus of CO₂ storage in Uzbekistan. In total, six onshore sedimentary basins have saline aquifers of significant capacities making them favorable options for geological CO₂ storage. Among these, the Amu-Darya basin with storage capacity of 7670.4 Mt covers the territories of Uzbekistan, Turkmenistan, Iran, and Afghanistan. The sector belonging to Uzbekistan exceeds 90000 km².

The Fergana and Surkhandarya basins also offer considerable capacities, with about 675 Mt and 671 Mt respectively.

The East Aral, Mangyshlak, and Ustyurt basins present the largest potential, with a combined capacity exceeding 25 Gt; with individual storages of approximately 9588Mt, 1963Mt and 14025Mt respectively [1].

21.5 Regulatory Framework

Laws and regulations to control greenhouse gas emissions in Uzbekistan has been approved by the country which grants legal entities, individuals and private entrepreneurs the right to implement green projects [2]. However, these laws do not clearly state whether Carbon Capture and Storage (CCS) technology is permitted.

21.6 Issues for the Assessment

Geological evaluation of the identified sites appears to be in its preliminary stages. All reports are theoretical, and hence storage potential is likely to carry great uncertainty.

21.7 Future Updates

21.7.1 Future CRSC Cycles

Future updates will be necessary if soon to be depleted fields within the six identified basins which are being considered for EOR and EGR are repurposed for storage.

Lastly, future updates would look for more clarity and details on the implemented laws which permit green projects.

21.8 References

1. Kamolov, A., Turakulov, Z., Norkobilov, A., Variny, M., and Fallanza, M. 2024. Regional resource evaluation and distribution for onshore carbon dioxide storage and utilization in Uzbekistan, 10.21203/rs.3.rs-4557437/v1, https://www.researchgate.net/publication/381751756_Regional_resource_evaluation_and_distribution_for_onshore_carbon_dioxide_storage_and_utilization_in_Uzbekistan
2. Uzbekistan establishes legal framework to reduce greenhouse gas emissions; Uzbekistan establishes legal framework to reduce greenhouse gas emissions

22 Vietnam

22.1 Summary

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

Classification	CO ₂ storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	0.924	0.00
Undiscovered	20.826	0.076
Aggregated*	21.750	0.076

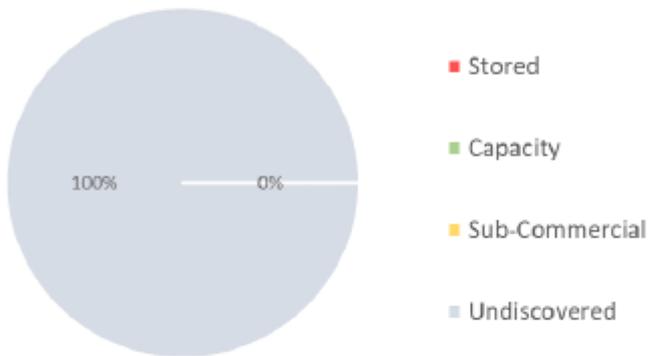
* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Vietnam.

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

- There are 28 sites at both local and regional scale, located across a minimum of 7 basins both onshore and offshore.
- Three of these evaluations have a project defined.
- 9 sites in the country are saline aquifers with the remaining 19 sites sitting in the Petroleum category.
- There are no active CCS projects in Vietnam.
- The Vietnamese Government have not yet development a CCS specific regulatory framework.

