CCS in the Asia-Pacific Region

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GLOBAL CCS INSTITUTE

OIL AND GAS CLIMATE INITIATIVE

Disclaimer

Development of the final section of this report was commenced in February 2026 and therefore does not incorporate any subsequent developments.

Limitations

This report assesses selected APAC economies and does not represent a comprehensive assessment of every Asia-Pacific country or project. Policy, legal and regulatory analysis reflects information available to the authors as of early 2026. Storage analysis is screening-level and based on public data, published estimates and the Global CCS Institute’s basin-screening methodology; it does not confirm project-ready storage capacity. Economic results are scenario-based model outputs from GENZO and associated input-output analysis, not forecasts. References to projects, companies or jurisdictions are included for analytical context and do not imply endorsement by OGCI or its member companies.

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Executive Summary

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Executive Summary

The Asia-Pacific region[1] has significant potential to deploy CCS as part of a broader decarbonisation pathway, particularly where industrial growth, energy security and hard-to-abate emissions need to be managed together. CCS development across APAC remains less mature than in Europe and the United States, but momentum has increased since the early 2020s as climate ambition, net-zero commitments, regional cooperation and CCS-specific legal frameworks have developed. This report has been prepared to assess the conditions under which CCS could move from policy recognition and early project activity toward scalable regional deployment. It brings together three complementary strands of analysis: (1) a review of CCS policy, legal, regulatory and commercial frameworks across Australia, Brunei, Indonesia, Japan, Malaysia, South Korea, Thailand, Vietnam and Singapore; (2) an assessment of CO_2 storage potential in key APAC countries, including storage resources, basin suitability and barriers to deployment; and (3) economic and energy-system modelling of CCS pathways for ASEAN countries and key regional trading partners, including Australia, Japan and South Korea.

Policy, Legal, Regulatory and Commercial

Policy recognition of CCS is increasing across selected Asia-Pacific economies. Australia and Japan were early movers, while several Southeast Asian nations have more recently begun introducing CCS-specific legislation, policy measures and funding mechanisms. Although progress remains uneven and many frameworks are still developing, the overall direction is toward broader recognition of CCS as one potential tool to support hard-to-abate industrial decarbonisation, energy-system resilience and regional carbon management.

A defining trend in APAC is the strong link between domestic CCS support and international climate cooperation. Countries including Australia, Japan, Thailand, Cambodia, and Singapore are explicitly referencing CCS in their current NDCs. Singapore, Thailand, Malaysia and Indonesia also emphasise that stronger climate action depends on climate finance, technology transfer, and capacity building on CCS.

Regional collaboration on CCS is accelerating with a growing number of MoUs and bilateral agreements being concluded, notably involving Japan, Australia, Singapore, Indonesia, Malaysia, and South Korea. These agreements focus on enabling cross-border CCS value chains in the region, and beyond. Most APAC countries, however, do not have dedicated frameworks for cross-border CO_2 transport and storage. Further, efficient transboundary CCS value chains likely require further harmonisation of national legal and regulatory frameworks.

Another major trend is the accelerated development of legal and regulatory frameworks covering the full CCS project lifecycle and including provisions for transboundary CO_2 transport and storage. However, the pace of development and implementation of these frameworks vary significantly between countries in the region. Over the past two years, Indonesia, Malaysia, Japan, Thailand, New Zealand and South Korea have established or proposed CCS legal frameworks, while Australia has continued to refine operator obligations through regulations and guidance. These developments are important because they are laying the legal foundations not only for domestic storage projects, but also for future regional transport and storage hubs. Many countries in the region do not have CCS-specific legal frameworks, which creates uncertainty for regional CCS deployment.

Carbon markets are also expanding across APAC and are increasingly seen as a potential mechanism to support CCS deployment. Since 2024, Thailand and Vietnam have both established emissions trading

1 The analysis covers selected APAC economies rather than the entire Asia-Pacific region. The legal and regulatory review focuses on Australia, Brunei, Indonesia, Japan, Malaysia, South Korea, Thailand, Vietnam and Singapore. The storage analysis assesses selected countries with available public subsurface data, and the economic modelling focuses on ASEAN economies plus Australia/New Zealand, Japan and South Korea.

schemes, albeit these schemes are yet to be implemented. At present, South Korea, Japan, Malaysia, Indonesia, Australia, and Singapore have established mandatory and/or voluntary carbon markets. However, only a limited number of schemes currently allow or propose CCS-related credit generation, and major barriers remain, including inconsistent rules, weak market interoperability, limited methodologies for CCS credits, and carbon prices that are still too low to support commercial-scale projects.

This report provides an analysis of policy, legal, regulatory, and other information current as of February 2026. As developments in this space occur rapidly, developments may have occurred since this date that are not reflected in this report.

Table 1 summarises the adequacy of legal and regulatory regimes in APAC as they relate to CCS projects. The analysis of each country's policy, legal and regulatory regime can be found in section 2.0, and the results of the gap analysis, and identified opportunities are included in section 4.0.

Table 1. Summary of key regulatory considerations for CCS projects included in legal and regulatory regimes across APAC

Specific provisions identified · Partial provisions identified · No specific provisions identified

CCS Project lifecycle	Australia	Brunei	Indonesia	Japan	Malaysia	South Korea	Vietnam	Singapore
Classification of CO_2	Specific	Partial	Specific	Specific	Specific	Partial	Partial	Specific
Ownership regime for sub-surface	Specific	None	Partial	None	Partial	None	None	None
Design standards for CCS projects	Specific	None	Specific	Partial	Specific	Partial	None	None
Transboundary movement of CO_2	Specific	None	Partial	None	None	Partial	None	None
Surface access and reclamation	Specific	None	Specific	None	Specific	None	None	None
Leakage provisions	Specific	None	Specific	Partial	Specific	Specific	None	None
Transport of CO_2	Specific	None	Specific	Partial	Specific	Specific	None	Partial
Monitoring and verification requirements	Specific	None	Specific	Specific	Specific	Partial	None	Partial
Storage and siting	Specific	None	Specific	Specific	Specific	Specific	None	None
Closure	Specific	None	Specific	Partial	Specific	Partial	None	None

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CO_2 Storage and Infrastructure

Analysis of regional storage finds that APAC has numerous suitable storage basins and abundant potential CO_2 storage resources, but the level of data quality, public information and site-specific characterisation varies widely by country. Nine nations were reviewed in detail: Australia, Brunei, Indonesia, Japan, Malaysia, the Philippines, South Korea, Thailand and Vietnam. Timor-Leste, Lao PDR, Myanmar and Cambodia were not assessed due to a lack of data, and Singapore was found not to have a sizeable domestic storage basin within its borders.

Australia's Northwest Shelf is identified as having very high prospects for CCS deployment, with multiple suitable and highly suitable basins, gigatonne-scale hydrocarbon field resources and several CO_2 transport and storage projects in development.

Brunei is assessed as having significant resources in both hydrocarbon fields and saline formations within a highly suitable basin and comparatively limited domestic emissions. It could potentially deploy CO_2 storage operations to support a domestic CCS industry and potential international CO_2 imports, however the country lacks a CCS-specific legal and regulatory framework, CCS-specific domestic policies or incentives, and active CCS facilities.

Indonesia is already moving into the execution phase of CCS deployment, with multiple hydrocarbon companies progressing CCS facilities associated with natural gas development and hydrocarbon or ammonia production. A national CO_2 storage resource atlas does not yet exist and further work is required to characterise saline formation storage resources.

Malaysia has several highly suitable storage basins, including the Malay, Sarawak and Sabah basins, and is positioning itself as a potential regional CO_2 storage hub.

Other countries present a mix of opportunities and constraints. Thailand's Malay and Pattani basins require targeted site-scale characterisation and may offer near- to long-term storage opportunities. Vietnam's Bach Ho Formation has potential but Vietnam does not yet have a comprehensive national storage atlas and a CCS-specific legal and regulatory framework. South Korea has limited suitable sedimentary basins and will require further data acquisition to de-risk storage prospects. Singapore has no sizeable domestic storage potential and will therefore require transboundary CO_2 transport to decarbonise emissions from sectors such as petrochemicals and refining.

Across the region, the report identifies three recurring storage-side barriers: saline formation storage resources are largely unknown and uncharacterised; published estimates often lack transparency on location, methodology, assumptions, limitations or input data; and public access to subsurface data is limited. These barriers restrict confidence in storage resource assessments and constrain the development of bankable CCS projects. Addressing them likely requires national storage atlases, targeted site-scale appraisal, improved data access, and clearer links between storage characterisation, permitting and project development.

Economics

The economic analysis uses the Global Economic Net Zero Optimisation model, GENZO, a bottom-up technology-focused model based on the Open Source Energy Modelling System framework. GENZO models 24 regions simultaneously and represents trade in energy, commodities and physical CO_2 for storage. For this study, results are presented for ASEAN countries including Brunei, Indonesia, Malaysia, the Philippines, Singapore, Thailand, Vietnam and the rest of Southeast Asia, as well as Australia/New Zealand, Japan and South Korea. The model evaluates three scenarios: Low Storage Growth, Accelerated Storage Growth and Accelerated Emissions Trading.

The modelling indicates that constrained storage development increases the cost of reaching net zero. It also shows that storage availability affects CO_2 prices, physical CO_2 transport needs and broader energy-system structure. Where domestic storage is unavailable or constrained, CO_2 shipping becomes more important. Singapore, which has no domestic storage capacity, and South Korea, which has very limited storage capacity, rely on transport of captured CO_2 to other regions where storage is available.

Under the modelled Accelerated Storage Growth scenario, CCS-related investment is estimated to contribute to regional value added and employment over the period assessed, with employment initially associated with construction and later shifting toward CCS operations, power plants, industry and CO_2 transport. These estimates are indicative scenario outputs and should not be read as forecasts.

01

The Regulation of CCS in the Asia-Pacific region

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1 The Regulation of CCS in the Asia-Pacific region

1.1 Introduction and scope

Across the Asia-Pacific (APAC) region, CCUS technologies are increasingly identified as essential to the decarbonisation efforts of several nations. Many governments are exploring the domestic adoption of CCS but are also actively seeking collaboration within the region to develop project models centred on CO_2 transportation and storage. In this context, the development of robust legal and regulatory frameworks is a critical component of a national policy aimed at incentivising and facilitating the technology, not only domestically but also as regional project models are pursued.

Although there are similarities between CCS and wider oil and gas industry operations, there are several aspects of the technology that raise a variety of unique legal and regulatory issues within international, national and regional legal and regulatory frameworks. Consideration of these issues across each element of the CCS value chain (the capture, transport, and storage of CO_2), is important for the development of an effective regulatory process.

A review of the CCS-specific legal and regulatory frameworks developed worldwide to date, indicates that regulators and policymakers have primarily chosen to adopt one of two approaches to the regulation of CCS. Either existing regulatory frameworks have been enhanced to incorporate CCS-specific provisions, or there has been development of stand-alone CCS-specific legal frameworks. A further option has been the development of project-specific legislation that regulates the operation of a single project.

In recent years, several governments have also taken steps to review and assess the capacity of their national regimes to support the deployment of both demonstration and large-scale integrated projects. CCS-specific regimes determine roles and responsibilities and regulate many aspects of the project lifecycle. In nations where CCS-specific legislation has yet to be considered or implemented, operators and regulators will be required to determine the legality of these operations under existing regimes governing, amongst others, environmental protection, planning, land use, mining and energy activities.

This report provides an assessment of the current regional and domestic regulation of CCS technologies in the APAC region. Additional details on the assessment are provided under each country's relevant subsection. The assessment focuses on the extent to which current frameworks regulate CCS and identifies gaps and barriers to CCS deployment that presently exist within national frameworks. The review concludes with recommendations as to how gaps can be closed to facilitate regional CO_2 transport and storage activities.

1.2 Approach to the analysis

In this analysis, the Institute has assessed the legal frameworks and regulatory regimes of nine countries in the APAC region; Australia, Brunei, Indonesia, Japan, Malaysia, South Korea, Thailand, Vietnam, and Singapore. To undertake this assessment, the Institute has utilised an assessment model that seeks to determine how comprehensive an individual jurisdiction's legal and regulatory framework is when regulating a CCS project throughout the CCS project lifecycle. The assessment focuses upon several key criteria, which comprise issues that are likely critical to the regulation of a CCS project, from its planning and operational stages through to the post-closure phase. The five core assessment criteria consider the:

- Clarity and efficiency of the administrative process under the legal framework for applying for and obtaining regulatory approval for CCS projects.
- Comprehensiveness of the legal framework in providing for all aspects of a CCS project, including siting, design, capture, transport, storage, closure and monitoring.
- Extent to which legal and regulatory frameworks provide for the appropriate siting of projects and adequate Environmental Impact Assessment (EIA) processes.
- Provision for meaningful and effective stakeholder and public consultation.
- Management of liabilities associated with closure, monitoring and accidental releases of stored CO_2.

The Institute has focused its review on the extent to which the regulatory frameworks in the APAC region address these core issues and assessed whether there are any observed gaps in the national regulation of CCS projects in the context of regional CO_2 transport and storage models. The review has also sought to provide targeted recommendations for addressing gaps and deficiencies within existing legal and regulatory frameworks that will facilitate CCS activities domestically and enable seamless regional CO_2 transport and storage activities. The report is structured as follows:

- Section 2 sets out the legal and regulatory frameworks of each jurisdiction in their current state (as of February 2026) and the extent to which these frameworks facilitate CCS activities. Each country's analysis concludes with high-level summaries, offering a brief overview of the gaps in their respective legal and regulatory frameworks.
- Section 3 provides an overview of business models currently deployed globally. It may provide valuable insights for applicability in APAC, as CCS hubs and transport networks are being contemplated.
- Section 4 of this report provides recommendations on the policy, legal and regulatory frameworks of each country. The specific gaps in each country are listed and recommendations for addressing these gaps are also provided.

02

Review of local CCS law and regulation, and policy in the APAC region

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2 Review of local CCS law and regulation, and policy in the APAC region

2.1 Australia

Australia is taking steps to deliver its climate ambitions through legislated emissions reduction commitments and substantial investments in clean energy technologies to support the global clean energy transition. The US EIA's International Energy Outlook 2023 has estimated Australia's and New Zealand's energy use to be 8.86 EJ in 2040 growing to 9.7 EJ in 2050 (US Energy Information Administration, 2023).

