Indonesia’s CO2 Storage Resources Maturity to Support Low-Emission Energy Systems

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https://doi.org/10.5109/7405130

出版情報：Evergreen. 13 (1), pp.86-95, 2026-03. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Japan
バージョン：

EVERGREEN - Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 13, Issue 01, pp. 86-95, March, 2026

Indonesia's CO_2 Storage Resources Maturity to Support Low-Emission Energy Systems

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(Received May 28, 2025; Revised July 06, 2025; Accepted December 22, 2025)

Abstract: The decarbonization of the energy system to achieve a global Net-Zero Emission (NZE) in 2050, requires the significant deployment of all low-emission energy technologies. One potential technology that has been proven effective for reducing carbon dioxide (CO_2) emissions is carbon capture utilization and storage (CCUS). Indonesia plays a critical role in global CCUS deployment efforts due to the country's vast sedimentary basins with geological media suitable for CO_2 storage. However, limited research has been published to addresses the maturation of CO_2 storage resources. Therefore, this study aimed to close the gap associated with Indonesia's maturing CO_2 storage resources and how it can support low-emission energy systems using an internationally agreed-upon standard. Sites that support large and commercial-scale CCUS project development were identified by applying a minimum threshold of 10 million tonnes (Mt) for CO_2 storage resources. The results showed that based on the 728 oil fields with CO_2 storage resources of 1.31 gigatonnes (Gt), only 14, with 0.81 Gt are available and classified as Sub-Commercial. Moreover, out of the 340 gas fields with 8.84 Gt, 66 fields exceed the threshold with a value of 8.42 Gt, comprising 0.025 Gt of Commercial and 8.40 Gt Sub-Commercial. The basin-scale assessment for deep-saline reservoirs in 21 basins totaled 680.57 Gt and is classified as Undiscovered. Gas reservoirs showed the most technical and commercial readiness for CO_2 storage in Indonesia in the short term. This study's results are instrumental in delivering early, large-scale volumes of low-emission energy production, such as fossil power generation and hydrogen from reformed natural gas in key regions of Asia.

Keywords: CCUS; commercial readiness; gas reservoirs; low-emission energy production

1. Introduction

CCUS is a cost-effective low-carbon technology that has been globally adopted to help achieve net-zero emissions by 2050[1,2]. This technology involves capturing and compressing CO_2 from large point sources or directly from the atmosphere. The captured gas is then transported either through pipeline, ship, or truck. The gas is then injected into deep geological formations where it is trapped for permanent storage[3,4]. The net decrease in CO_2 emissions depends on the amount of gas captured from the source location and how the CO_2 is used.

CCUS plays a crucial role in low-carbon hydrogen production, power generation, and heavy industry. This technology includes carbon removal from the atmosphere

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through BECCS, DACCS, and as a source of CO_2 for synthetic fuels[5]. Due to its ability to contribute to both CO_2 emissions reduction at point sources and directly remove CO_2 from the atmosphere, CCUS is essential for supporting low-emission energy systems in meeting the reduction targets[6-8].

1.1. CCUS's role in low-emission energy systems

The role of CCUS in energy system transition has been analyzed both nationally and globally. The International Energy Agency (IEA) stated that CCUS played a major role in achieving NZE, accounting for approximately 8% of cumulative emissions reductions by 2050[2]. Regarding the energy-intensive industries at the core of the European economy, the incorporation of CCUS led to cost effective decarbonization while maintaining similar activities and preserving existing jobs[9]. Moreover, CCUS is perceived as a major decarbonization technology for the power and industry sectors in ASEAN countries[10]. CCUS has the potential to grow from a limited base in this region to 200 Mt/year CO_2 by 2050[11].

The energy transition in the United States of America showed that the use of fossil power plants with CCUS reduced system costs[12]. This shift enabled the consistent adoption of certain fossil power plants to substitute for investments in batteries for flexibility. Additionally, the electricity sector in Indonesia hinged on CCUS to achieve NZE by 2060 without nuclear power plants[13], aiming for a 13% share of CCUS in its energy mix[14]. The potential for CCUS adoption in Indonesia's energy sectors such as power and upstream oil and gas[15-17], gasification and fuel production[18,19], and the potential of CCUS to increase oil recovery (CO_2 EOR)[20-22] has been explored in detail. Future CCUS implementation will help determine the penetration of low-emission energy sources, such as hydrogen and synthetic fuels, in achieving net-zero emissions.

1.2. CO_2 storage's role in low-emission energy systems

Global projections anticipate a rapid scale-up in capture capacity, with expected growth from 45 Mt of CO_2 per year today to 1.0 Gt of CO_2 by 2030 and 6.0 of Gt CO_2 over the following 20 years[1]. Approximately 95% of the total CO_2 by 2050 is expected to be stored in permanent geological formations, and the remaining 5% is anticipated to be used for synthetic fuels[6]. Therefore, CO_2 storage is a critical component in achieving the potential benefits of CCUS.

The role of CCUS in the Japanese energy sector demonstrated that the availability of CO_2 storage resources significantly influenced optimal decision making across in the power sector and end-use industries, particularly in meeting emission reduction targets[23]. This highlights the crucial role of storage availability in reducing emission costs. Similarly, in Europe, the existence of operational CO_2 storage sites capable of handling hundreds of millions of tonnes annually were essential for achieving NZE[7].

A study by the IEA showed that limiting the availability of CO_2 storage would increase the cost and complexity of energy transition efforts and achieving emission reductions across major sectors[24]. In a restricted storage scenario, energy transition will require substantially higher investments compared to scenarios with full storage access. Moreover, the industrial sector has experienced a sharp rise in mitigation costs due to increased reliance on emerging and less cost-effective technologies. These outcomes highlighted the essential role of CO_2 storage in enabling a more efficient and economically viable pathway toward NZE.