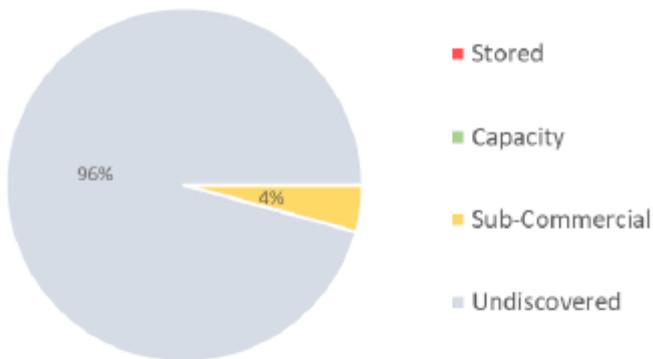
A) Project

Mid-Case Storage Resource



B) Project and Non-Project

Mid-Case Storage Resource



C) Storage Resource by Type

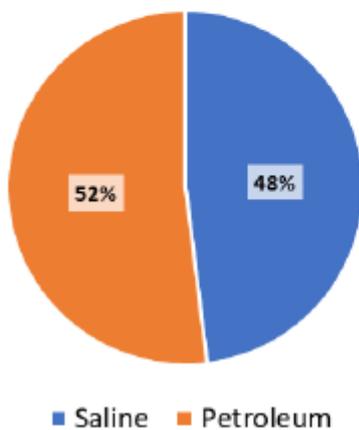


Figure 22-1: Vietnam spread of Storage Sites.

A) Spread of storage resource in Vietnam sites (24) across SRMS classifications, where a project has been specified. B) Spread of storage resource in all Vietnam sites across SRMS classifications; both project specified and not. C) Split of Vietnam resource between saline aquifers and hydrocarbon fields, both project specified and not.