The nation has seen strong historical policy and regulatory support, dating back to the 2000s, for CCS. However, this support has fluctuated over the past decade. For example, the current Labor government, elected in 2022, reduced support established by previous governments for the technology under various incentive and grant programs. In particular, the October 2021 Bill, which had allowed CCS projects to generate Australian Carbon Credit Units (ACCUs) for stored CO_2 volumes, was later reversed in respect of all new projects. Since 2023 however, there has been steady, year-on-year momentum in policy support to incentivise CCS. In 2023, the government introduced reforms to the Safeguard Mechanism (SGM) that set baseline emissions for major emitters, that decreases on an annual basis by 4.9% until 2030, effectively meaning that companies will be required to emit less each year or purchase the corresponding offsets. Significantly for CCS, this development indicated potential for deployment to be spurred in hard-to-abate industrial sectors.

Since then, the government has established policy support for CCS through commitments in national policy documents, federal budget allocations, grant programs, legal and regulatory measures and institutional support. For example, in May 2024, the Australian Government released its Future Gas Strategy, which maps out the government's plan for how gas will support the transition to net zero (Australian Department of Industry Science and Resources, 2023). Action item five of the strategy is "promoting geological storage of CO_2 and support our region's transition to net zero". Key measures envisaged under this action item include the release of offshore acreage for (GHG) storage activities and the establishment of a new transboundary CCS program that provides carbon management solutions to regional partners (Australian Government, 2024).

The government emphasised the role of CCS in achieving the country's contribution to achieving Paris Agreement targets, and this commitment was articulated in its updated NDC that was submitted in 2025. To support this commitment, the government published the Net Zero Plan in 2025, a whole of economy strategy to achieve its 2050 emissions target, involving 6 sectoral emissions reduction plans to support its net zero strategy. CCS features within the Resources Sector Plan, which spans 2025 to 2035 (Australian Government, 2025b). The plan envisages the expansion of CCS to 2030, the continued growth of CCS to 2035 and the continued use of CCS beyond to 2050 (Australian Department of Industry Science and Resources, 2025).

Australia was an early mover nation in establishing sophisticated legal and regulatory frameworks to facilitate CO_2 storage at the federal, state and territory levels. At the federal level, the Commonwealth Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGSA) serves as the primary legislation governing offshore greenhouse gas storage activities. The OPGGSA provides a detailed and integrated framework for conducting CCS activities in Commonwealth waters. Since its enactment, the government has focused on establishing greater regulatory clarity for the technology by ensuring legal frameworks are fit-for-purpose in regulating new applications and project models. Measures to this end include strengthening the OPGGSA through amendments to allow single GHG titles across Commonwealth and state or Northern Territory waters, updating regulations to facilitate project permitting, issuing guidelines, and establishing governance structures within regulatory agencies to streamline the administration of the OPGGSA.

Australia is also poised to take a leading role within the region in facilitating the CCS industry to establish transboundary CCS value chains, engaging actively with regional stakeholders to collaborate in the development and promotion of these cross-border initiatives. To this end, Australia has also taken steps to remove regulatory barriers to enable the transboundary transport and geological storage of CO_2. In November 2023, the federal parliament passed the Environment Protection (Sea Dumping) Amendment (Using New Technologies to Fight Climate Change) Bill 2023 enabling transboundary CO_2 export and import activities. The legislation made Australia the first country in the region to establish a domestic permitting regime for transboundary CO_2 export and import activities pursuant to the provisions of the London Protocol.

In November 2024, the government accepted the 2009 amendment to the London Protocol and deposited an instrument of provisional application of the 2009 amendment with the International Maritime Organisation (IMO) (DCCEEW, 2025a). In the interim, Australia has also been negotiating bilateral agreements with neighbouring countries to cooperate on CCS and conduct cross-border CO_2 transport and storage. Agreements are currently in place between Singapore and the Republic of Korea (Australian Government Department of Foreign Affairs and Trade, 2022; DCCEEW, 2024).

In June 2025, the Australian government released consultation documents relating to offshore CO_2 sequestration under the Sea Dumping Act, with a focus upon the draft Offshore CCS National Action List (NAL), the National Assessment Guidelines (Guidelines), and an updated Sea Dumping permit application. CCS project operators seeking to load captured CO_2, transport and dispose CO_2 in Australian waters must comply with the guidelines, submit information required as part of the Sea dumping permit and ensure compliance with the Offshore CCS National Action List (NAL) in addition to complying with domestic regulatory requirements relating to offshore CO_2 storage at the Commonwealth and state level (DCCEEW, 2025b).

Australia's Net Zero plan also highlights the government's intent to leverage Australia's geological capacity within the international market for transboundary CO_2 storage operations. The plan highlights the Regional Cooperation Initiative on Carbon Sequestration as a mechanism for setting up the institutional framework for facilitating transboundary operations, including setting up bilateral agreements with regional and partner countries interested in investment and trade in CCS in Australia.

2.1.1 CCS-RELATED POLICY LANDSCAPE

2.1.1.1 National Developments

Emission Reduction Fund (ERF)

The Emissions Reduction Fund (ERF) is a voluntary scheme from the Australian Federal Government that enables entities (businesses, landowners, households for example) to reduce their emissions. Through the scheme, the Australian Government purchases Australian Carbon Credit Units (ACCUs) from registered participants through auctions. By creating a revenue stream, this methodology incentivises organisations, especially in the private sector, to proactively reduce emissions (Australian Government & Clean Energy Regulator, 2021b).

Only certain projects are eligible for registration under the ERF (Australian Government & Clean Energy Regulator, 2021a), these projects:

I. Should not have started before registration with Australia's Clean Energy Regulator (CER).

II. Cannot be a requirement of a State, Territory or Federal law.

III. Cannot have been executed under another State, Territory or Federal program if it were not registered under the ERF.

After meeting these eligibility requirements, the ERF requires the following actions for participation (Australian Government & Clean Energy Regulator, 2017):

I. Register the project and the organisation and join the scheme.

II. Participate in an Australian Government auction administered by the CER and secure a contract. ERF does not require a carbon abatement contract for participation and ACCUs can be allocated without a contract (more information on contracts is included below.

III. Execute the project while ensuring alignment with the methodology submitted during registration.

IV. Report on the project at the required intervals and ensure auditing requirements are met.

After these requirements have been met, the organisation can claim and receive ACCUs for the emissions reductions achieved by the project. The ACCUs can then be sold to the Australian Government or on the secondary market.

Australian Carbon Credit Units (ACCUs)

While several activities can potentially qualify to be eligible under the scheme, the scheme provides revenue only if the activities generate ACCUs. The ERF includes a Safeguard Mechanism whereby large emitters are required to keep their emissions below or within a baseline level (Australian Government & Department of Industry Science Energy and Resources, 2021). The Safeguard Mechanism ensures that emissions reductions associated with ACCUs are not offset by increases in emissions elsewhere, including those from large corporate emitters.

ACCUs can be earned for projects that store or avoid generating CO_2. One tonne of CO_2 or CO_2-equivalent1F1F GHG that is stored or not generated generates one ACCU. Under the ERF scheme, these ACCUs have monetary value and can be sold to generate revenue. The Australian Government, through the Clean Energy Regulator (CER) can buy them from those entities that are successful in ERF auctions. This transaction takes place through a formal commercial agreement called a carbon abatement contract set up between the entity and the Clean Energy Regulator. The CER can enter into different types of such contracts (Clean Energy Regulator, 2026a). In May 2026, one ACCU was trading at AU$37.50.

With the increasing scrutiny from the financial sector to encourage compliance with the Paris Agreement and the Glasgow Climate Pact, there has been a corresponding rise in private sector demand for ACCUs. The CER has been working to set up an Australian Carbon Exchange to facilitate the smooth trading of ACCUs between corporate entities and individuals (Australian Government & Clean Energy Regulator, 2022a).

CCS-specific methodology

The CCS-specific methodology was designed to encourage and enable projects, developed by the corporate sector, that capture and permanently store GHG (including CO_2) in geological formations underground to receive ACCUs

The CCS-specific methodology is set out in the Carbon Credits (Carbon Farming Initiative—Carbon Capture and Storage) Methodology Determination 2021 and is commonly known as the Carbon Capture and Storage method (Australian Government Clean Energy Regulator, 2024).

This method, specific to CCS projects, gives credit to those emissions reductions that result from carbon capture and permanent storage of GHG (including CO_2) in underground geological formations. The Amendment Rule passed in 2021 considers the long lifecycle of CCS projects (from initiation to execution) and enables a longer accounting period. Most projects registered with the ERF, and not covered by this methodology, have an 18-month deferral limit to initiate the crediting period. However, CCS projects governed by this methodology have a 60-month limit.

A positive development of the CCS method under the ERF is that it provides for a 25-year crediting period, which is the period over which the Clean Energy Regulator may issue ACCUs. However, as with other large infrastructure projects, a CCS facility follows a phased process with decision gates that determine and guide its development. The process of moving from identification to concept selection, to design, to construction, to start-up, and finally then to operation has lead times between stages. Evidence from the Institute's CCS facility database shows it has taken 6 to 8 years on average for CCS projects to progress through the full development cycle, from identification to operation. This is no different when compared to any other large-scale infrastructure development process.

In contrast, the ERF only allows a 5-year window between registering a project and commencing operations to deliver reductions in emissions. The project start date can only be varied once and project delays will reduce the time of the crediting period. This tight timeframe requires project developers to make final investment decisions and commence construction without certainty as to how potential delays may affect project revenues. This will hinder the ability for developers to cover the costs associated with reductions in CO_2 emissions. As well as creating commercial challenges, this could place projects at risk of not meeting additional criteria.

Updates to the Safeguard Mechanism

In March 2023 the Australian Parliament passed the Safeguard Mechanism Amendment bill. The new arrangements under the bill took effect in July 2023 after the associated rules and regulations were finalised by the government. Through the amended Safeguard Mechanism, the government intends to reduce 205 million tonnes of CO_2-e ($MtCO_2$-e) through to 2030, a key component of Australia's commitment to reduce GHG emissions by 43% from 2005 levels. The amended mechanism will now require covered facilities to reduce their net GHG emissions – the baselines – over time. Facilities must reduce net baseline emissions by 4.9% each year through to 2030.

Since 1 July 2023, baselines for new and existing facilities have been set using 'international best practice (Clean Energy Regulator, 2026b). This has implications for LNG facilities and CCS has been identified as a key tool for achieving net zero targets in this sector.

The amended Safeguard Mechanism can have a bearing on the generation and pricing of ACCUs. A potential consequence of the amended Safeguard Mechanism could require the government to limit new projects coming online due to the hard cap on total GHG emissions. To ensure that GHG emission levels are reducing to meet the 2030 goals, the decline rate of net and gross GHG emissions from covered facilities through to 2030 will be studied by the Climate Change Authority.

Covered facilities will still be able to use ACCUs to offset the excesses in GHG emissions. However, there will be additional requirements for facilities that need to use ACCUs to offset more than 30% of their emissions. Facilities will need to provide a justification to the Clean Energy Regulator, with the government indicating that cost and the availability of technology are valid justifications (The Hon Chris Bowen MP & Australian Government, 2023). Under the amended Act, the mechanism will also allow for Safeguard Mechanism Credits (SMCs) to be issued. These are triggered only when a covered facility's GHG emissions go below the baseline level. Each tonne of CO_2-e reduced below the baseline generates one SMC. The SMCs can also be traded between other facilities and bear resemblance to the ACCUs in this respect. The generation of SMCs is designed to incentivise covered facilities to reduce their emissions below baseline and to consequently avail of benefits through the generation of tradable

SMCs. The availability of SMCs won't limit the access to ACCUs, however new provisions will be put in place to avoid double counting (Australian Government & Department of Climate Change, 2023; Tim Power et al., 2023).

2.1.1.1.1 Background to the Safeguard Mechanism and the 2023 Amendment

The Safeguard Mechanism came into effect in July 2016 after it was established under the National Greenhouse and Energy Reporting Act of 2007. The mechanism designated certain facilities as covered under its program. These facilities are considered large and emit more than 100,000 tCO_2-e per year. The typical sectors covered include gas processing, gas production, manufacturing, and mining. The mechanism covers around 30% of Australia's GHG emissions from 215 facilities. The mechanism is designed to set a ceiling for the covered facilities and does so by setting baselines for emissions from these facilities. Thus, each reporting year the covered facilities are required to limit their net scope 1 emissions to their associated baselines(Clean Energy Regulator, 2026b; DCCEEW, 2026). However, facilities that emit or will need to emit above their baselines can offset the excess emissions by purchasing ACCUs.

The amendments introduced in 2023 capped the total emissions from covered facilities to 1,233 $MtCO_2$-e over the period from 2021 to 2030, which required yearly emissions from all covered facilities to fall from 143 $MtCO_2$-e (projected for 2022-2023) to 100 $MtCO_2$-e by 2023 (DCCEEW, 2023).

Facilities covered by the Safeguard Mechanism that come online before 1 July 2023 will have baselines set using guidance in the Safeguard Rule elaborated in the National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015. The baselines are set using calculations that take the forecasted production and associated emissions intensity into consideration in which industry averages have an impact.

The amendment to the Safeguard Mechanism also has implications with other Acts passed by Parliament. Notably, the Climate Change Act will also be amended. New facilities or facilities that need expansion that meet the covering threshold for the Safeguard Mechanism will have additional requirements; they will be required to provide an estimate of their scope 1 emissions. The provisions were put in place since new and expanded facilities will impact how emissions safeguarded by the mechanism decline over the decade. Consequently, this has been termed as a pollution trigger since it could have an impact on project approvals and when projects come online (Gilbert & Tobin, 2023).

If levels are not declining at the required rate, the baseline levels could need to be reduced or other changes to the Safeguard Mechanisms may be necessary to achieve the desired emissions reduction outcomes.

2.1.1.2 State-level developments

Western Australia

In 2024, the state of Western Australia joined the early-mover states of Victoria, South Australia and Queensland and released its own CCS-specific legislation. The new Petroleum Legislation Amendment Bill (2023) regulate CCS activities within the state and in alignment with the commonwealth government's OPGGSA (Western Australian Government, 2024). Secondary regulations under the primary Act provide further detail for CCS operations within the state. In this regard, the government has enacted a set of injection and storage regulations to support the Act and is currently amending broader petroleum regulations to extend their scope to CCS activities.

Future State

In April 2023, the Government of Western Australia (WA) released Future State through the Department of Jobs, Tourism, Science and Innovation, which sought to expand on the state's traditional industrial strengths in energy and mining. The policy aligns with the Diversify WA framework, which aims to build a diversified economy. The government has acknowledged and highlighted CCUS technology as a targeted sector-specific diversification opportunity that can be developed and commercialised. Industry engagement and cross-sector collaboration is highlighted as key to developing the roadmaps that will be necessary to implement the opportunities.