Conversely, the accessibility of large CO_2 storage sites will support the adoption of CCUS, particularly where storage resources are limited or where development processes face delays. The rapid adoption of CCUS can be realized by applying a cross-border approach[25], such as regional cooperation and shared infrastructure in Southeast Asia[11]. The incorporation of offshore CO_2 storage resources with CO_2 shipping can also lead to the flexibility and contingency of the CCUS value chain, particularly where several CO_2 storage facilities are available.

The first steps for evaluating CCUS deployment focus on identifying and estimating the CO_2 storage resources in geological formations[26]. Given the long lead times - often spanning three to ten years - for developing operational CO_2 storage sites, and the fact that not all discovered resources can be commercially realized, maturity assessment is crucial for guiding strategic resource management and long-term planning. Recent evaluations in the Malay Basin have demonstrated the value of maturity assessment through systematic resource characterization, revealing a broad distribution of suitable geological CO_2 storage zones within saline aquifers[27]. These findings provided a strong technical foundation to support Malaysia's CCUS ambitions and stimulated further development activities. Additionally, the study highlighted the potential for these storage sites to function as regional hubs and the strategic importance of maturity assessments in enabling coordinated cross-border CCUS infrastructure in the region.

To date, no comprehensive national-level maturity assessment has been conducted across ASEAN countries, particularly in Indonesia. Therefore, this study aims to address this knowledge gap and is expected to provide valuable insights for shaping CCUS implementation roadmaps and identifying commercially viable projects within the energy and extractive industries in key regions.

1.3. Development of CO_2 storage in Indonesia

Various geological setting within sedimentary basins, such as oil, gas, deep saline reservoirs, and coal seams, present viable options for long-term CO_2 storage[3,28-31]. Each geological medium had its advantages and disadvantages[32]. Oil reservoirs, at depletion possess smaller storage capacity than gas or deep saline reservoirs. If the reservoirs are suitable for CO_2 EOR, their storage potential will increase while the storage cost decreases, as it compensated by revenue from additional oil recovered. Gas reservoirs have significant CO_2 storage potential due to their large size and high recovery factor, which ranges between 80% and 90%. Saline formations are the ideal solutions for CO_2 geological storage due to their large capacities and extensive spatial distribution in most sedimentary basins[3,26]. Meanwhile, CO_2 storage in coal seams is achieved thorough adsorption as opposed to storage in the rock pore space of hydrocarbon or saline formations.

Indonesia is renowned in Southeast Asia for its abundance of sedimentary basins . Approximately 128 tertiary sedimentary basins spread out from Sumatra in the West to Papua in the East. However, only 47 basins had been drilled for petroleum, with 20 currently producing oil and gas[28]. The identification of storage resources in the Indonesian sedimentary basins is crucial for unlocking the potential of CCUS both within the country and regionally. Several studies have been conducted, but lonely a few focused on selected sedimentary basins.

Table 1 shows that the estimated results from previous studies do not accurately represent Indonesia's storage resources, which include abundant sedimentary basins. The results also varied widely, due to differences in data sources, study areas, and the assessment methods employed. Additionally, no assessment was performed to classify the resources according to their maturity status or commercial readiness.

A CO_2 storage resources refers to the quantity (mass or volume) of CO_2 that can be stored in a geologic formation[36]. This quantity depends on varying degrees of technical uncertainty and commercial possibility. A consistent categorization system has enhanced the comparison between projects, group of projects, and storage efficiency. Such a system must consider both technical and commercial factors that impact the project's economic feasibility, productive-life, and related cash flows[26,36].

A recent study reported that the aggregated CO_2 storage resource in Indonesia was estimated at over 692 Gt[37]. The study covered all sedimentary basins across the country with estimation levels ranging from basin to field-scales for saline aquifers and hydrocarbon reservoirs, respectively. This research showed that Indonesian geological CO_2 storage resources enable the use of CCUS to support sustainable low-emission energy production. Additionally, the government's support through both legal and regulatory frameworks[38,39] provided the relevant platform for the large-scale CCUS projects, such as the Tangguh natural gas processing plant[40].

This study aims to assess the maturity of Indonesia's CO_2 storage resources as a critical enabler for accelerating the deployment of CCUS technologies, aligning with both national and global low-carbon energy objectives. The assessment adopts the Society of Petroleum Engineers

Table 1: Previous studies on Indonesian CO_2 storage resources estimation

Evaluator	Basins (Formations)	CO_2 Storage (Gt)		Evaluation Method	Data Source Used
		Oil and Gas Fields	Saline Formation		
LEMIGAS - ADB[15]	South Sumatra (Talang Akar, Lahat)	0.9 (134 fields)	7.4	Analytical - Volumetric Analysis[a)]	LEMIGAS Reports; LEMIGAS Reserves Database @Jan 01, 2010
	South Sumatra (Batu Raja, Telisa)		0.2		
LEMIGAS - World Bank[16]	South Sumatra (Talang Akar, Batu Raja, Lemat)	0.6 (52 fields)	3.7 (P50)	Analytical - Volumetric Analysis[b)]	LEMIGAS Reports; LEMIGAS Reserves Database @Jan 01, 2014
	N. West Java (TA, Batu Raja)	0.4 (33 fields)	4.9 (P50)		
Y.E. Li et al.[34]	South Sumatra	1.0 - 1.2 (8 fields)	13 - 23	Analytical - Volumetric Analysis[c)]	C&C Reservoirs; Wood Mackenzie Database
	North Sumatra	0.5 - 0.7 (15 fields)	5 - 8		
	Kutai	1.9 - 2.5 (12 fields)	32 - 67		
R. Setoguchi[35]	N. West Java, East Java (Parigi, Massive/Main/ Batu Raja, Talang Akar)	Not Available	64 (Mid Case)	Analytical - Volumetric Analysis[d)]	Neftex® Predictions Database
	North Sumatra, Central Suamtra, South Sumatra (Upper Benio, Sihapas, Telisa, Batu Raja, Pematang)		56 (Mid Case)		

[a)]Storage Efficiency Factor of 1%; [b)]Storage Efficiency Factor of 14%; [c)]Conservative to Optimistic Cases based on minimum and maximum of both Hydrocarbon Recovery and Storage Efficiency factors and; [d)]Storage Efficiency Factor of 2%.