22.2 Resource Statement

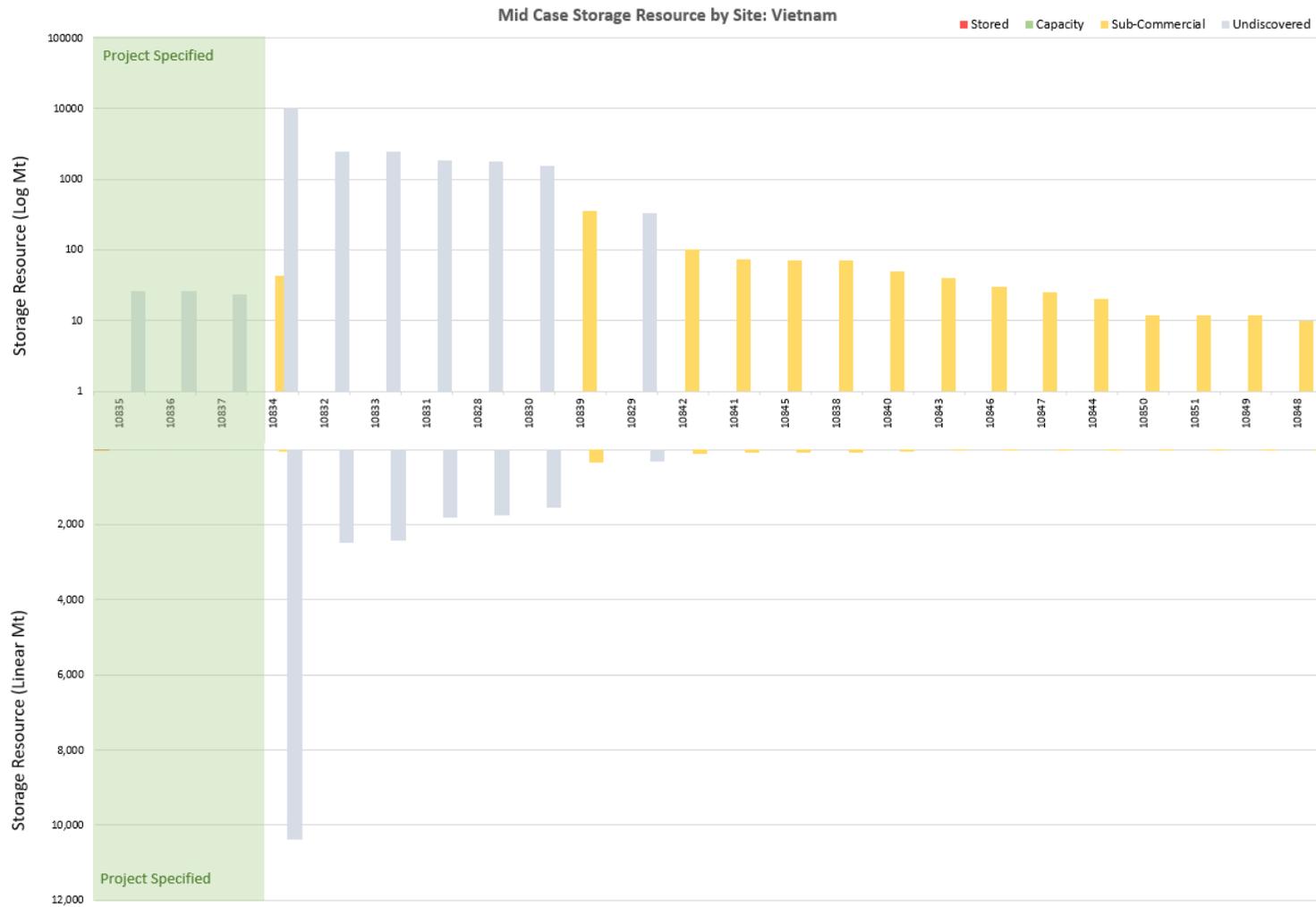


Figure 22-2: Storage resource summary for Vietnam compiled in the CSRC.

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

22.3 Evaluation History

The published resources for Vietnam describe three main evaluations over the past decade:

The oldest regional evaluation of Vietnam's carbon storage potential was carried out by the Asia-Pacific Economic Cooperation in partnership with CO₂CRC (2010) [3]. This assessment solely focused on storage of CO₂ co-produced with natural gas in south-east Asia but data for Vietnam is limited to formation data, development plans and storage estimates noted briefly in the appendix tables. For all resources presented, a simple simulation was conducted to determine the maximum rate of CO₂ that can be injected over the injection period without the pressure in the reservoir exceeding its fracture pressure.

The main, published regional study for storage in Vietnam was produced by the Asian Development Bank (2013) [15], it uses qualification criteria to screen for depleted petroleum resource and also gives six basin play resource estimates. This screening limited petroleum resource to fields in the Cuu Long, Panjang and Nam Con Son Basins. The best storage targets are in the Cuu Long basin – this has been verified by a suitability score, calculated for each field. Besides storage resources and suitability score however, data quality is quite poor for these fields, i.e. there is no formation data, and it is not possible to locate specific fields on the map figure. Storage estimates were calculated by replacement volume. As well as these gas field estimates, the report also gives storage resources for six Vietnamese basin plays (only considering storage by structural/ stratigraphic trapping at depths greater than 1000m). The estimation approach appears to be volumetric, although no methodology was given.

Vo Thanh, 2019 [50] present a study that is solely focused on CO₂ storage combined with CO₂ EOR in the fractured basement reservoir of the Nam Vang depleted field in the Cuu Long Basin. Fractured basement plays are considered unconventional in the petroleum industry and have rarely been considered for carbon storage. The main purpose of the study was to create an efficient workflow for generating accurate static geological models of fractured basement reservoirs that can be used to calculate CO₂ storage resources. Here, faulting data from seismic was combined with porosity data from well logs using artificial neural network technology, these were then integrated into a static model using the Co-Kriging tool. The accuracy of this model was validated by performing drill stem test matching. The resource was calculated by volumetric method (E ranged 0.1 – 0.9) using this static model. This is the first resource within fractured basement reservoir to be included in the CSRC.

22.4 Resource Review

22.4.1 Pilot Projects

Vietnam has no known pilot projects.