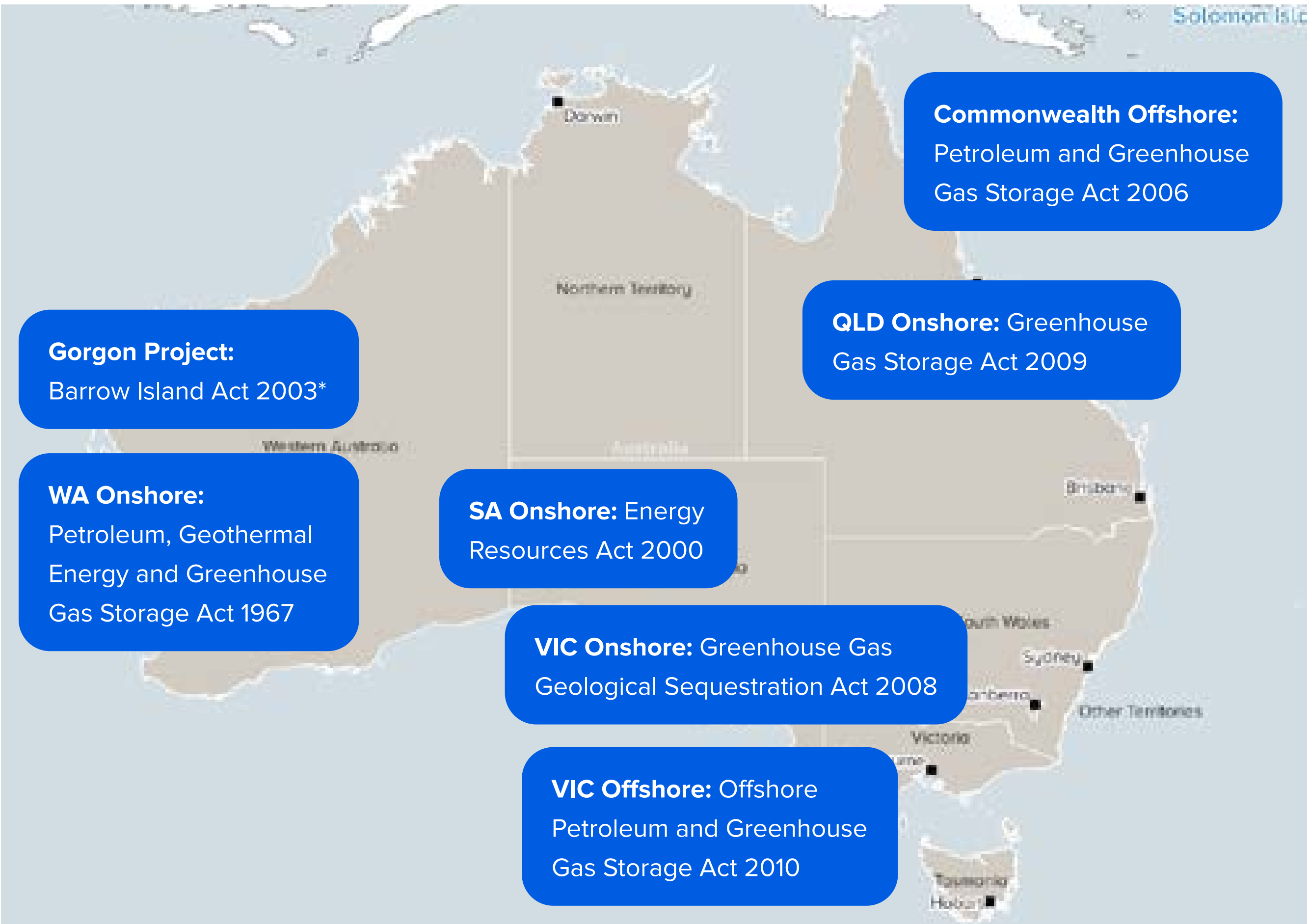
The government also recognised that the decarbonisation of hard-to-abate sectors like mining and energy will need CCUS as a key supporting technology for Australian industry participants to remain competitive in the global marketplace. At the end of 2023, the WA government also announced $4.3m towards a CCUS Action Plan to establish a world-leading CCUS industry in WA (Western Australian Government, 2023).

Carbon Capture Utilisation and Storage Action Plan
Consequently, in 2025, Western Australia released its Carbon Capture Utilisation and Storage Action Plan. The strategy outlines key objectives and priority actions in its plan to deploy CCS to support the transition to a low-carbon economy in the state. Among its priority actions, the plan highlights the implementation of a leading legal and regulatory framework for CCUS and the attraction of investments and strategic international partnerships to prime its position as a key player in the international market for CCUS (Government of Western Australia, 2025).

2.1.2 ASSESSMENT OF LEGAL AND REGULATORY FRAMEWORK

The development of the Commonwealth's regulatory framework to facilitate CCS commenced in the early 2000s. The resulting framework in its current iteration reflects numerous efforts over the course of two decades to develop, refine and expand legislation to address the various aspects of the CCS project lifecycle. Figure 1 below indicates the established legal and regulatory frameworks that are applicable to CCS projects located in Australia, or CO_2 storage hubs involving CO_2 captured overseas.

Figure 1. Australian CCS legal and regulatory frameworks



The following sections will analyse the regulatory framework for CCS projects in Australia across the Commonwealth, state and territory levels.

Existing approval process for applying for and obtaining regulatory approval for CCS projects

The roles and responsibilities across every major aspect of the CCS project lifecycle are well defined within Australia's regulatory framework for CCS.

The Commonwealth's OPGGSA establishes a comprehensive licensing framework to authorise CCS activities, from the exploration phase through to injection and closure phases. This framework largely mirrors the approvals regime for petroleum exploration and production activities. Figure 2 identifies the key permits and activities authorised by the permits through each of the project phases and milestones.

Figure 2. Key permits/licenses and associated authorised activities under the OPGGSA

Relevant title	GHG Assesment Permit	GHG Injection License	Site Closure Certificate	Closure Authorisation/ Transfer of liabilities
Timeline	Decision to grant permit within 12 months of application	Decision to grant license upon Ministerial discretion	Decision to grant certificate is within 5 years of application	Decision to declare end of closure assurance period at least 15 years after the grant of the site closure certificate and upon Ministerial discretion
Project period	Exploration	Operation	Closure	Post-closure
Activities	Exploration & monitoring	Construction, injection, storage & monitoring	Decommissioning & monitoring	Monitoring

Key permits and licenses to authorise CCS activities under the OPGGSA

The OPGGSA has established a statutory title scheme in order to provide access and property rights in relation to CO_2 storage sites. Statutory titles enable project operators to conduct exploration and exploitation of the subsurface in the offshore areas for GHG substance storage. Each title corresponds to the different stages of developing and operating a CO_2 storage site. The relevant titles are depicted in Figure 2.

Exploration and operation phases

During the exploration phase, an operator seeking to undertake exploration for a potential storage site in Commonwealth waters, will be required to obtain a 'GHG assessment permit'. The permit enables the holder to conduct exploration activities for potential GHG storage formations and potential GHG injection sites, within the designated permit area.

A GHG assessment permit may be transitioned to a 'GHG holding lease', where a declaration of an identified GHG storage formation is made and an operator wishes to delay injection and storage activities. In other instances, following the declaration of an identified GHG storage formation, injection and permanent storage activities are subsequently authorised under a 'GHG injection license'.

The award of a GHG injection license entitles the holder to inject a GHG substance into an identified GHG storage formation within the license area, provided that the injection well is situated within the license area. The license authorises the permanent storage of the injected GHG, as well as the equivalent rights to exploration and appraisal activities, which are afforded under either an assessment permit or a holding lease. Similar to all other forms of title under the OPGGSA, it is an offence to undertake these activities without authorisation.

Closure and post-closure phases

The OPGGSA establishes a formal procedure for the closure of a storage site. While based upon the existing petroleum model, these provisions were introduced by the Commonwealth government to address some of the novel challenges of the CCUS process, as highlighted in the development of the regulation.

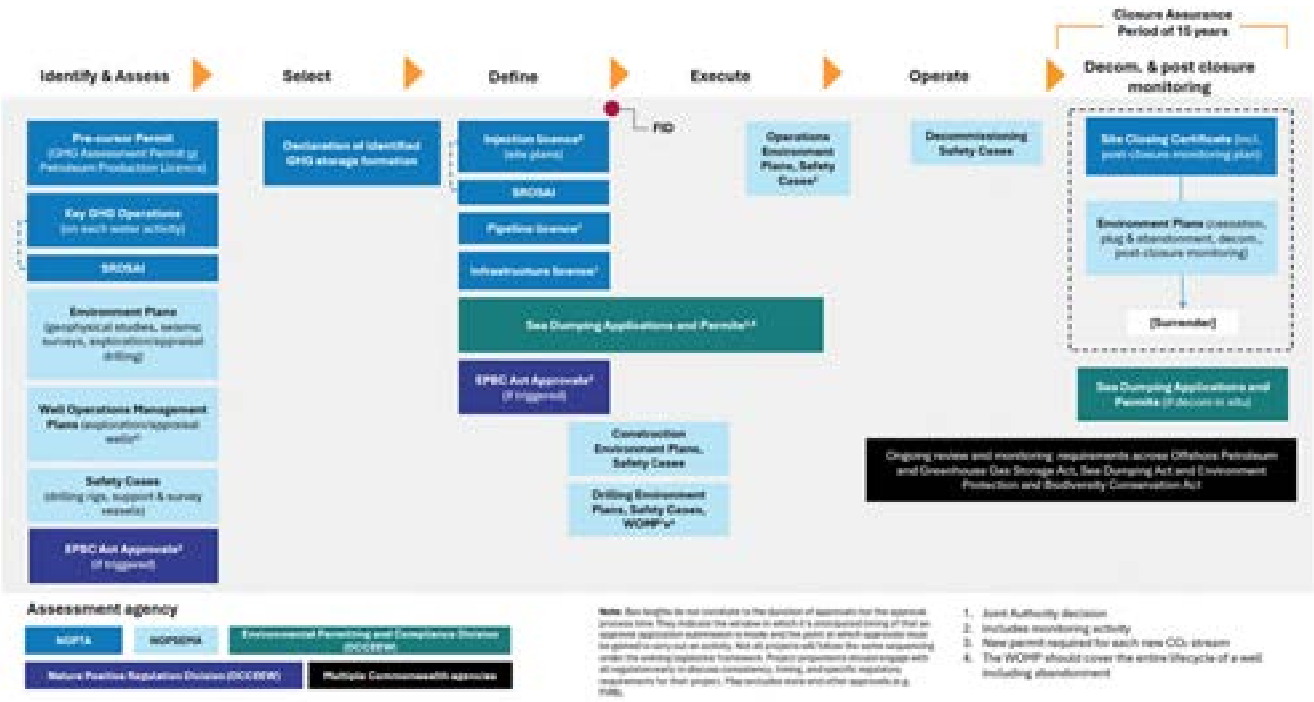
Upon completion of injection activities, the holder of an injection license must apply to the Minister for a site closure certificate, in relation to the storage formation specified in the license. The responsible Minister is required to assess whether injection operations have ceased in accordance with the requirements of the Act, following which they may issue a pre-certificate notice, which confirms that the Minister is prepared to issue to the applicant a site closing certificate in relation to the storage site.

Once a notice has been issued and the applicant has paid the required security, then a site closure certificate must be issued. Within five years of an operator's application, a Minister must make an assessment of whether or not to grant a certificate.

While these statutory titles authorise key phases of the CCS process, there are further approvals within the OPGGSA that must be obtained relating to the environmental, safety, operational, decommissioning, closure and post-closure aspects of the CCS process. There are also licenses that must be obtained for the construction and operation of pipelines and infrastructure in Commonwealth waters.

Furthermore, in addition to the OPGGSA, there are wider Commonwealth legislation that will be applicable to a CCS project operating in Commonwealth waters that regulate the marine environment. Figure 3 indicates the various permits, licenses and approvals that need to be obtained across the lifecycle of a CCS project (National Offshore Petroleum Safety and Environmental Management Authority, 2023).

Figure 3. Schematic of the permitting and licensing process for CO_2 transport and offshore storage



State-level regulatory frameworks

The approvals process for CCS activities in the states and territories reflect the Commonwealth framework. Approvals must be consistent with existing environmental and health regimes and require consideration of "public interest" prior to granting authorisation to conduct CCS activities. The Australian regimes clearly allocate responsibilities between project operator and regulator at each stage of the CCS project lifecycle, with the operator conferred with distinct rights under each applicable licence.

Australia's regulatory framework for CCS was originally based on a nationally consistent set of guidelines for regulating CCS, known as the Carbon Dioxide Capture and Geological Storage Australian Regulatory Guiding Principles. Regulatory authorities such as NOPTA and NOPSEMA issue guidance to industry on applying for various GHG storage authorities and complying with obligations relating to such authorities.

Regulatory roles and responsibilities of government and agencies

At the Commonwealth level, the Department of Industry, Science and Resources (DISER) and the Department of Climate Change, Energy, the Environment and Water (DCCEEW) are the primary government departments that oversee Australia's Commonwealth offshore GHG storage regulatory framework. The Minister for Resources is responsible for approving CCS projects.

The National Offshore Petroleum Titles Administrator (NOPTA) administers the approvals process, and the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) regulates the environmental and safety aspects of the CCS process Table 2.

Table 2. Responsible authorities for approval and administration of statutory titles, permits and authorities under the OPGGSA

	Acreage Release	GHG Assessment Permit	Declaration of an Identified GHG Storage Formation	GHG Injection Licence	Site Closure Certificate	Declaration of Closure Assurance Period	Sea Dumping Permit
DCCEEW	Responsible for Approval						
Responsible Commonwealth Minister		Responsible for Approval	Responsible for Approval	Responsible for Approval	Responsible for Approval	Responsible for Approval	Responsible for Approval
NOPTA		Administering Authority	Administering Authority	Administering Authority	Administering Authority	Administering Authority	
NOPSEMA		Approvals for requirements such as environment, health, and safety plans; Advisory Role		Approvals for requirements such as environment, health, and safety plans; Advisory Role			

Responsible for Approval | Administering Authority | Advisory Role | Approvals for requirements such as environment, health, and safety plans

Comprehensive application of the legal framework across all aspects of a CCS project

As a federal state, the storage of GHG is regulated at both the Commonwealth and state and territory levels in Australia. In each jurisdiction, the regulatory regime addresses all aspects of the CCS project lifecycle to varying degrees. The most comprehensive regulatory framework is by far the Commonwealth legal regime.