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(SPE) Storage Resources Management System (SRMS) approach[36] to identify storage resources that are viable for near-term development, and those requiring further investigation or exclusion, thereby improving resource appraisal efficiency and strengthening confidence in Indonesia's geological CO_2 storage potential. The results of this study are crucial for informing strategic long-term resource management planning and providing the technical basis to support evidence-based policy decisions. Moreover, such precompetitive evaluations reduce investment risk, facilitate private sector involvement, and help accelerate the availability of storage infrastructure. Ultimately, this study supports national efforts to reduce greenhouse gas emissions, attract international investments, and promote the development of a green, low-emissions energy system at the national and regional levels.

2. Methodology

Indonesia's CO_2 storage maturity is assessed by classifying the maturity of storage resources using the SPE-SRMS approach, an internationally recognized standard[36]. The SPE-SRMS is a project-based classification method with progression based on commercial triggers, including regulatory systems and related development milestones. This method enables the mapping of storage resource maturity progression in a key evolving industry, leading to consistent resource terminology and enhanced communication with major stakeholders, thereby improving confidence in resource assessments for CCUS potential customers. The resources classification framework by SPE-SRMS is shown in Figure 1.

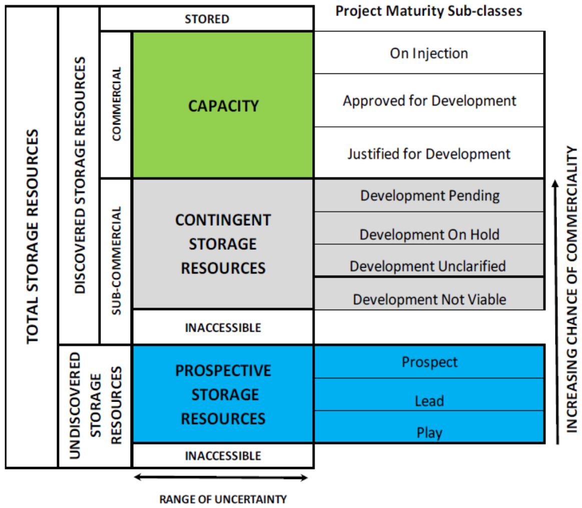

Fig. 1: Resources classification framework based on project maturity

A fundamental step in classification involves defining criteria for the discovery of storable quantities, followed by differentiating between commercial and subcommercial projects. CO_2 storage resources in depleted oil and gas fields are classified as Discovered if one or more wells have been confirmed have significant accessible pore volume for storage through testing, sampling, and/or logging. Additionally, these fields have demonstrated effective containment, having trapped hydrocarbons through geological processes prior to production. Next, the storable quantities are deemed Commercial and classified as Capacity if there is a firm intention to proceed. Such an intention is based on a reasonable development timeline, economic viability, sustained market demand, the availability of injection infrastructure, and the absence of legal, regulatory, or socio-environmental barriers to project implementation. Otherwise, they are considered Sub-Commercial and classified as Contingent. The CO_2 storage resources in deep saline reservoirs are classed as Undiscovered Prospective due to the lack of subsurface data and the absence of wells drilled within the target geologic formation.

The database on storage resources developed under joint research between ERIA, BRIN, and the Testing Center for Oil and Gas LEMIGAS[37] is further assessed against the SPE-SRMS approach to define the CO_2 storage resources maturity. This approach excluded CO_2 EOR, coal seams, mineralization, and organic-rich shales. As this study aims to support large, commercial-scale project development in low-emission energy systems, a minimum threshold of 10 Mt for resources is applied[41]. The classification of resources according to the SPE-SRMS is based on data from reserve reports, published evaluations, and expert judgment.

3. Results and Discussion

A notable study was performed to evaluate the CO_2 storage resources across the Indonesian sedimentary basins[37]. The evaluation was performed in the basin scale for deep saline reservoirs and on the field scale for oil and gas reservoirs. This study further assesses the commercial readiness of the resources to support the deployment of CCUS in the low-emissions energy system. A conceptual approach to decarbonizing the energy systems is also presented to demonstrate the importance of key findings.

3.1. CO_2 storage maturity in deep saline reservoirs

Based on the evaluation, 21 of the 128 basins across the archipelago were supported by sufficient data for CO_2 storage estimation in deep saline reservoirs. Of the 21 basins, 19 were production basins and two discovery basins, whose status is determined by the maturity of oil and gas exploration and production activities[33]. A volumetric approach was used to estimate the CO_2 storage resources. The method is typically used when limited or no-specific data are available[31].