22.4.2 Depleted Oil & Gas Fields

While Depleted fields represent the only discovered resource in Vietnam. They range in size from 355Mt to just 10Mt and are all located within the Cuu Long and Nam Con Son Basins,

offshore southern Vietnam. The Asian Development Bank (2013) [15] gives resource estimates for twelve depleted fields in the Cuu Long basin and two for the Nam Con Son basin. These estimates are not accompanied by any reservoir data or exact locations within the basin; the fields presented were screened using desirable qualifying criteria e.g., capacity, injection rate and confinement. The selected fields are also accompanied by a suitability score which includes the above criteria plus number of existing active and abandoned wells, contamination risks for other resources, and an economics section including existing infrastructure, monitoring potential, availability, and willingness of operator. The Cuu Long basin is located closest to the large stationary emissions of southern Vietnam. Field CL16 in the Cuu Long has the largest discovered resource (355Mt) in Vietnam and carries the highest suitability score in Asia Development Bank, 2013 report [15].

The Nam Vang field (Cuu Long basin) is estimated to have 43.2Mt storage potential.

22.4.3 Saline Aquifers

The saline aquifer resources in Vietnam fall into two categories, large basin play aquifers and small aquifers that are near high CO₂ fields in the region. The large-scale basin play resources are given for all but one of the sedimentary basins, overall, they represent over 90% of the country's total resource [15]. However, these resources are not accompanied by any additional data e.g., storage efficiency factors or reservoir and wells data.

The smaller scale saline aquifers represent less than 1% of the country's aquifer resource, given by CO₂CRC (2010) [3]. All three resources are considered projects because they include development plans and simple reservoir simulations (injection without exceeding fracture pressure), as well as in-depth formation data. But as these resources were chosen specifically for their proximity to offshore high CO₂ fields, their location may not be optimized for storage from large onshore emitters.

22.5 Regulatory Framework

Despite being South-East Asia's 3rd largest oil and gas producer [51], Vietnam has not developed any laws specific to CCS deployment. To progress any CCS activities in Vietnam a legal and regulatory framework is required.

Vietnam's latest emissions reduction plan [52] submitted to the UN, commits the country to cut emissions by 9% based on business-as-usual projections, using a 2014 baseline. However, this would still see emissions grow by 844Mt during this time period due to new infrastructure development, e.g. Vietnam's large cement sector is the third largest producer in the world.

Due to this lack of regulatory framework for CCS, all storage resources for Vietnam in the CSRC are classified as inaccessible under the SRMS.

The Global CCS Institute's CCS Readiness Index (2018) [8] ranks Vietnam just above 70 percent for inherent interest meaning that it has a high fossil fuel dependency and therefore is likely to

need CCS projects to meet future climate goals, additionally CCS is the only way to decarbonize the country's mammoth cement industry. Currently it appears that Vietnam is more focused on CO₂ EOR projects over storage projects due to their financial incentives (e.g., storage combined with EOR in the Nam Vang Field, Cuu Long basin).

22.6 Issues for the Assessment

The largest issue encountered by the Cycle 3 assessment is the lack of data that accompanies the seven basin play resources (90% of the country's total resource). The only data provided is the resource estimate and location; any additional information on storage efficiency factors used, and the relative porosities and depositional environments would increase the credibility of these resources.

More specific locations and reservoir data for the depleted petroleum fields from the Asia Development Bank 2013 [15] report would dramatically increase the credibility of these sites.

22.7 Future Updates

The Future assessments should include any new or updated information on the storage resources in Vietnam. The issues discussed above mean that the overall resource classification is likely to be assessed at a lower maturity than necessary.

In terms of additional resources for future evaluations, Vietnam would benefit from some detailed appraisals on larger scale aquifers as currently the only detailed aquifer studies have ~25Mt storage potential in each site. Also, any studies of both petroleum and aquifer resources for Vietnam's northern basins would improve the distribution of storage resource throughout the country – including giving storage options for emitters associated with Vietnam's capital Hanoi.

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