The OPGGSA regulates the exploration process, construction and operation of infrastructure facilities and the injection of GHG substances in commonwealth waters. Operators are required to secure the appropriate form of tenure to undertake activities throughout the project lifecycle and the legislation introduces a permitting model that enables exploration for a suitable storage site, through to eventual injection operations.

The states of Victoria, Queensland, South Australia and Western Australia have all now enacted legislation to regulate the geologic storage of GHG. Together with the enactment of the Commonwealth OPGGSA, these regulatory activities have resulted in three distinct Australian storage frameworks; state or territory onshore legislation; state or territory offshore legislation and the Commonwealth offshore legislation.

The following section will explore how the legal and regulatory frameworks in Australia have addressed the various aspects of the CCS project lifecycle, and the comprehensiveness of each regime in addressing each aspect. The table below provides a brief overview of the current regulatory landscape and the extent to which it addresses key elements of the CCS project life cycle.

Table 3. Key considerations in Australia's CCS legal and regulatory framework

Classification of CO_2	✓	The legal and regulatory frameworks in Australia at both Commonwealth and state/territory levels do not share a universal and consistent definition of CO_2; however, in practice, the definitions provided across each jurisdiction's regulatory framework is similar.
Ownership regime for sub-surface	✓	Ownership of the sub-surface, in both onshore and offshore territory in Australia is consistent across all jurisdictions, with the Crown (or State) vested with ownership of the geological reservoir within the sub-surface that will be used to store CO_2.
Design standards for CCS projects	✓	Design standards for CCS projects vary at the Commonwealth and state level. For example, in South Australia, pipeline construction and operation must comply with the requirements of Australian Standard (AS) 2885 Pipelines- Gas and Liquid Petroleum. The OPGGSA includes detailed provisions applicable to pipeline and infrastructure construction and operation in Commonwealth waters. A pipeline licence will specify the design, construction, size and capacity of the pipeline, the route of the pipeline and the position in relation to the seabed. An infrastructure licence under the OPGGSA authorises the construction and operation of infrastructure facilities associated with GHG storage activities. An applicant is required to provide information such as the technical advice and the financial resources available to the applicant.
Transboundary movement of CO_2	✓	Australia amended its Environment Protection (Sea Dumping) Act 1981 to enable the export of CO_2 from Australia to another country for dumping purposes through the passage of the Environment Protection (Sea Dumping) Amendment (Using New Technologies to Fight Climate Change) Bill 2023. In addition, there are general regulations applicable to the transport of CO_2 within the territories of each jurisdiction, which may be potentially applicable to the transboundary movement of CO_2.

Surface access and reclamation	✓	The requirements applicable to surface access and reclamation activities in the natural resources sector govern CCS activities at both the Commonwealth and state levels, with certain additional provisions in some jurisdictions applicable to CCS activities. For onshore CO_2 storage activities, state-level legislation has imposed obligations such as providing written notice to land-owners or occupiers, and compensation to land-owners where a licensee enters the land to conduct regulated activities. Specific obligations vary across each jurisdiction.
Leakage provisions	✓	There are substantial provisions across all the CCS-specific frameworks in Australia at the Commonwealth and state/territory levels dealing with CO_2 leakage. The aim of these provisions is to identify, mitigate and account for actual or potential leakage of CO_2 during the operational phase of a project. Regulatory authorities across the various jurisdictions possess wide-ranging powers to manage leakage, for which the project operator bears liability. Under the OPGGSA for example, leakages are categorised as “serious situations” or “reportable incidents” where the responsible Commonwealth Minister may require the licensee to take steps to rectify the serious situation, including ceasing or suspending operations. Under Victoria’s onshore legislation, a licence holder is required to enter into a compensation agreement with the holder of a resource authority prior to conducting any operations under an injection licence. Both Commonwealth and state level legislative frameworks require or enable regulatory authorities to impose conditions under the relevant authority that project operators take out and maintain insurance for any expense or liabilities relating to CCS operations, including to remedy the effects of leakage.
Transport of CO_2	✓	The Commonwealth and state regulatory frameworks relating to petroleum and gas exploration and production operations have been amended to enable transport of CO_2 streams, typically through a pipeline licence. For example, the OPGGSA includes detailed provisions applicable to pipeline construction and operation in Commonwealth waters. A pipeline licence authorises the licensee to construct and operate a pipeline for the purpose of conveying a GHG substance. The pipeline licence will specify the design, construction, size and capacity of the pipeline, the route of the pipeline and the position in relation to the seabed. Similarly, under Queensland onshore legislation, the transport of CO_2 is enabled through a GHG stream pipeline. A project operator is required to apply for and be granted a pipeline licence to operate a GHG stream pipeline.

Monitoring and verification requirements	✓	Across all jurisdictions, project operators authorised to conduct CO_2 storage activities under various authorities are required to comply with detailed monitoring and reporting regulatory requirements. The regulations under the OPGGSA prescribe a range of monitoring and record-keeping obligations, such as how particular volumes must be reported on and sampling methodology and record-keeping requirements. In Victoria, an operator may be required to carry out monitoring and to engage in risk mitigation as required. The Minister may also monitor the behaviour of GHG substances stored in geological formations. In South Australia, licensees are required to maintain a record of all regulated activities conducted under a licence, including the results of analysis of geological samples and a record of compliance audits. Australia's Commonwealth regime also empowers regulatory authorities to oversee compliance with monitoring obligations; the National Offshore Petroleum Safety and Environmental Management Authority is authorised to conduct inspection of storage sites to monitor compliance with environmental management obligations. Other obligations across the various jurisdictions include the requirement to submit an environment plan for approval, which includes appropriate implementation strategies and monitoring, recording and reporting requirements.
Storage and siting	✓	A geological formation that has been identified as suitable for CO_2 storage is required to satisfy a variety of site characterisation and assessment requirements as specified in the various legal and regulatory frameworks of each of the jurisdictions. No permit or licence to conduct CO_2 storage will be issued without satisfaction of these characterisation requirements. In Victoria, an application for a GHG injection and monitoring licence in respect of a particular offshore area on which an underground geological formation has been discovered must be accompanied with details regarding the geological suitability of the formation for permanent CO_2 storage.

Closure	✓	The various Australian jurisdictions have set up detailed and comprehensively regulated closure regimes for CCS projects. Under the Victorian onshore regime, for example, an operator must surrender the right to inject a GHG substance under the licence upon completion of injection activities. The surrender process involves obligations such as notifying the Minister, removing all infrastructure and rehabilitating the site where injection took place. The onshore regime also allows surrender of a licence with the consent of the Minister upon certain conditions being met, including that the injected GHG substance is behaving and will continue to behave predictably. Under the Commonwealth OPPGSA, a licence holder is required to apply for a site closure certificate within 30 days of ceasing injection operations. An applicant is required to include comprehensive details such as modelling of the behaviour of the injected GHG substance, including the applicant's analysis of such modelling, as well as an evaluation of expected migration pathways and both short and long-term consequences of migration. In the Commonwealth regime, the Minister may declare a "closure assurance period" at least 15 years after the cessation of injection operations, where it is demonstrated that several criteria have been met.

Siting of projects and the Environmental Impact Assessment framework

Risk mitigation and management underpin Australia's legal framework for CCS activities. This is evidenced by comprehensive environmental protection regimes that are applicable at each stage of a CCS project, including to aspects such as approval and conducting authorised activities under a licence.

A project operator will be subject to a variety of obligations, including obtaining the necessary environmental approvals when applying for relevant permits and authorisations and complying with ongoing monitoring and reporting responsibilities. Dedicated regulatory authorities in each jurisdiction oversee and administer the environmental approvals and environmental compliance obligations of projects.

Environmental impact assessment processes across the capture, transport and storage phases

Legislation across all Australian jurisdictions mandates that activities involved in the CCS value chain, including capture, transport, and storage, must not pose a threat to the environment. The requirement for that project operators prepare environmental impact assessments is a key mechanism established by the legal framework towards ensuring this objective.

Obtaining exploration or injection permits in Queensland, for example, requires project operators to first obtain environmental authorisations under the Environmental Protection Act of 1994. In South Australia, licensees are prohibited from conducting regulated activities unless a statement of environmental objectives is in force for the relevant activities.

Siting and storage decisions also involve consideration of environmental legislation across Australia. In Victoria, compliance with environmental obligations is a pre-requisite in the issuing of licences, permits and leases for both onshore and offshore CO_2 storage activities. At the Commonwealth level, both state and Commonwealth elements to environmental assessment and approval processes apply for any matter of national environmental significance.

Stakeholder and public consultation

Public engagement requirements feature heavily across each jurisdiction in Australia and approval decisions relating to projects typically require decision-makers to consider the public interest when determining the grant of CO_2 storage permits.

In Victoria, a project operator is required to ensure ongoing engagement with stakeholders, including those with whom consultations have taken place. Victoria's onshore regime requires authority holders to consult with the local community by sharing relevant information regarding the operation of the project and providing an opportunity for community members to express their views. An applicant for a CO_2 storage licence is required to submit a community consultation plan, which must be approved by the relevant Minister and provided to the community.

In addition, some of Australia's jurisdictions, such as Queensland, have developed a public interest test, which requires decision-makers to consider wider factors such as government policy, environmental impacts, employment creation, social impacts and the overall economic benefit for the state prior to granting an authority to conduct CO_2 storage.

Under the Commonwealth regime, expansive public consultation requirements apply in the preparation of environment plans.

The regimes also build in notification requirements at various stages of the CCS process. In Queensland, the public is required to be notified when granting a GHG storage site lease, for entry and during the environmental approval process. In addition, Commonwealth and state legislation relating to Aboriginal and Torres Strait Islander land also require project operators to consult with the community in respect of various decisions relating to a project.

Liability

The closure and post-closure phases of a CCS project are well-established in Australian legislation. The project operator's roles and responsibilities during these phases are set out in detail and are broadly consistent across the jurisdictions. However, the approach towards post-closure liability varies in each state.

Table 4. Closure and post-closure regulatory considerations

Closure of CCS projects	✓	Under the Commonwealth Act, a formal procedure is established for the closure of a storage site. Upon completion of injection activities, the holder of an injection licence must apply to the Minister for a site closure certificate, in relation to the storage formation specified in the licence. Once an application is made to the Minister, they may also direct the holder of the injection licence to conduct site closure activities including the removal of all property from the relevant area, plugging or closing off all wells made in the surrender area, and the conservation and protection of the natural resources in the surrender area. Victoria and Queensland similarly impose several obligations on the project operator relating to site closure.

Risk mitigation upon closure	✓	The closure of a project entails compliance with a detailed risk assessment framework in each jurisdiction. In Queensland, the cessation of injection and decommissioning of wells does not automatically imply the end of a project operator's responsibilities under a GHG lease. Ongoing monitoring is required to mitigate risks. Queensland's regime also requires GHG lease holders to conduct an assessment of the behaviour of substances injected under the lease, expected migration pathways and short and long-term consequences of migration, when submitting an application to surrender the title. The applicant may be required to report on whether the risks of leakage and migration of injected substances have been reduced to as reasonably practicable. Notably, the Minister may refuse to approve the surrender of the licence if the Minister considers the risks to have not been reduced as much as is reasonably practicable. Under the Commonwealth OPGGSA, a similarly robust risk assessment framework applies at the stage of closure. As the state will assume monitoring after the site's closure, a project operator must submit a monitoring program to be followed by the state. Other requirements include estimating the total costs and expenses of a monitoring program post-closure and specifying the form and amount of security to be lodged as part of a site closure application. After the issue of a site closure certificate, the Commonwealth regime also requires the project operator to retain liability for the storage site and monitoring responsibilities in order to ensure that there is no significant risk of a significant adverse impact for a period of 15 years. At the end of this period, upon being satisfied that no risk is present, the Commonwealth will declare the end of the "closure assurance period".
Financial security requirements	✓	As the Commonwealth assumes the monitoring role and liability for CO_2 stored within a sub-surface geological formation after site closure, provision has been made to enable the state to recover the costs of long-term monitoring from the project operator.
Transfer of liability	✓	The approach to post-closure liability across the jurisdictions in Australia varies. Under the Commonwealth regime and Western Australia's Barrow Island Act, the state will indemnify the project operator against liability claims made after the end of the closure assurance period is declared. Post-closure transfer of liability is not explicitly addressed in Victoria and Queensland, however, in both jurisdictions such a transfer may be presumed as the injected CO_2 becomes the property of the state upon surrender of an injection licence.

2.1.3 LEGAL ISSUES FOR CONSIDERATION

Australia's legal and regulatory framework for CCS is advanced and sophisticated. CCS-specific legal and regulatory regimes at both the Commonwealth and state/territory levels address the various aspects of a CCS project throughout its lifecycle. The comprehensive and detailed nature of the regulatory frameworks, which clearly identify roles and responsibilities across each stage of a CCS project, provide greater certainty to operators and regulators alike.

However, while there are a few projects that have tested the legal and regulatory framework, uncertainty still remains about how effectively the framework will operate across the full CCS project lifecycle and adapt to practical project realities (including satisfying the relevant criteria for obtaining surface and subsurface permits, conforming to design standards, registration with regulatory authorities to obtain credits, securing CO_2 transportation pathways, and verifying long-term storage to qualify for site closure, to name a few. Furthermore, the current arrangements in Australia remain complex, as there are multiple regulatory frameworks to navigate across the Commonwealth and state and territory jurisdictions. Achieving consistency of regulatory obligations across the various jurisdictions is a key priority. For example, post-closure liability is not addressed in state legislation and where cross-border CO_2 transport to storage sites in Australian offshore or onshore territories is contemplated, state and territory legislation obligations are not clarified. A national approach to the assessment and approval of CO_2 transport is critical to provide project operators with greater certainty regarding risks, including risks relating to leakage and liability.

In relation to transboundary CO_2 export and import activities, Australia ratified the 2009 amendment to the London Protocol and has implemented its obligations through domestic legislation. Despite these developments, the wider regulatory framework generally does not provide clarity as to how CO_2 export and import activities straddling internal boundaries will be navigated.

The Institute has recommended in a submission to the Australian government's inquiry into the amendment bill introducing CO_2 export and import provisions into the Sea Dumping Act that further development and clarification of roles and obligations may be required under the Act with regard to the regulatory administration and approval of CO_2 export activities. The practical implementation of the new amendments will likely engage a wide range of potential stakeholders, including international regulatory authorities, which may lead to protracted time frames for approving CO_2 export permits. As such, the clarification of roles and obligations, including where they overlap with existing domestic legal and regulatory regimes that may be applicable to a project, is key to the effective and efficient implementation of new provisions relating to CO_2 export.