The CO_2 storage resources of the 21 basins was estimated to be 680.57 Gt. Figure 2 illustrates a GIS map of the

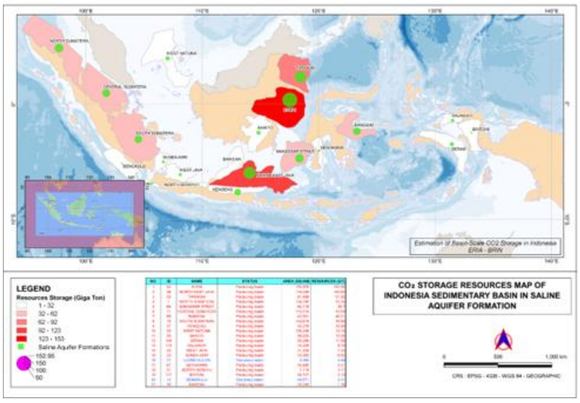

Fig. 2: Distribution of CO_2 storage resources in the deep saline reservoir across the Indonesian sedimentary basins

distribution of CO_2 storage resources across these basins[38]. The green circle radius on the map depicts the size of CO_2 storage resources, with the top three being Kutai, North-East Java, and Tarakan. Meanwhile, the Kutai basin exhibits a significant potential CO_2 storage resources of 152.95 Gt, as it is a very good reservoir, thick, and widely spread within the Balikpapan formation. The storage resources in northeast Java are mainly distributed across the Ngaryong formation, which contains notable areas and reservoirs with thick sections and good porosity. Among several formations identified in the Tarakan basin, the Tarakan sandstone formation has a larger area and thicker, resulting in CO_2 storage resources of 91.92 Gt.

During the assessment of the storage resource sizes available for the extensive CO_2-related projects in deep saline reservoirs, different commercial levels and technical uncertainty were involved. Estimation related to unknown geological formations or uncharacterized parts of discovered geologic formations resulted in significant uncertainties due to an incomplete data set. Therefore, these resources were assigned to Undiscovered Prospective (3U) according to the SPE-SRMS maturity class.

The subsequent maturation stages should be conducted to limit basin assessments to specific sites with viable drilling targets. However, these activities are time-consuming and costly.

3.2. CO_2 storage resources in oil and gas reservoirs

CO_2 storage resources in the oil and gas fields were evaluated using a voidage replacement basis based on the estimated ultimate recovery for each field, which were under development or approved for development. This approach assumes that the net volume of fluids produced and injected over field life can be replaced by an equivalent reservoir volume of CO_2. The researchers evaluated 1,068 fields, comprising of 728 oil fields and 340 gas fields, distributed across over 19 producing sedimentary basins.

The total CO_2 storage resources at the 1,068 gas and oil fields were estimated at 10.14 Gt. The storage resources were estimated to be 1.31 Gt and 8.84 Gt in the 728 oil fields and 340 gas fields, respectively. They have been discovered and characterized, but the CO_2 storage project(s) are not yet considered for commercial development, resulting in their classification as Contingent Storage Resources, denoted as C1 according to the SPE-SRMS maturity class. The total probable and possible categories denoted C2 and C3 in all oil and gas fields were 1.22 and 1.20 Gt, respectively. Figure 3 shows a GIS map illustrating the distribution of proven resources across the 19 producing basins. In general, gas fields have significantly larger storage resources compared to oil fields due to their large size and higher recovery factor.

The storage resources in oil fields are distributed mainly within Central and South Sumatra, West Java, and Kutai basins (Figure 4). These top fourth basins represent approximately 80% of the total storage resources in oil fileds. Further analysis also revealed that the proven CO_2 storage resources in the Central Sumatra basin, amounting to 346 Mt, is distributed across 199 oil fields. Therefore, the storage resources of each field are relatively small, making most of them unusable for commercial development. Similarly, in the South Sumatra basin, the ratio of CO_2 storage resources to the number of oil fields is much smaller, suggesting the storage resources of each oil field within the region are much smaller. However, in the West Java and Kutai basins, the storage resources are relatively large, both exceeding 300 Mt, with a relatively small number of oil fields, namely 43 oil fields and 50 in West Java and Kutai, respectively. Therefore, the individual oil field in West Java and Kutai has relatively large CO_2 storage resources that potentially supported large-scale commercial CCUS projects.

The minimum threshold of 10 Mt is applied to filter sites suitable for large-scale commercial CCUS project development. This threshold led to the discovery of only eight basins with CO_2 storage resources exceeding 10 Mt (Figure 4). These resources are distributed across 14 oil fields, totaling 0.81 Gt. The largest CO_2 storage resource in the oil fields is located in the West Java basin and is sourced from a single field.

Storage resources in gas fields were primarily found in Kutai, North Sumatra, Bintuni, and Timor Sea basins (Figure 5). These four basins accounted for 74% of the total storage resources in the gas fields. The number of gas fields with CO_2 storage resources above 10 Mt is relatively large and is present in almost all basins, totatling 8.40 Gt. The CO_2 storage resource in the Timor Sea basin originated from a single field, and was deemed sufficient economic scale for a CCUS project of 995 Mt. The Bintuni basin has a storage potential of 1,206 Mt distributed over nine gas fields. One of the gas field is projected to be economically accessible for development. Meanwhile, an estimated 25 Mt of CO_2 could be stored in the reservoir.