In practical terms, this will also require reviewing and improving the capacity of regulatory agencies to administer the approvals process for CO_2 export permits under the Sea Dumping Act.

A further consideration is that Australia's domestic mechanisms for reporting GHG emissions and regulatory and reporting schemes, do not clarify reporting obligations relating to transboundary CO_2 export and import activities, which the Institute identifies as a critical gap that is yet to be addressed. Surrounded by high emitters and trading partners within the APAC region, many of whom do not possess sufficient domestic geologic storage capacity, Australia is in a unique position to facilitate transboundary CCS chains between these countries. To realise the opportunities afforded, it is crucial that domestic GHG inventories and regulatory reporting schemes clarify reporting obligations to ensure that emissions reductions from transboundary CO_2 export and import operations are accurately quantified and verifiable.

These issues hold implications for CCS project operators aiming to deploy project models involving the regional transport and storage of CO_2. We recommend the following with regard to removing the regulatory barriers identified:

I. A harmonised and national approach to the regulation of CCS is a key priority for Australia if the nation is to act as a regional transport and storage hub. To this end, states and territories could consider mirroring Commonwealth legislation to provide consistency across aspects such as post-closure liability, CO_2 transport and permitting.

II. Improving regulatory capacity to facilitate permitting projects is also key to ensuring the timely implementation of projects in line with commercial timelines and climate change mitigation targets.

III. Clarifying the project operator's and regulator's roles and responsibilities in the context of transboundary CO_2 export and import activities is essential to incentivise deployment.

IV. Australia's unique position in the APAC region can facilitate transboundary CCS chains, but reporting must be clarified for accurate quantification of emissions reductions.

2.2 Brunei

Brunei's national GHG emissions are dominated by emissions arising from the energy sector, with the country relying almost exclusively on oil and natural gas. The government is cognisant of the role of fossil fuels in both domestic power generation and the export industry sector and is seeking to address their impacts.

While there isn't a recent readily available national energy forecast for Brunei, the US EIA's International Energy Outlook 2023 has estimated the energy use of the Asia Pacific region outside of Japan, South Korea, Australia, New Zealand, China, and India to be 70.8 EJ in 2040 and growing to 83.2 EJ in 2050 (US Energy Information Administration, 2023).

Brunei submitted its third NDC under the Paris Agreement in 2025, committing to achieve a 20% reduction in GHG emissions by 2035 in comparison to the business-as-usual scenario. Brunei in its NDC said it aims to adopt a multi-sectoral climate change mitigation strategy in order to deliver its climate-related ambitions (Brunei Climate Change Office, 2025).

2.2.1 CCS-RELATED POLICY LANDSCAPE

The government has not referenced the nation's need for CCS or the potential to deploy it in any of its recent climate change or energy policies. However, in 2020, the Brunei government announced it was investigating the role for CCUS in addressing the country's industrial emissions. An MoU was also signed between Shell Eastern Petroleum and Brunei Shell Petroleum to explore CO_2 transport and storage options in Brunei and Singapore (Shell Singapore, n.d.). However, the government has not announced any further policy commitments or mechanisms to support projects.

2.2.2 ASSESSMENT OF LEGAL AND REGULATORY FRAMEWORK

Brunei does not have a CCS-specific legal and regulatory framework. A basis for conducting CO_2 storage activities may, however, be found in aspects of the existing legal regime. Provisions governing environmental impact assessments, as well as those regulating exploration and injection, and monitoring of oil and gas operations, may be applicable to CCS activities. The following sections examines current legal and regulatory frameworks in Brunei, with a view to determining whether CCS operations may be adequately incorporated within their scope.

Existing approval process for applying for and obtaining regulatory approval for CCS projects

Brunei does not possess a dedicated regulatory framework for CCS operations and there are presently no specific government agencies or bodies dedicated to overseeing or permitting CCS projects. In the absence of a CCS-specific framework, project proponents would be required to navigate existing regulatory frameworks, primarily those related to the oil and gas sector, and interact with the regulatory agencies that administer and regulate this sector. The principal regulatory authority for the sector is the Petroleum Authority.

Under the current framework, project operators in the oil and gas sector are required to obtain a petroleum mining agreement and licences. Approval is also required under the Petroleum Pipelines Act 1984 in respect to the construction of any pipelines or associated infrastructure.

Despite the absence of legislation, Brunei is showing interest in CCUS implementation, and Brunei Shell Petroleum (BSP), in which the government holds a 50% stake, is researching CCS feasibility in the country, indicating a growing focus on CCS initiatives. The current framework is likely to be extended to CCS projects, however, it is not adequate for regulating a full-scale project.

Comprehensive application of the legal framework across all aspects of a CCS project

Currently there is no dedicated legal framework that regulates CCS projects in a fully- integrated manner or across the various stages of the CCS project lifecycle. Table 5 provides a brief overview of the current regulatory landscape and the extent to which it addresses key elements of the CCS project life cycle.

Table 5. Key considerations in Brunei's CCS legal and regulatory framework

Classification of CO_2	✓	CO_2 has not been defined or classified in the context of CCS projects in Brunei. However, depending on the volume emitted, CO_2 could be classified as a "hazardous substance" under the Environmental Protection and Management Order (EPMO) or a "harmful substance" under the Prevention of Pollution of the Sea Order (POPSO). Discharging CO_2 without relevant approvals and licences may lead to legal liability.
Ownership regime for sub-surface	✗	Sub-surface ownership issues in the context of CCS projects are not clarified. Ownership of extracted petroleum is typically vested in the holder of the mineral rights under the Petroleum Mining Act.
Design standards for CCS projects	✗	Although there are no CCS-specific design standards, CCS projects may be subject to various environmental requirements under an EPMO, including environmental impact assessments, design standards, pollution control, and insurance against liabilities. Compliance with these standards is essential.
Transboundary movement of CO_2	✗	Brunei has not ratified the London Protocol and there are no specific measures in place to regulate the transboundary movement of CO_2. Compliance with the London Protocol would be required if importing CO_2 for sub-seabed sequestration from a country that is a Party to the Protocol.
Surface access and reclamation	✗	There is no CCS regime for surface access and reclamation in existing legislation.
Leakage provisions	✗	As there are currently no specific laws in place for CCS projects, the general obligations and liabilities under existing petroleum, pipeline and environmental legislation could apply with respect to leakage or contamination. For instance, causing pollution or damage to the environment is an offence under the EPMO.

Transport of CO_2	⊗	There is no regulation for CO_2 transportation in Brunei. Existing petroleum and pipeline laws may be extended to cover CO_2 transportation, but this remains uncertain.
Monitoring and verification requirements	⊗	CCS projects are not subject to special monitoring and verification requirements. Instead, the general environmental legal and regulatory framework applies, necessitating the preparation of an Environmental Management and Monitoring Plan.
Storage and siting	⊗	No specific laws or permit regime govern the storage siting of CO_2 or establish a clear closure regime for CCS projects. However, an Environmental Impact Assessment could be required that could consider the suitability of the site.
Closure	⊗	As there is no specific CCS legislation, there is no clear closure or post-closure regime in place for CCS projects.

Siting of projects and the Environmental Impact Assessment framework

Brunei's environmental protection legal regime under the Environmental Protection and Management Order (EPMO) 2015 establishes EIAs for activities that may pose a significant environmental impact. It is likely, therefore, that CCS projects in Brunei may also be required to obtain an EIA in order to proceed. General requirements imposed on a scheduled activity under the EPMO include appropriate mitigation and monitoring measures pursuant to an environmental management and monitoring plan to ensure environmental protection and hazard prevention.

The EPMO provides discretion to local authorities to authorise activities that may potentially impact the environment. State agencies also have broad powers of inspection, entry search and seizure, and to take samples. These requirements may be imposed on CCS projects in Brunei.

Stakeholder and public consultation

There are no public consultation and participation requirements in the context of CCS projects in Brunei. However, the Petroleum Pipelines Act requires the Minister to provide notice to landowners that a pipeline may be laid through their land, and the project proponent must also provide notice to impacted owners. It is unclear if such requirements may be extended to CCS projects.

Liability

While there are no specific regulations addressing the closure of CCS projects, it's likely that general environmental laws would apply, and specific requirements for decommissioning or dismantling could be imposed as part of approvals under the EPMO. Furthermore, the absence of CCS-specific laws means that there is no dedicated risk assessment framework for liability.

Post-closure liability for CCS project operators is not explicitly covered, but existing pipeline and environmental laws could impose liabilities, such as compensation for pipeline damage or remedial orders for environmental incidents like leakage. Under the latter, proponents may be required to take all reasonable measures to prevent further pollution or damage to the environment in the event of an environmental incident.

2.2.3 LEGAL ISSUES FOR CONSIDERATION

Brunei's existing regime, while potentially able to facilitate a CCS project, contains several noteworthy regulatory gaps relating to certain key stages of the project lifecycle and aspects unique to emerging project models. These include provisions relating to liability and closure, the transboundary movement and classification of CO_2, ownership of CO_2 and storage and siting.

The lack of a clear and efficient administrative process for obtaining regulatory approvals for CCS projects and administrative architecture for implementing and overseeing key regulatory aspects of CCS projects are further deterrent for projects, causing significant uncertainty. With initiatives underway to investigate the role of CCS in addressing Brunei's industrial emissions, establishing a regulatory pathway to facilitate CCS projects will be a key priority for Brunei.

In particular, Brunei has opportunities to provide CO_2 storage as a service to neighbouring countries and develop cross-border CCS agreements; providing regulatory clarity on aspects such as CO_2 stream criteria, liability management in the context of cross-border projects and permitting arrangements between countries can attract international trade in CO_2 storage for the nation.

2.3 Indonesia

There have been significant developments in Indonesia's commitments, both internationally and domestically, to combat climate change in recent years, with the establishment of strengthened emissions reduction targets accompanied by policy packages to facilitate energy transition.

Indonesia submitted an updated Nationally Determined Contribution (NDC) in 2022 committing to reducing GHG emissions by 32% relative to the business-as-usual scenario by 2030. The NDC also states that a conditional reduction of 43%, may be pursued, conditional upon Indonesia receiving climate finance and support from developed nations in technology transfers and capacity building. Indonesia has also committed to achieving net zero emissions by 2060 or earlier (Government of Indonesia, 2022). In 2025, Indonesia submitted its second NDC that posits that emissions are expected to peak in 2030 and establishes a new 2030 target of between 1.35 and 1.49 $GtCO_2e$, a reduction of approximately 8–17.5% compared with the emissions level committed to under the previous NDC. Emissions are then expected to begin declining by 2035, reaching between 1.26 and 1.49 $GtCO_2e$ (Government of Indonesia, 2025).

Among the avenues Indonesia is exploring to achieve its climate targets, CCS is set to play a pivotal role within Indonesia's decarbonisation strategy for the energy and industrial sectors. The Indonesian government has previously promoted the conclusions of various studies that highlight the significant potential that CCS may play in reducing emissions from Indonesia's fossil fuel–intensive power generation mix and increasing energy consumption. Several of the government's more recent climate change and energy-related policies and announcements have explicitly acknowledged the critical role of the technology in facilitating Indonesia's energy transition.

2.3.1 CCS-RELATED POLICY LANDSCAPE

The Energy Sector Roadmap to Net Zero Emissions in Indonesia, developed by the Ministry of Energy and Mineral Resources (MEMR) in partnership with the International Energy Agency, identifies CCUS as a key technology for managing emissions associated with industry, electricity generation and fuel consumption. The Roadmap aims for the capture of 6 Mtpa of CO_2 onwards from 2030, with the ultimate goal of 190 Mtpa of CO_2 in 2060 (International Energy Agency, 2022).

In addition, the MEMR is targeting the establishment of 16 CCS/CCUS projects to be operational by 2030 (Ministry of Energy and Mineral Resources of Indonesia, 2024). These developments should be considered within the wider context of the Indonesian government's commitment to phase out coal-fired power generation, indicating the major role CCS technologies is expected to play in decarbonising the sector.

Presidential Regulations

In recent years, Indonesia has established a plethora of regulations that establish a supportive policy framework for CCS in the country. These regulations provide various incentives and support for conducting CCS operations ranging from legal and regulatory frameworks to authorise CCS operations, carbon pricing and national policy strategies that recognise CCS as a critical decarbonisation tool. The following section provides a thematic review of the various regulations established by the government to support CCS. It should be noted that the discussion below highlights the regulations establishing the legal and regulatory framework for CCS as one of the policy tools used by the government to support CCS deployment. However, a more detailed examination of these frameworks is provided in section 2.3.2.

Regulations establishing legal and regulatory frameworks to authorise CCS

In 2023 and 2024, Indonesia established a comprehensive regulatory framework comprising a suite of regulations that build on its oil and gas permitting regimes to facilitate CCS. The first of these regulations was developed by the MEMR; MEMR 2/2023 has synergies with CCS (see discussion of the framework in detail in section 2.3.2 below).

Subsequently, Presidential Regulation No. 14 of 2024 was enacted, covering the implementation of domestic CCS activities and supporting the government's ambition to achieve its net zero targets. Indonesia has the capacity for substantial CO_2 storage, and this regulation recognises that CCS technology will play an important role in reducing emissions. The regulation could support Indonesia in establishing carbon capture hubs, both domestic and international, with emphasis on the region. The regulation discusses the following provisions:

- Cooperation contract: CCS activities under a cooperation contract would fall under what would typically be classified as upstream oil and gas operations. Cooperation contracts will include provisions that can be included in production sharing contracts (PSCs). They are designed to be used within Indonesian mining working areas. A contractor using a cooperation contract will store CO_2 in depleted reservoirs or in saline aquifers. The contractor will have to get approval to implement CCS and a certification that validates carbon storage capacity. Further regulations from the MEMR may apply. After approvals have been granted by the MEMR, CCS can be included in the PSC.
- CCS with an exploration licence and storage operations licence: The MEMR will designate carbon storage areas and open tendering for the same. CCS activities will require three licences; exploration, storage, and carbon transportation. Only business entities that are established and conducting business-related activities within Indonesia will be eligible.
- The law also covers other topical areas of relevance to CCS, namely:
    - CCS operations,
    - Site closure,
    - Measurement, reporting, and verification,
    - Emergency response,
    - Safety and environmental concerns,
    - Cross-border transportation,
    - Taxation status of revenues from storage fees.

The most notable aspect of Indonesia's regime is the clear provision that allows CCS operation costs to be recoverable under the existing upstream Production Sharing Contract (PSC) framework.