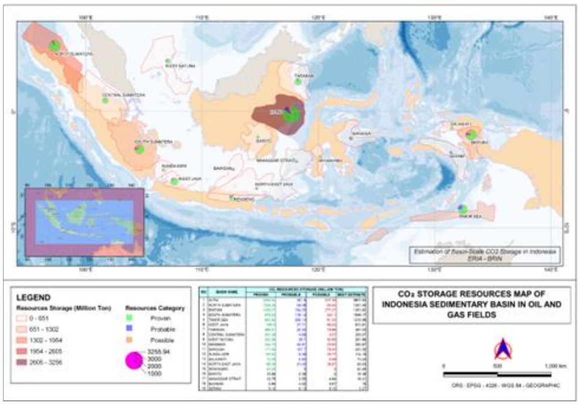

Fig. 3: Distribution of CO_2 storage resources in the oil and gas reservoir across the Indonesian sedimentary basins

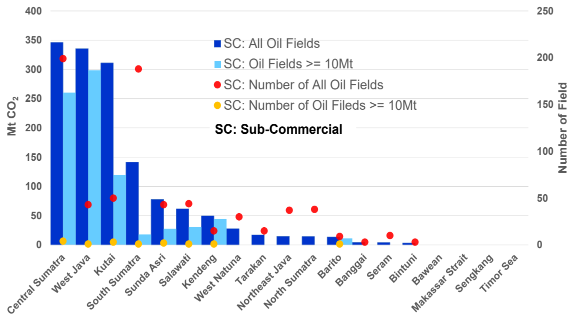

Fig. 4: Profile of CO_2 storage resources and number of oil fields without and with threshold of 10 Mt

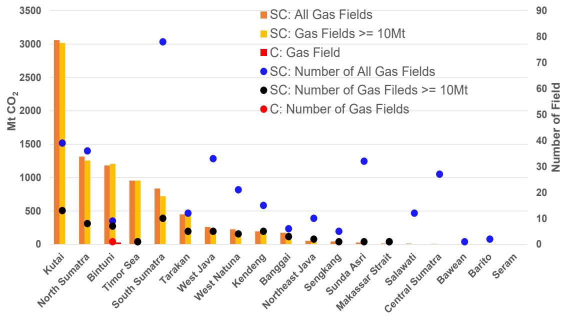

Fig. 5: Profile of CO_2 storage resources and number of gas fields with and without threshold of 10 Mt

This storage resource is then classified as Commercial. Thus, gas fields are the most technical and commercially ready for CO_2 storage in Indonesia in the near future.

3.3. Indonesia's CO_2 storage resources maturity

Figure 6 shows the distribution plot of the Indonesian CO_2 storage resources per basin based on the SPE-SRMS maturity class. Only fields with CO_2 storage resources exceeding 10 Mt are included. The only large-scale commercial project anticipated to be commercial in the near future is situated in the Bintuni basin. A total of 689.80 Gt aggregated storage resources, with 680,57 Gt classed as Undiscovered Prospective, while the remaining 9,21 Gt and 0.025 Gt are classed as Sub-Commercial

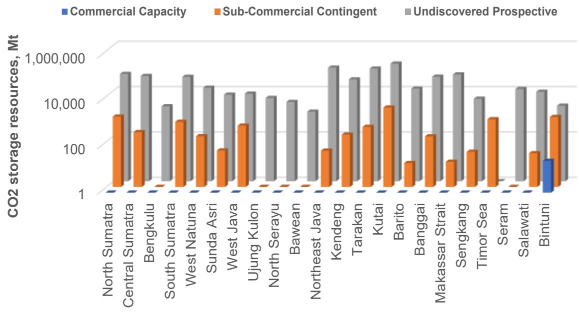

Fig. 6: Plot of CO_2 storage resources by basins and their SRMS maturity class

Contingent and Commercial Capacity, respectively.

The assessment of CO_2 storage resource maturity using the SPE-SRMS framework indeed entailed several inherent risks, particularly due to its project-based classification structure, which is closely tied to commercial decision points. Therefore, it is important to note that storage resource maturity is influenced by technical factors and subject to commercial uncertainties.

For Undiscovered Storage Resources, two primary risk components arise: (1) the uncertainty in confirming the presence of storable quantities within the targeted geological formation, and (2) once discovered, the possibility that the volumes identified may not achieve commercial storage. Progression at this stage typically involves decisions to acquire additional data or conduct further studies to reduce geological and commercial uncertainty, and to justify advancement to exploration drilling.

For Contingent Storage Resources, the focus shifts to identifying and mitigating key contingencies such as technical, regulatory, infrastructural, or economic factors that currently prevent the project from achieving commercial status. Supporting analyses at this stage should focus on derisking these constraints through targeted data acquisition and feasibility assessments.

At the Capacity class level, decisions are linked to actions that advance the project toward full regulatory approval, infrastructure development, and the commencement of injection operations. Therefore, the resource maturity evaluation under SPE-SRMS is intrinsically a risk-management process, requiring iterative technical validation and commercial justification to advance projects through successive stages. As the current study adopts a national-level assessment, risk-management processes should be undertaken at the individual project site level[28].

3.4. Applications to support low-emission energy Systems

Figure 6 shows that Indonesia is well suited to be part of the regional CCUS hub due to its high potential of CO_2 storage resources. The potential of CCUS hubs, as shown in Figure 7 was identified based on the information presented in Figure 6, The proposed basins contain

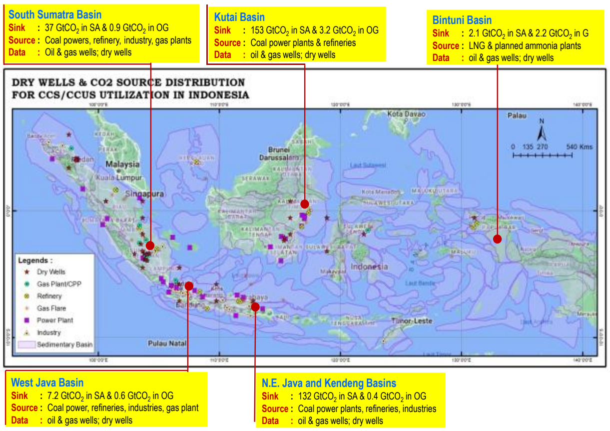

Fig. 7: A conceptual approach for a CCUS hub to support low-emissions energy production

abundant hydrocarbon and coal. These regions are also active economic zones characterized by many fossil-based developed industries, which will result in increased demand for CO_2 storage in the near future.