A new addition to the regulatory package was introduced in late 2024: Regulation No. 16 of 2024 on the Organisation of Carbon Storage in Carbon Storage Permit Areas (Regulation 16 of 2024). Regulation No. 16 of 2024 provides further detail on the process established under Presidential Regulation No. 14 of 2024, released earlier in 2024, for conducting CCS activities in Carbon Storage Permit Areas (WIPK). The new regulation covers aspects such as the allocation of WIPKs, grant of relevant permits, management of CCS-related assets, carbon storage business activities, fees and royalties and closure of CO_2 storage activities. The new regulation complements the requirements established by the earlier CCS-specific regulations, PR 14 of 2024 and MEMR 2/2023.

Regulations establishing carbon pricing
Indonesia earlier passed Presidential Regulations (PRs) in 2020 and 2021. Presidential Regulation No. 98 of 2021 is about implementing carbon pricing as a tool to achieve the country's NDC targets. The document defines climate change mitigation as efforts to reduce GHG emissions while increasing carbon sequestration. GHGs include carbon. Sequestration is defined as "absorption of GHG from the atmosphere, naturally or through... technology".

In December 2025, Regulation No. 98 of 2021 was repealed and replaced by Presidential Regulation No. 110 of 2025 on the Implementation of Carbon Economic Value Instruments and National Greenhouse Gas Emissions Control. The new regulation made several changes to its predecessor through measures such as the introduction of carbon allocations for NDC planning and target setting, detailed rules for certification and use of carbon units, introduction of a carbon unit registry system, the introduction of tradeable GHG Emissions Quotas which enable covered installations to meet compliance obligations and the expansion of the suite of "carbon economic value" instruments to include carbon trading, result-based payments and carbon taxes and levies. Key for CCS, however, is the new regulation's expansion of the sectors covered by Indonesia's national GHG accounts, to include the oil and gas sub-sector. This may lead to further reporting requirements for the sector and quota-based emissions obligations, providing opportunities for the recognition of CCS as a potential emissions compliance pathway within the national system.

Regulations establishing national policy strategies that reference CCS
Presidential Regulation No. 18 of 2020 is a broad document covering the country's vision, macroeconomic framework, infrastructure development, and resilience amongst several other topical areas (Cabinet Secretariat of the Republic of Indonesia, 2020). The National Medium Term Development Plan for 2020-2024 (PR No. 18 of 2020) is a national legal and policy document. It lays out Indonesia's policy direction and strategies and provides sectoral guidance on policy measures for energy, water security, maritime, and food security, to name a few. While the document does not list CCS for GHG emissions reduction, it discusses carbon sequestration as a mitigative strategy for the forestry sector through afforestation and reforestation. There could be scope to include CCS under the policy measures for resilience and low-carbon development to support GHG emissions reductions.

2.3.2 ASSESSMENT OF LEGAL AND REGULATORY FRAMEWORK

Regimes applicable to CCS
Over the course of 2023 and 2024, Indonesia set up a comprehensive regulatory framework comprising a suite of regulations that build on its oil and gas permitting regimes to facilitate CCS. The establishment of four regulations in two years signals Indonesia's commitment to advancing CCS. The four main regimes applicable to CCS in Indonesia, their scopes and the distinction between them are presented in Table 6. Their respective scopes are examined in further detail in the following sections, followed by an assessment (against the Institute's assessment model) of their coverage and comprehensiveness across key stages of the CCS project lifecycle.

Table 6. The four main regimes applicable to CCS and CCUS operations in Indonesia

Regulation	Issued Year	Scope
Regulation No. 2 of 2023 on the Organisation of Carbon Capture and Storage (CCS) and Carbon Capture, Utilisation and Storage (CCUS) for Upstream Oil-and-Gas Business Activities (MEMR 2/2023)	March 2023	Regulates the deployment of CCS and CCUS in upstream oil and gas activities.
Presidential Regulation No 14/2024 concerning the Implementation of Carbon Capture and Storage Activities.	January 2024	Expands regulatory framework beyond upstream oil and gas operations to include dedicated carbon storage licence areas.
MEMR Regulation No. 16 of 2024 on the Organisation of Carbon Storage in Carbon Storage Permit Areas	December 2024	Governs CCS activities in designated carbon storage licence areas and the issuance and administration of carbon storage licences.
PTK 070	January 2024	Implementing guideline of CCS and CCUS operations in the upstream oil and gas sector.

MEMR Regulation No. 2 of 2023

MEMR Regulation No. 2 of 2023 on the Organisation of Carbon Capture and Storage (CCS) and Carbon Capture, Utilisation and Storage (CCUS) for Upstream Oil-and-Gas Business Activities (MEMR 2/2023) is part of a suite of regulations introduced by the government to facilitate the country's energy transition and fulfill its climate change mitigation targets.

The new regulatory framework under MEMR 2/2023 builds on the existing legislative regime applicable to oil and gas exploration and production operations and provides a comprehensive framework for CCS and CCUS projects, including project operator and regulator roles and responsibilities, approval requirements, and monitoring and reporting obligations. In its current format, the Regulation addresses various aspects that relate to the implementation of CCS and CCUS in relation to oil-and-gas business activities.

The scope of MEMR 2/2023 comprises:

- Authorisation process for conducting CCS and CCUS activities in oil and gas areas,
- Monitoring and Measurement, Reporting and Verification (monitoring and MRV),
- Economic aspects and assets,
- Emergency response systems,
- Guidance and supervision,
- Administrative sanctions.

PR 14/2024

In January 2024, to complement the regulatory framework established under MEMR 2/2023, the Indonesian government introduced a broader overarching regulatory framework for regulating CCS activities in the country. PR 14/2024 outlines how CCS activities are to be implemented pursuant to MEMR

2/2023 and establishes a new licensing framework for authorising CCS activities outside the scope of the upstream oil and gas sector (Presidential Regulation (PERPRES) Number 14 of 2024: Implementation of Carbon Capture and Storage Activities, 2024).

The regulation, comprising 77 articles, is broad in nature and covers aspects such as:

- The implementation of CCS activities pursuant to cooperation contracts,
- Carbon storage permits and the process for awarding such permits,
- CO_2 exploration, storage and transport,
- Closure of CCS activities,
- CO_2 storage capacity for domestic needs,
- Ownership of CCS assets,
- Cross-border CO_2 transport,
- Environmental and safety requirements,
- Incentives for CCS activities,
- Business models for CCS.

PTK 070

PTK-070 outlines the implementation of CCS and CCUS activities by oil and gas contractors, offering guidelines for each stage of their operations. This technical regulation, issued by SKK Migas11F[2], is applicable to upstream oil and gas contractors engaged in CCS/CCUS activities within their Work Area Click or tap here to enter text.(Implementation of CCS and CCUS in Oil & Gas Work Areas (PTK-070), 2024).

MEMR Regulation 16 of 2024

To complement the frameworks introduced by MEMR 2 of 23, PR 14 of 2024 and PTK 070, the government introduced MEMR 16 of 2024, providing for a pathway to conduct CCS activities in areas designated as WIPKs (Ministry of Energy and Mineral Resources, 2024). These areas enable a broader range of parties, beyond Contractors conducting CCS in Oil and Gas Work Areas on the basis of production-sharing contracts, to conduct CCS activities through Exploration and Storage Operation Permits. The latest regulation elaborates on the process and procedure for designating WIPKs, obtaining permits, conducting CO_2 storage operations pursuant to the relevant authorisation and closure of sites.

Existing approval process for applying for and obtaining regulatory approval for CCS projects.

The approvals process for CCS activities in Indonesia require interactions with several regulatory authorities responsible for administering and overseeing various aspects of the CCS project lifecycle, from the CO_2 emissions captured through to its transport, utilisation and storage. The following table provides a brief overview of the regulatory agencies involved and their functions and responsibilities in the course of approving and overseeing CCS and CCUS operations under MEMR 2/2023, PR 14/2024 and PTK 070.

Table 7 provides a brief overview of the current regulatory landscape and the extent to which it addresses key elements of the CCS project life cycle.

2 SKK Migas is a 'Special Task Force for Upstream Oil and Gas Business Activities', an institution established by the Government of Indonesia under Presidential Regulation No. 9 of 2013.

Table 7. Indonesian competent authorities and role in CCS activities

	Function	Role
Ministry of Energy and Mineral Resources (MEMR)	Approval and Oversight	• Approves the work plan proposed by oil and gas contractors for CCS and CCUS activities, • Designates and offers Carbon Storage Permit areas for business entities/permanent establishments, • Issues Exploration and Storage Operation permits.
Ministry of Environment and Forestry	Approval and Oversight	• Oversees the environmental assessment and approval aspects of proposed CCS and CCUS projects
The Special Task Force for Upstream Oil and Gas (SKK Migas)	Management	• Responsible for the management of upstream oil and gas business activities under the guidance, coordination and supervision of MEMR. Responsibilities include: • Handling reports on the implementation of CCS/CCUS from oil and gas contractors to be submitted to MEMR, • Supervising and evaluating the implementation of CCUS activities.
Aceh Oil and Gas Management Authority (BPMA)	Management	• A government agency with joint management and control responsibilities in relation to upstream business activities in the oil and gas sector located onshore and offshore in the Aceh authority area.

Through the enactment of MEMR 2/2023 and PR 14 of 2024, Indonesia has established two discrete pathways to authorise CCS activities in the country. Under MEMR 2 of 2023, a production sharing contract scheme authorises CCS activities in designated oil and gas working areas by business entities or permanent establishments (defined as Contractors). Under PR 14 of 2024, an alternate licensing pathway is established; CCS activities may also be conducted in designated "Carbon Storage Permit Areas" by a wider range of parties on the basis of two distinct permits – exploration permits and storage operation permits. These two pathways are explored in greater detail below.

Authorisation of CO_2 storage site exploration and injection activities pursuant to Cooperation Contracts

A Contractor is authorised to conduct exploration and exploitation activities pursuant to a Cooperation Contract, which is a form of production-sharing agreement involving both state and private parties and that is beneficial to the Indonesian government. The Contract must be obtained from the MEMR. The state parties that are involved in a Cooperation Contract are SKK Migas and BPMA.

A Contractor is also able to enter into a cooperation contract with a third party in order to carry out CCS activities within a designated working area, subject to approval from SKK Migas and BPMA.

Under a Cooperation Contract, Contractors must propose a plan detailing how CCS and CCUS activities will be carried out within the designated working area (covered by a field development plan). The plan should include an assessment of the technical, economic, operational, safety and environmental and closure aspects of the proposed CCS or CCUS project.

An approved proposal (containing the assessment of the technical aspects of the CCS project) will lead to an amendment to the Cooperation Contract. Contractors through SKK Migas and BPMA may submit the proposal for approval to the MEMR. If approved, the Cooperation Contract or field development plan covering the designated working area for the CCS or CCUS project will be amended to allow CCS activities pursuant to the approved proposal.

The MEMR Regulation 2/2023 establishes clearly defined responsibilities for the project operator and regulators at each stage of the CCS project lifecycle.

Project operator responsibilities include:

- Submitting a proposal for conducting CCS and CCUS activities pursuant to a Cooperation Contract for oil and gas in a designated working area.

- Preparing a proposal and implementation plan in accordance with the requirements set out in MEMR No. 2 of 2023, which includes implementation of environmental and social impact assessments, engineering, procurement and construction processes, commissioning of CCS and CCUS operations, operation safety management, environmental management, emergency response activities, repair and maintenance, monitoring and verification and closure of a project.

- Periodically measuring, reporting and verifying GHG emissions reductions achieved as part of the CCs or CCUS project, to be submitted to the relevant regulatory authority.

MEMR 2/2023 also enables receiving and storing third party CO_2 emissions. The MEMR has the authority to supervise and oversee projects, and grant the relevant approvals to operators to conduct activities relating to a project, including approval of the project plan submitted by the operator.

PR 14/2024 establishes further regulations on the implementation of Cooperation Contracts. For example, the Cooperation contract can be negotiated as follows (Presidential Regulation (PERPRES) Number 14 of 2024: Implementation of Carbon Capture and Storage Activities, 2024):

- Production sharing contract with re-imbursement of operating costs,

- Gross-split profit-sharing contract,

- Other cooperation contracts.

Licences and Permits

Indonesia's latest PR 14/2024 lays out an alternate licensing pathway and process to award rights over CCS work areas from exploration to end-of-life. This permitting process is separate from the regime for contractors based on PSCs. The promulgation of PR 14/2024 expands the scope of industries and contexts for which CO_2 storage activities can be conducted, by granting CO_2 storage licenses outside of the oil and gas cooperation contract framework.

Storage Exploration Licence

MEMR will issue an Exploration Licence to the successful applicant of the limited selection or tender process (or its directly owned or controlled affiliate), once the application is submitted through the Online Single Submission (OSS) business licensing system and meets all required administrative, technical, environmental, and financial criteria.

This licence grants the holder the right to conduct Injection Target Zone (ITZ) exploration activities within the designated area. These activities include data collection, drilling, sub-surface studies, and mitigation of ITZ leak risks. The Exploration Licence is valid for six years and may be extended once for an additional four years.

If the licensee fails to meet the firm commitment requirements of ITZ exploration activities, the shares of the Exploration Licence holder cannot be transferred to another party. Upon fulfilling the firm commitment activities for ITZ exploration, any majority share transfer within the Exploration Licence holder requires prior approval from the MEMR. Further regulations concerning share transfer procedures for Exploration Licence holders will be clarified in upcoming MEMR regulations.

If exploration activities pursuant to an Exploration Licence leads to the discovery of commercial carbon storage capacity, holders of an exploration licence must submit a detailed working plan for ITZ exploration activities, known as the ITZ Plan for Development and Operation, which requires approval from the MEMR.

Storage Operation Permit

An Exploration Permit holder can apply for a Storage Operation Permit to conduct CO_2 injection and storage operations. Applications for Storage Operation Permits must comply with the relevant technical, financial, administrative and environmental criteria and be submitted through the OSS System. Once granted, the key obligations applicable to Storage Operation Permit holders include:

- the preparation of annual work plans outlining all operational activities planned under the permit, such as construction, drilling, injection and monitoring and budget plans for approval by the MEMR.
- Periodic and incidental monitoring and reporting obligations
- The provision of financial guarantees to demonstrate how compliance will be ensured for applicable requirements

These permits are only awarded to a single business entity or a consortium of business entities. Permanent Establishments, the other type of entity that can engage in CCS activities under a Production Sharing Contract, that hold an exploration permit cannot obtain a Storage Operation Permit and will need to establish a business entity in order to obtain this permit. Storage operation permits are granted for a period of 30 years and is non-transferable.