Furthermore, the proposed hubs contain mature hydrocarbon fields with enhanced recovery opportunities, as well as large-scale CO_2 storage resources from existing gas fields, undiscovered deep saline reservoirs with the potential to store large volumes of CO_2, and several coal power generation facilities. It also has an available pipeline infrastructure that could be leveraged for CCUS transport. Therefore, low-emission energy production can be supported by CCUS to achieve sustainable economic development and address global climate change challenges, especially given that fossil power generation, hydrogen from reformed natural gas, and energy-intensive and hard-to-abate industries in key regions are promising within these regions. Nevertheless, input from stakeholders is required to fulfill the relevant conditions for optimizing CCUS hub[42)]. The analytic hierarchy process approach could be applied to rank and prioritize the identified CCUS hubs[43,44)].

In the context of low-emission energy production, it is crucial for Indonesia as a country with coal dependency is high to address the integration of geological CO_2 storage with underground coal mining in scenario involving concurrent operations. Such co-development of saline aquifers and coal seams in sedimentary basins results in geomechanical conflicts when concurrently exploited in shared subsurface strata[45,46)]. The studies provided theoretical and technical guidance for optimizing CO_2 storage integrity and coal mine safety in tectonically active basins with implication to CCUS project. Therefore, the magnitude of deformation associated with combined applications should be included in the subsequent assessment of geological storage maturity.

4. Conclusions

Presenting the maturity of Indonesia's CO_2 storage resources represents a groundbreaking step toward advancing CCUS technologies to support global low-emission energy goals. The country has the potential to become a regional leader in decarbonization efforts with a total estimated storage capacity of 689.80 Gt, of which 680.57 Gt is classified as Undiscovered Prospective. Gas reservoirs, highlighted for their technical and commercial readiness, contribute 8.40 Gt, while oil fields add another 0.81 Gt, both classed as Discovered Contingent. Among these, a field in the Bintuni basin is identified as commercially viable with a Capacity of 0.025 Gt through the utilization of CO_2 for enhanced gas recovery. The successful implementation of this project will require coordinated efforts among the field operator, local and central government authorities, research institutions, and community stakeholders. Such collaboration could establish a foundation for developing a large-scale CCUS hub in the region, aligned with Indonesia's energy transition objectives.

This initiative strengthened the government ability to implement evidence-based policies aimed at reducing emissions, attracting international investments, and generate green jobs. Knowing the storage commercial readiness also positions Indonesia as key implementer of the decarbonization strategy in Southeast Asia due to its 128 sedimentary basins, with 21 assessed for deep saline storage reservoirs and a combined potential of 680.57 Gt. For businesses, this insight provided opportunities to tap into markets for low-carbon technologies, particularly in industries such as fossil power generation, hydrogen production, and synthetic fuels, supported by existing pipeline infrastructure, including strategically located storage sites such as the Kutai, West Java, and North Sumatra basins.

The integration of robust resource mapping with sustainable energy development will help Indonesia strike a balance between economic growth and environmental responsibility. The collaborative efforts of research institutions, industries, and policymakers are also necessary to fully realize the benefit of CO_2 storage potential. Thus, Indonesia, as a regional CCUS hub, can lead Southeast Asia in addressing climate challenges, foster energy innovation, and pave the way for a sustainable, low-carbon future.

Acknowledgements

The authors express their gratitude to the Economic Research Institute for ASEAN and East Asia (ERIA) and the National Research and Innovation Agency (BRIN) for their support for this research. The research is also supported by the Testing Center for Oil and Gas LEMIGAS of the Directorate General of Oil and Gas, and the Center for Geological Survey (PSG) of the Geological Agency, Ministry of Energy and Mineral Resources of

Indonesia. The authors are also grateful to Jonathan Setyoko Hadimuljono. The perspectives presented within this publication might not represent the opinions of the supporting organizations.

Nomenclature

ASEAN	Association of Southeast Asian Nations
BECCS	biomass energy with carbon capture and storage
BRIN	National Research and Innovation Agency
CCUS	carbon capture, utilisation, and storage
CO_2	carbon dioxide
DACCS	direct air carbon capture and storage (CCS)
ERIA	Economic Research Institute for ASEAN and East Asia
Gt	gigatons
GCCSI	Global CCS Institute
IEA	International Energy Agency
MEMR	Ministry of Energy and Mineral Resources
Mt	Megatonnes
NZE	Net-zero emissions
OGCI	Oil and Gas Climate Initiative
PSG	Center for Geological Survey
SPE	Society of Petroleum Engineers
SRMS	storage resources management system