Transportation Permit

Enables business entities or holders of a storage operation permit to conduct CO_2 transport activities via pipelines. The permit enables the transport of CO_2 from the carbon capture facility up to the injection point. To apply for this permit, the key criteria include proof of compliance with environmental regulations, safety regulations and financial capacity. Applicants should also provide evidence of a Carbon Transportation Agreement if transporting CO_2 sourced from other entities. Permits are granted for a period of 20 years and can be extended for a further period of 10 years.

Comprehensive application of the legal framework across all aspects of a CCS project

Indonesia's MEMR 2/23, PTK 070, PR 14 of 2024 and MEMR 16 of 2024 establish a comprehensive and integrated framework addressing each stage of the CCS or CCUS project's lifecycle. Table 8 summarises these four regulations with relevance to CCS, as it relates to various aspects of the CCS project lifecycle and the extent to which wider legislation covers these aspects.

Table 8. Key considerations in Indonesia's CCS legal and regulatory framework

Classification of CO_2	✓	**MEMR 2 of 2023** CO_2 is covered under the definition of a greenhouse gas and is referred to as CO_2 captured from upstream oil and gas business activities and other industries within MEMR No. 2 of 2023. **PR 14/2024** Defines CO_2 as "carbon dioxide (CAS 124-38-9) with certain concentration specifications originating from emissions captured and processed using various technologies by observing good engineering standards and principles, originating from upstream oil and gas business activities, power generation, industry, and other emission producing activities produced domestically or abroad with the aim of being injected into an injection target zone (Presidential Regulation (PERPRES) Number 14 of 2024: Implementation of Carbon Capture and Storage Activities, 2024)
Ownership regime for sub-surface	✓	There is no uniform provision clarifying the ownership status of the pore space and sub-surface geological reservoirs in the context of CCS within Indonesia's legal framework. However, Indonesia's constitution vests ownership of the land, water and natural resources of Indonesia with the state. The use of sub-surface areas also requires authorisation from the relevant statutory authority. Furthermore, the state is the ultimate owner of minerals and coal, and land titles do not give holders of the land any rights to minerals or coal located on or under the land.
Design standards for CCS projects	✓	**PR 14/2024** Indonesia has also expressly adopted ISO27914:2017 into national standards. Presidential Regulation 14/2024 (part of the suite of geological storage regulations) references SNI ISO27914:2017 as a minimum baseline, with provisions accepting other internationally recognised standards approved by government authorities. **MEMR 2/23** Imposes various health and safety obligations on project operators, such as safety checks and monitoring requirements to prevent harm to the environment and human health, which require construction and operation of CCS projects in a specific manner to prevent harm. Further, there are general health and safety requirements relating to oil and gas business activities in Indonesia that specify certain requirements, both administrative and technical, that need to be fulfilled by legal entities to meet safety standards.

Transboundary movement of CO_2	✓	Indonesia has not ratified the London Protocol, although the country has announced its intention to participate in transboundary CO_2 storage activities involving the import of CO_2 into Indonesia. If CO_2 will be imported from a country that is a Party to the London Protocol, Indonesia would need to comply with the requirements under the London Protocol pursuant to the exporting country's obligations. **PR 14/2024** However, PR 14/2024 establishes that CO_2 can only be imported into Indonesia for storage if a bilateral agreement is in place with the exporting country. These bilateral agreements are anticipated to contain information on compliance with obligations under the London Protocol. A key feature of PR 14 of 2024 is the allocation of 30% of CO_2 storage capacity for CO_2 sourced from overseas.
Surface access and reclamation	✓	**MEMR 2/2023** Indonesia's MEMR 2/2023 only allows CCS projects to take place within designated working areas that are covered by Cooperation Contracts. Surface access in such areas has not been addressed and would likely be governed by existing licensing and permitting requirements of the Mining Law and other regulations relating to land use. How surface access is granted under these regimes varies according to the type of land in question. Forestry land and state-owned land require permits from the relevant government ministry or regulatory agency. Access to private land requires a permit from the landowner. A key feature of the Indonesian legal framework in relation to surface access is the requirement for project operators to prepare reclamation and mine closure plans. These plans must be prepared prior to commencing exploration activities and must be approved by the government after feasibility studies are completed. Reclamation plans are prepared for a period of 5 years and carried out by the company within 30 calendar years after the completion of mining activities. For oil and gas activities in particular, a Cooperation Contract is required to allocate a certain portion of funding to carry out post-operation reclamation activities. A Cooperation Contract also contains the specific obligations of a Contractor in relation to post-operation reclamation activities. In addition, SKK Migas specifies rules on abandonment and site restoration (ASR) for Cooperation Contract contractors. ASR plans must be approved by SKK Migas. Minimum requirements for post-operation activities in the upstream oil and sector include the closing of wells, dismantling of facilities and site restoration.

Leakage provisions	✓	Indonesia's framework establishes comprehensive provisions relating to the risks of CO_2 leakage as part of CO_2 storage operations. **MEMR 2/2023** The Contractor under a Cooperation Contract is responsible for CO_2 leakage and is required to conduct monitoring, establish emergency response systems and undertake repairs in the event of leakage. **General environmental law framework** Under Indonesia's environmental law framework, strict liability immediately arises where environmental pollution and/or damage result from operations that pose a significant threat to the environment or involve the use of hazardous or toxic substances. Indonesia's environmental law regime also grants rights to the Government to submit compensation claims for environmental pollution or loss caused by business activities and strict penal provisions apply where air, water, or sea quality standards are violated.
Transport of CO_2	✓	CO_2 transport is broadly defined in Indonesia as the transportation of CO_2 via pipelines, trucks, shipping or other methods developed through scientific and technological advancements. **PR 14 of 2024** PR 14/2024 recognises CO_2 transport as part of CCS operations that may be conducted by both Cooperation Contract holders and Carbon Storage Licence holders. Significantly, the regulation also recognises CO_2 transport as a business that may be conducted by third party business entities. PR 14/2024 establishes a separate CO_2 transport licence that business entities or Carbon Storage Operation Permit must obtain from the Ministry of Energy and Mineral Resources and the Ministry of Transport to conduct CO_2 transport operations. Cooperation Contractors are not required to obtain a separate CO_2 transport licence when transporting CO_2 within or between designated working areas if it is conducted pursuant to CCS activities authorised by the Cooperation Contract. Carbon transport permits are granted for CO_2 transport by pipeline (above ground and underwater) and trucks, ships and/or other permits. The granting process and authority differs between the modes of transport. CO_2 transport permits are granted for up to 20 years (except for transport by trucks/ships or other methods) and can be extended for a maximum of 10 years per extension.

Monitoring and verification requirements	✓	**MEMR 2/2023** MEMR 2/2023 establishes comprehensive monitoring and verification requirements for CCS and CCUS projects across their lifecycles. For example, operators are required to prepare a monitoring, verification and reporting plan at the pre-implementation phase of the project, covering all stages of the project, from planning through to post-closure. There are requirements in relation to measuring, reporting and verifying the emissions reduction contributions of projects and utilisation of the economic value of the carbon. Post-closure monitoring requirements are imposed on the project operator, involving conducting monitoring activities 10 years after the cessation of injection operations or until the results of monitoring activities demonstrate that CO_2 has been permanently stored with no leakage detected. The results of monitoring activities must also be reported to the Directorate General and SKK Migas or BPMA every 6 months. **PTK-070** PTK-070 issued by SKK Migas requires monitoring and MRV to be carried out at every stage of the CCS process, from capture through to transport and storage, to ensure the safe and permanent storage of CO_2. Cooperation Contractors are required to report their GHG reduction activities to SRN PPI, a web-based data and information management system, to record data from climate-change related mitigation, adaptation and carbon credit generating activities. Contractors are also required to set aside the costs of monitoring activities for a period of 10 years after site closure.
Storage and siting	✓	**MEMR 2/2023** MEMR 2/2023 establishes a host of geological and technical requirements relating to the storage and siting of projects within the areas designated for conducting CCS and CCUS projects. Specific requirements include mandating that CO_2 is injected into “Injection Target Zones”, in accordance with good engineering rules, and that CO_2 is to be stored in Injection Target Zones that contain an impermeable layer as a cover. Injection Target Zones include hydrocarbon reservoirs, saline aquifers and coal layers for coal bed methane activities. **PR 14/2024** PR 14/2024 defines injection target zones as a rock system in a geological formation consisting of storage zone layers, buffer zone layers, impermeable zone layers and geological traps that are able to accommodate injected CO_2, safely and permanently while meeting environmental safety standards. As Indonesia is not a party to the London Protocol, compliance with the specific requirements under the Protocol for ensuring the environmentally safe geological storage of CO_2 is not required.

Closure	✓	**MEMR 2/2023** A comprehensive closure regime is in place for CCS and CCUS projects under MEMR 2/2023, which establishes the conditions that effect the closure of a project. Closure is effected when the capacity of the storage reservoir is full, captured CO_2 sources are not available, the Cooperation Contact has expired, the safety and integrity requirements of CO_2 storage operations have been fulfilled or in the event of any extraordinary circumstances causing the closure of projects. A Contractor is required to submit a closure plan for approval to SKK Migas and the Director General of Oil and Gas. Closure plans must include plans to prevent damage to the environment, human health, resources and the assets of the state. Closure activities must be verified by the Director General of Oil and Gas or an independently appointed verifier, and must satisfy good technical standards or principles. Verification procedures are required to be issued by the Director General of Oil and Gas.

Closure	✓	**PR 14/2024** PR 14/2024 also establishes site closure requirements. Conditions for closure of a CCS/CCUS facility include a lack of carbon emissions for injection, the expiration of the contract without renewal, unsafe conditions, the injection zone reaching its capacity, or force majeure. The closure plan is required to include: • Details regarding the reservoir, equipment, installations, facilities, and the well used for CCS/CCUS closure, • Total carbon emission reductions achieved, • Estimated costs, • Closure timeline, • A mitigation plan addressing potential environmental damage, risks to human safety, resource damage, and harm to equipment, installations, and facilities. PR14/2024 provide that upon closure approval, the contractor's rights, obligations, and responsibilities are ended. The Minister will be responsible for supervising the storage site henceforth. **MEMR 16/2024** The new MEMR 16/2024 also establishes a range of closure obligations applicable to Carbon Storage Permit holders, complementing the requirements established under its earlier counterpart, PR 14 of 2024. The latest regulation stipulates that carbon storage operations can be closed when storage capacity has been exhausted, no more CO_2 is to be injected or unsafe conditions arise. As stipulated by PR 14/2024, a closure plan is required of a Storage Operations Permit holder, outlining timeline, process, costs, monitoring and risk mitigation measures. The closure plan must be approved by the MEMR and an independent verification authority. Once closure has been approved, a further 10-year period of monitoring is stipulated to assess risks such as leakage and contamination. A post-closure stewardship fund has also been established which will cover the costs of closure and post-closure monitoring. After the completion of the post-closure monitoring phase, responsibility for the WIPK area covered by the Carbon Storage Permit is transferred to the state. **Wider legal regimes** General requirements that apply to all oil and gas and mining closure activities under existing mining and energy legislation are also likely to apply to CCS and CCUS projects. These include requirements to submit reclamation plans (in the case of mine closure), provide reclamation guarantees to the government and compliance with the conditions within Cooperation Contracts for post-operation activities (in the case of oil and gas operations).

Siting of projects and the Environmental Impact Assessment framework

The new legal regime for CCS and CCUS projects established by MEMR 2/2023 requires projects to draft "mitigation and management of environmental, social and public involvement impacts in accordance with the existing laws and regulations", which will likely bring CCS and CCUS projects under the scope of Indonesia's AMDAL process. The AMDAL process is Indonesia's own system for conducting environmental impact assessments which involves several elements, consisting of a Terms of Reference, an Environmental Impact Analysis Report, an Environmental Management Plan and an Environmental Monitoring Plan.

AMDAL is an abbreviation in Bahasa which translates to *Environmental Impact Assessment*. Alongside AMDAL, two other Bahasa abbreviations of interest are UPL-UKL and SPPL. UPL-UKL abbreviates *Environmental Management Efforts and Environmental Monitoring Effort, and SPPL abbreviates Statement of Environmental Management and Monitoring Ability* from the Bahasa equivalent, respectively. These three regulatory regimes are responsible for ensuring that projects in Indonesia meet their environmental obligations. In April 2021, Indonesia's federal Minister of Environment and Forestry (MOEF) issued Regulation No. 4 of 2021 on the list of business and/or activities required to have environmental impact analysis, environmental management efforts, and environmental monitoring effort or statement of environmental management and monitoring ability (Arma Law, 2021). Businesses ad activities that are required to have AMDAL, UPL-UKL, or SPPL are classified and included in Appendix I of the MOEF Regulation 4/2021. Projects that have a significant impact on the environment are required to have AMDAL.

The Minister of Environment decides which business or activity requires an AMDAL based on the scope of work involved, the proximity of the development to protected zones, and their potential impact on the environment. The types of businesses and activities that are required to obtain an AMDAL are set out under regulations established by the Ministry for Environment. While CCS and CCUS projects are not explicitly mentioned within these regulations, activities that produce hazardous and toxic waste are included, which could cover CCS and CCUS projects.

In relation to site characterisation and CO_2 storage site exploration activities, it is a key requirement under MEMR 2/2023 that Cooperation Contract contractors submit a plan that details the implementation of a CCS project which includes at least technical, economic, operational, safety and environmental aspects of the project. Among these, there are specific requirements to submit an assessment on the geology, geophysics and reservoirs, and the engineering, safety, environment, evaluation and risk mitigation aspects of transport, storage and injection operations. The project operator's satisfaction of these aspects must comply with specified standards and technical rules under MEMR 2/2023, in order for the implementation plan to be approved.

MEMR 2/2023 allocates various responsibilities to the project operator in relation to risk mitigation and management, including the preparation of implementation plans, reporting requirements and monitoring plans that guarantee the safety of workers, installations, equipment and the environment. Operators are also obliged to reserve costs for monitoring activities for the mandatory 10-year monitoring period after the closure of a project. In addition, significant discretion is awarded to SKK Migas and BPMA to approve or reject proposals for projects under MEMR 2/2023, while the Minister for Environment determines whether projects will need to apply for an AMDAL and how the set criteria apply. Risk management of environmental effects is thus built into the legal framework for CCS projects in Indonesia.