References

1) IEA, “Net Zero Roadmap: A Global Pathway to Keep the 1.5oC Goal in Reach - 2023 Update,” (2024). https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach.
2) IEA, “CCUS Policies and Business Models: Building a commercial market,” (2023). https://www.iea.org/reports/ccus-policies-and-business-models-building-a-commercial-market.
3) IPCC, “IPCC Special Report on Carbon Dioxide Capture and Storage,” (2005). https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_wholereport-1.pdf.
4) E. L. V. Guzmán, and L. G. Sant’Anna, “Integrated assessment of global carbon capture, utilization, and storage projects,” International Journal of Greenhouse Gas Control, 131, p. 104031 (2024). doi.org/10.1016/j.ijggc.2023.104031.
5) IPCC, “Climate Change 2022: Mitigation of Climate Change Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change,” (2022). https://www.ipcc.ch/report/ar6/wg3/.
6) IEA, “Net Zero by 2050: A Roadmap for the Global Energy Sector,” (2023). https://www.iea.org/reports/net-zero-by-2050.
7) D. Y. Shu, S. Deutz, B. A. Winter, N. Baumgärtner, L. Leenders, and A. Bardow, “The role of carbon capture and storage to achieve net-zero energy systems: Trade-offs between economics and the environment,” Renewable and Sustainable Energy Reviews,” 178, p. 113246, (2023). doi: 10.1016/j.rser.2023.113246.
8) H. A. Daggash, C. F. Heuberger, and N. Mac Dowell, “The role and value of negative emissions technologies in decarbonising the UK energy system,” International Journal of Greenhouse Gas Control, 81, pp. 181–198, (2019). doi: 10.1016/j.ijggc.2018.12.019
9) Carbon Capture & Storage Association, “CCUS Set-Plan,” (2022). https://ccus-setplan.eu/wp-content/uploads/2022/09/2.3.pdf.
10) H. C. Lau, “Evaluation of Decarbonization Technologies for ASEAN Countries via an Integrated Assessment Tool,” Sustainability, 14, 5827, (2022). doi.org/10.3390/su14105827.
11) IEA, “Carbon Capture, Utilisation and Storage: The Opportunity in Southeast Asia,” (2021). https://www.iea.org/reports/carbon-capture-utilisation-and-storage-the-opportunity-in-southeast-asia/.
12) M. S. Zantye, A. Arora, and M. M. F. Hasan, “Renewable-integrated flexible carbon capture: a synergistic path forward to clean energy future,” Energy & Environmental Science, 14,(7), pp. 3986–4008, (2021). doi: 10.1039/d0ee03946b.
13) A. Dwijatmiko, A. Nurrohim, J. Santoso, A. Sugiyono, A.H. Kuncoro, I. Rahardjo, A. Subandriya, E. Siregar, “Optimizing electricity supply for Jawa-Madura-Bali: Scenarios for achieving net zero emissions,” Evergreen, 11 (3), pp. 2567–2579, (2024), doi: 10.5109/7236897.
14) N. A. H. Kuncoro, J. Santoso, I. Fitriana, A. Nurrohim, A. Sigiyono, E. Djubaedah, V. Nurliyanti, “Towards net zero emission in Indonesia: Strategic Fuel Demand Analysis for Sustainable Electricity (2022-2060),” Evergreen, 11 (4), pp. 3606–3617, (2024). doi: 10.5109/7326993.
15) Asian Development Bank, “Prospects for Carbon Capture and Storage in Southeast Asia,” (2013). https://www.adb.org/sites/default/files/publication/31122/carbon-capture-storage-southeast-asia.pdf.
16) World Bank, “The Indonesia Carbon Capture Storage (CCS) Capacity Building Program CCS for Coal-fired Power Plants in Indonesia, Report No. ACS14654,” (2015). https://openknowledge.worldbank.org/server/api/core/bitstreams/e245e3ec-4887-55e0-9419-b2a70127b915/content.
17) Nurkamelia, Sugihardjo, B. Widarsono, Usman, Suliantara, S. Kepies, D. Dwiyananti, D. Sunarjanto, M. Romli, and T. M. Susantoro, “Potential of CCS in East Kalimantan’s Coal-Power sector for achieving Net-Zero emissions,” Evergreen, 11, (3), pp. 2555–2566, (2024). doi: 10.5109/7236896.
18) Directorate General of Mineral and Coal – MEMR,

"Application of CCUS/CCS in Coal Downstreaming," (2023).Unpublished.
19) The Testing Center for Oil and Gas LEMIGAS and the Mitsubishi Indonesia Representative, "Feasibility Study on Ammonia Co-Combustion into Coal Power Plant," (2025). Unpublished.
20) Asian Development Bank, "Carbon Dioxide-Enhanced Oil Recovery in Indonesia: An Assessment of its Role in a Carbon Capture and Storage Pathway," (2019). https://www.adb.org/publications/carbon-dioxide-enhanced-oil-recovery-indonesia.
21) Usman, U. P. Iskandar, D. Sismartono," A Novel Development for CO2-EOR in South Sumatra," in Proceedings Indonesia Petroleum Association, Forty-Third Annual Convention & Exhibition, IPA19-BC-572, Jakarta, Indonesia. (2019). https://www.ipa.or.id/en/publications/a-novel-development-concept-for-co2-eor-in-south-sumatra.
22) T. M. Susantoro, Sugihardjo, K. Wikantika, D. Sunarjanto, P. Usman, B. Widarsono, A. Rahmadi, M. Romli, P. Wahyudi, and S. Kepies, "CCUS-EOR Optimization to achieve zero emission program targets in Northwest Java Basin," Evergreen, 10 (3), pp. 1809–1818, (2023). doi: 10.5109/7151730.
23) T. Otsuki, Y. Shibata, Y. Matsuo, H. Obane, and S. Moritomo, "Role of carbon capture and storage in energy system for net-zero emissins in Japan," International Journal of Greenhouse Gas Control, 132, (2024) p. 104065. pp. 1-13.
24) IEA, "Exploring Clean Energy pathways: The role of CO2 storage," (2019). https://www.iea.org/reports/the-role-of-co2-storage.
25) K. Zhang and H. C. Lau, "Regional opportunities for CO2 capture and storage in Southeast Asia," International Journal of Greenhouse Gas Control, 116, p. 103628, (2022)., doi: 10.1016/j.ijggc.2022.103628.
26) IEA, "CO2 storage resources and their development: An IEA CCUS Handbook," (2022). https://www.iea.org/reports/co2-storage-resources-and-their-development.
27) I. De Jonge-Anderson, H. Ramachandran, A. Widyanita, A. Busch, F. Doster, and U. Nicholson, "Regional screening of saline aquifers in the Malay Basin for CO2 storage," International Journal of Greenhouse Gas Control, 143, p. 104347, (2025). doi: 10.1016/j.ijggc.2025.104347.
28) S. Bachu, "Screening and Ranking of Sedimentary Basins for Sequestration of CO2 in Geological Media in Response to Climate Change," Environmental Geology, 44(3), pp. 277–289, (2003). doi: 10.1007/s00254-003-0762-9.
29) S. Bachu, D. Bonijoly, J. Bradshaw, R. Burruss, N. P. Christensen, S. Holloway, and O. Mathassen, "Estimation of CO2 Storage Capacity in Geological Media – Phase 2," (2007). https://fossil.energy.gov/archives/cslf/sites/default/files/documents/PhaseIIReportStorageCapacityMeasurementTaskForce.pdf.
30) CO2CRC, "Storage Capacity Estimation, Site Selection, and Characterisation for CO2 Storage Projects, Report No. RPT08-1001, (2008).
31) A. Goodman, A. Hakalaa, G. Bromhalb, D. Deelb, T. Rodostab, S. Frailey, M. Small, D. Allen, V. Romanov, J. Fazio, N. Huerta, D. McIntyre, B. Kutchko, and G. Guthrie, "US DOE Methodology for the Development of Geologic Storage Potential for Carbon Dioxide at the National and Regional Scale," International Journal of Greenhouse Gas Control, 5 (4), pp.952–965, (2011). doi: 10.1016/j.ijggc.2011.03.010.
32) A. Raza, R. Rezaee, C. H. Bing, R. Gholami, M. A. Hamid, and R. Nagarajan, "Carbon dioxide storage in subsurface geologic medium: A review on capillary trapping mechanism,"Egyptian Journal of Petroleum, 25 (3), pp. 367–373, (2015). doi: 10.1016 /j.ejpe.2015.08.002.
33) Geological Agency, MEMR, "Indonesia's sedimentary basin maps," (2022). https://www.esdm.go.id/assets/media/content/content-peta-cekungan-sedimen-indonesia-2022.pdf.
34) Y. E. Li, X. Wang, J. Jiao, A. Togaibokev, V. Nian, ,S. Zhong, P.Y. Hoo, W.L. Loh, A.K.S. Wissam, X.W. Tan, A. Usadi, S. Jones, G. Dasari, M. Lacasse, and G. Teletzke, "CO2 transport and storage feasibility and cost study for ASEAN," EarthArXiv (California Digital Library), (2022). doi: 10.31223/x56q1w.
35) R. Setoguchi, "Regional CCS Screening using Regional Database," The Asia CCUS Network (ACN) Knowledge Sharing Conference: CCS Screening in Southeast Asia using Regional Database, Online, (2023).
36) SPE, "CO2 Storage Resources Management System," (2023). https://www.spe.org/en/industry/co2-storage-resources-management-system/.
37) ERIA, "Estimation of Basin-Scale CO2 storage in Indonesia," (2023). https://www.eria.org/research/estimating-basin-scale-co2-storage-in-indonesia.
38) MEMR,."Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia concerning the Organization of Carbon Capture and Storage and Carbon Capture, Utilization and Storage for Upstream Oil-and-Gas Business Activities," Government of Indonesia: Jakarta, Indonesia, (2023). https://peraturan .bpk.go.id/Details/257307/permen-esdm-no-2-tahun-2023.
39) Government of Indonesia,."Presidential Regulation concerning the Organization of Carbon Capture and Storage Activities," Jakarta, Indonesia, (2024). https://peraturan.bpk.go.id/Details/276843/perpres-

no-14-tahun-2024.
40) M. Fajardy, C. Greenfield, and J. Tweeneboah, “CCUS projects around the world are reaching new milestones,” (2025). https://www.iea.org/commentaries/ccus-projects-around-the-world-are-reaching-new-milestones.
41) Halliburton, OGCI, and GCCSI, “CO2 storage resources catalogue – Cycle 4 Report,”, (2024). https://www.ogci.com/wp-content/uploads/2024/07/CSRC_Cycle_4_Main-Report_July_2024.pdf.
42) I. Fauzi and N. A. R. Ispandiari, “Green LNG Supply Chain: Optimizing distribution in Eastern Indonesia,” Evergreen, 11 (3), pp. 2624–2637, (2024). doi: 10.5109/7236902.
43) J. Bhadu, J. Bhamu, and P. Saraswat, “An Analytic Hierarchy Process (AHP) approach for prioritizing the industries 4.0 Technologies (I4.0T),” Evergreen, 10 (2), pp. 667–675, (2023). doi: 10.5109/6792813.
44) B. Pranoto, E. Hartulistiyoso, M.N. Aidi, D. Sutrisno, H. Soekarno, A.A. Martha, Q. Zahro, Y.I. Rahmila, and V. Nurliyanti, “Assessing the Sustainability of Small Hydropower Potential in the Threats of Natural Disasters: An Analytic Hierarchy Process-Based Approach,” Evergreen, 11,(3), pp. 2711–2719, (2024). doi: 10.5109/7236910.
45) K. Lin, T. Jin, N. Wei, Q. Chen, W. Zhao, J. Zhou, M. Ali, W. Wang, and X. Li, “A Comprehensive Analysis of the Mutual Feedback Mechanisms between CO2 Geological Storage and Underground Coal Mining in the Ordos Basin,” Energy & Fuels, 39(12), (2025), doi: 10.1021/acs.energyfuels.4c06309.
46) K. Lin, N. Wei, Y. Zhang, S. Liu, M. Ali, W. Wang, Q. Chen, and Y. Wang, “Hydro-mechanical interactions in CO2 storage: Critical parameters influencing coal mine at Shenhua’s CCS site,” Engineering Geology, 352 (2025) 108087, (2025), doi: 10.1016/j.enggeo.2025.108087.