PR 14/24 also stipulates that to obtain approval for commercial injection operations in an identified Injection Target Zone (ZTI), a Plan of Development and Operation is to be submitted by exploration permit holders to MEMR. The plan is required to contain details on the geology, geophysics, petrophysics, reservoir engineering, geomechanics, geochemistry, hydrogeology relating to the ZTI, as well as details of processing, transportation, injection, and storage operations, economics, safety and environment, risk evaluation and mitigation, closure, monitoring and MRV.

In addition, PR 14/24 elaborates that the study conducted for the ZTI Development and Operation Plan must contain details such as the depth and thickness of the ZTI, the hydraulic conductivity of ZTI, ZTI integrity, including maximum injection pressure within wells not exceeding fracture pressure limits, and geomechanics and geochemistry studies of the rock.

Stakeholder and Public Consultation

There are no public consultation requirements for CCS and CCUS projects under Indonesia's CCS legislation. However, activities and businesses that undertake the AMDAL process are required to involve the public, which has been defined to include a broad range of stakeholders that may be impacted by the proposed activities. Public involvement is implemented through a consultation process whereby stakeholders can submit opinions, suggestions and responses to the business plan relevant to the proposed activities. In addition, other general public notification obligations under Indonesia's wider legislation may also be applicable to CCS projects.

Liability

The project operator's responsibilities under the closure phase of a project are also detailed under MEMR 2/2023, which establishes a comprehensive framework aimed at risk management and mitigation during this phase. As discussed previously, responsibilities of the project operator during the closure phase of a CCS project include the preparation of a monitoring and MRV plan during the initial stages of the project in relation to the closure phase and conducting monitoring activities after the closure of a project. Further, the project operator must develop emergency response systems to detect leakage, which includes risk assessments to identify the risks that can arise from the failure of the injection and storage activities, and how the risks will be mitigated.

The preparation of reclamation plans in relation to mining activities is another example of project operator obligations that may be applicable to CCS projects under Indonesia's wider mining legislation. In the context of oil and gas activities, project operators are also required to allocate a certain portion of funds to conduct post-operation activities, as regulated in the relevant Cooperation Contract.

After the closure of the storage site, and until the relevant responsibilities are transferred, the operator remains liable for any leakage at the site while also being responsible for conducting post-closure monitoring and reporting activities.

Under Indonesia's environmental legislation, strict liability ensues where a party's operations pose significant risks to the environment. Environmental laws also impose obligations on project operators to ensure that air, water and sea quality standards are not violated. Waste management laws also govern the storage and disposal of hazardous and toxic wastes, and a project operator's non-compliance with these frameworks will incur liability.

MEMR 2/2023 permits Contractors to benefit from the carbon economic value generated by CCS activities. To do so, they must obtain approval from either SKK Migas or BPMA. Key requirements that must be complied with in order to avail of the carbon economic value include:

- Preparation of a measurement program annually that outlines the carbon emission inventory and project operator parameters,
- Utilising a measurement method, which can be either direct or indirect.

MEMR 2/2023 also indicates that the monetisation of CCS or CCUS involves at least one carbon trading activity in accordance with relevant laws and regulations. It also involves reimbursement of certain operational expenses.

Upon satisfactory completion of a Contractor's obligations during the operational phase, and the fulfilment of the specified conditions, a Contractor's rights and responsibilities under a Cooperation Contract for a CCS or CCUS project may be transferred to the state. The conditions that are to be met by the Contractor include the receipt of verification results from the Director General of Oil and Gas for the completion of CCS closure activities, monitoring results demonstrate there is no leakage, ground water contamination or other risks caused by CO_2 injection activities, and that the Cooperation Contract period has ended. Following approval from the MEMR provided in consultation with SKK Migas and BPMA, the contractor's rights and obligations for CCS or CCUS implementation in the working area will cease. Responsibilities over the CO_2 storage site in relation to site care and supervision will then transfer to the state.

Similarly, PR 14/24 establishes that the responsibilities for a depleted storage reservoir where CCS activities were conducted by a Contractor or Storage Operator are transferred to the state upon fulfilling the conditions of closure of a CO_2 storage site.

2.3.3 LEGAL ISSUES FOR CONSIDERATION

Indonesia has emerged as a leader in the South-East Asian region in the development of legislation to support CCS projects. MEMR 2/2023, PR 14 and PR 16 of 2024 establish a comprehensive and integrated legal framework that addresses aspects such as the classification of CO_2, design standards for projects, monitoring and reporting obligations, storage and siting, financial security requirements and the closure and post-closure stages of a project. As part of this regulatory framework, operators will be required, during the application stage, to prepare detailed proposal and implementation plans for the operation and monitoring of projects.

Gaps in the domestic legal framework remain, however, and further legislation will be necessary. A wider body of environmental and health and safety legislation is likely to be applicable to CCS operations; however, requirements under these existing regimes are not set out in an integrated manner. Indonesia has also announced its intention to import CO_2 for storage within its territory. It remains uncertain how this process will be regulated. The nation is not a party to the London Protocol, which includes recent amendments that set out a formal regulatory mechanism for managing the export and import of CO_2 for the purposes of sub seabed sequestration.

MEMR 2/2023 and PR 14/2024 represent landmark developments in terms of the regulation of CCS activities in Indonesia and the wider South-East Asia region. However, the practical realities of the regulatory model have yet to be tested. As observed in other jurisdictions with advanced CCS-specific frameworks, it is likely that consequential amendments to the regulatory framework will become necessary as projects seek to utilise this nascent regime. For Indonesian regulators and policymakers, it will be important to ensure that the regulatory model is flexible and that the relevant regulatory authorities remain adaptable to change and further development.

2.4 Japan

As a net importer of fossil fuels to meet domestic energy needs with a commitment to achieve net zero emissions by 2050, Japan has been actively engaged in international climate negotiations to promote strategies for achieving its emissions reduction targets, including through the adoption of climate solutions such as CCS. In January 2025, Japan submitted its updated NDC, which for the first time included CO_2 transport and storage in its emissions scope, and approved the 7th Strategic Energy Plan, which promoted CCS as a decarbonisation tool for thermal power (Agency for Natural Resources and Energy, 2025)

The US EIA's International Energy Outlook 2023 has estimated Japan's energy use to be 17.1 EJ in 2040 stabilising to 16.7 EJ in 2050 (US Energy Information Administration, 2023).

The technology is set to play a key role in achieving Japan's emissions reduction targets. The Ministry of Economy, Trade and Industry's (METI) release of the Long-Term CCS Roadmap in 2023 highlights the development of CCS and establishes a target of achieving a CO_2 storage capacity of 6-12 Mtpa by 2030 and between 120 and 140 Mt of CO_2 by 2050. In line with this strategy, Japan has recently selected the country's first nine advanced CCS projects that will receive priority support from the Japan Organisation for Metals and Energy Security (JOGMEC), and which will collectively store 20Mtpa of CO_2 (JOGMEC, 2024a).

The nation is also playing an active role in driving regional CCS deployment, convening strategic partnerships, driving the utilisation of clean fuels like hydrogen, and developing new technologies. Among these initiatives, METI established the Asia CCUS Network, together with the Economic Research Institute for ASEAN and East Asia, to facilitate discussion and knowledge sharing on incentivising the deployment of CCS in the region. In the second half of 2025, Japan also signed an MoC with Malaysia to strengthen CCS cooperation and explore the possibility (S&P Global, 2025).

In the context of these commitments, ensuring a facilitative legal and regulatory framework for CCS technologies has become a key priority for Japan. Among other efforts, the CCS Roadmap targeted the implementation of CCS-specific legislation by 2030. The CCS Roadmap also outlined how aspects such as monitoring of injected CO_2, liability of storage operators for damages, post-closure transfer of liability and insurance and financial security requirements should be addressed within the new framework. Accordingly, Japan promulgated the CCS Business Act in May 2024(Ministry of Economy Trade and Industry Japan, 2024).

In light of these developments, the following sections surveys the country's legal and regulatory landscape and its comprehensiveness in advancing a CCS project in Japan.

2.4.1 CCS-RELATED POLICY LANDSCAPE

Japan has sub-national cap-and-trade systems that have been in place since 2010 (World Bank, 2023). The Tokyo cap-and-trade program is a mandatory emissions trading system (International Carbon Action Partnership (ICAP), 2023a). It is tied to another sub-national cap-and-trade system in Saitama, a region near Tokyo. The country has had a carbon tax of Yen 289 per tonne of CO_2 emissions since 2012 (Carbon Direct, 2025).

The Japanese Government supports the development of international decarbonisation technologies on a bilateral and multilateral basis through the Joint Credit Mechanism (JCM). The JCM serves three main purposes:

- Facilitate investments by Japanese companies in sharing decarbonisation technology with the associated infrastructure in JCM partner countries,
- Support Japan and partner countries in the meeting the goals of their respective Nationally Determined Contributions (NDCs) while also ensuring that there are safeguards against double counting the reductions in emissions,
- Support cooperation between partnering countries while developing protocols consistent with Article 6 of the Paris Agreement.

The Japanese Government provides complete financial support for JCM projects through METI, the Ministry of Environment (MOE), and the New Energy and Industrial Technology Development Organisation (NEDO), a national research and development agency. JCM projects are demonstration projects through which METI and NEDO can share decarbonisation technologies.

As of April 2026, 31 countries across the world partner with Japan in the JCM and the JCM had financed 298 projects in these countries between since 2013. CCS is currently not included in the scope of the JCM (Global Environment Centre Foundation (GEC), 2025); however, METI is working to establish frameworks for the transfer and accounting of CO_2 reductions from cross-border CCS projects(Kensuke Shiomi & Ministry of Economy, 2023). There are three projects, two in Indonesia and one in Thailand, that are undergoing feasibility studies for potential inclusion under the JCM. They are:

- CCUS Project at Sukowati Oil Field in Indonesia, with Japan Petroleum Exploration Co. Ltd. (JAPEX) and JGC Corporation the associated companies,

- CCS Project in Gundih Gas Field in Indonesia, with JGC Holdings Corporation and J-Power the associated companies,
- CCS at Arthit gas producing field in Thailand, with Mitsui Oil Exploration Co. Ltd. and Mitsui & Co. Ltd. the associated companies.

Japanese government support for the JCM partner countries is listed in Table 9 (Carbon Markets Express, 2022). There was a call for proposals for JCM Model Projects for FY 2026 (Global Environment Centre Foundation (GEC), 2023). As of May 2026, a total of 12 projects were selected in FY2025 in eight rounds.

Japan also has a CCS demonstration project that is set up as a public-private partnership, the Japan CCS Co., Ltd. (JCCS), a company with several Tokyo-based shareholders (Japan CCS Co. Ltd., 2022a). The company lists several Japanese shareholders in the power, electric, petroleum, steel, and heavy industry sectors (Japan CCS Co. Ltd., 2022b). The Japanese Government has a 34% ownership share in one of the shareholders (Japan Petroleum Exploration Co., Ltd.). The company, with a capital reserve of Yen 242.5 million, was incorporated in 2008 to conduct research, demonstration projects, and feasibility studies related to CCUS and the associated transport and storage of CO_2. The flagship project is the Tomakomai CCS Demonstration Center in Tomakomai, Hokkaido.

The Japanese government, through JOGMEC, has announced support for nine CCS value chains that will capture CO_2 in Japan and store it in geologic formations either domestically (five projects) or elsewhere in the Asia Pacific region (four projects). Storage locations include (JOGMEC, 2025):

- Tomakomai area (saline aquifer)
- Tohoku region West Coast CCS (offshore saline aquifer)
- Niigata Prefecture (oil and gas field)
- East Coast of the Boso Peninsula, Chiba Prefecture (Offshore saline aquifer)
- Offshore Western Kyushu (offshore saline aquifer)
- Offshore Northern Peninsular Malaysia (offshore depleted oil and gas field)
- Offshore Sarawak, Malaysia (offshore depleted oil and gas field)
- Offshore East Coast of Peninsular Malaysia (offshore depleted field, saline aquifer)
- Oceania (offshore depleted oil and gas field, saline aquifer)

In 2025, METI designated the first two specified offshore areas for exploratory drilling, which allowed companies to start applying for drilling licenses to investigate CO_2 storage potential. These areas are Tomakomai and the East Coast of the Boso Peninsula areas,.

As part of legal amendments, JOGMEC has been assigned additional responsibilities with relevance to CCS that include risk management support, investment/debt guarantee services, and CCS site surveying (Japan Organization for Metals and Energy Security (JOGMEC), 2022).

Table 9. Japanese Government support for CCS

Entity	Program	Support type	Funding amount
Ministry of the Environment Japan (MOEJ)	JCM Model Project	Subsidy	Yen 17.1 billion over FY2022-2024
	F-gas Recovery and Destruction Model Project	Subsidy	Yen 60 million in FY2022
	Japan Fund for the JCM; managed by the Asian Development Bank (ADB)	Grants	Yen 1 billion in FY2022
Ministry of Economy, Trade and Industry (METI)		Technical cooperation / government commissioned projects	JPY 1.1 billion (through NEDO) in FY2022
	Green Transformation (GX)	Subsidy	JPY 150 trillion in total to bring about Japan's Green Transformation over the decade from 2021 to 2030 (Ministry of Economy, 2021). Includes commitment for the CCUS value chain (GR Japan, 2023) which could be up to JPY 20 trillion.
	Green Innovation Fund	Grants	JPY 2 trillion in total for multi-year decarbonisation demonstrations (through NEDO) in FY2020 (NEDO, 2024)

2.4.2 ASSESSMENT OF LEGAL AND REGULATORY FRAMEWORK

Prior to the enactment of the Carbon Dioxide Storage Business Act, offshore CCS projects could proceed under the permitting framework set out in Japan's Marine Pollution Protection Law, which incorporates Japan's obligations as a party to the London Protocol, including the amendment to Annex 1 of the London Protocol that added CO_2 streams to the list of substances that could be disposed at sea with a permit. Accordingly, the CCS permitting provisions in the Marine Pollution Protection Law established an application procedure for sub-seabed CO_2 storage, to be made to the MOE.

However, while it provided a legal basis for offshore CO_2 storage, the Marine Pollution Protection Law was designed primarily to prevent marine pollution and does not incentivise projects aimed at contributing to decarbonisation efforts. To address this, in 2024, the Japanese Diet passed the Carbon Dioxide Storage Business Act4F4F[3] (Ministry of Economy Trade and

3 It is important to note that the CCS Business Act has taken effect on the 22 May 2026 – outside the timeframe of this report (Lee & Ko, 2024; Misato Fukushima & Hiroyasu Konno, 2024a)

Industry Japan, 2024). The Act takes the form of framework legislation, with much of the detail still to be clarified. Key features of the Act include:

- Incentivising CCS activities as a business in Japan and overseas.
- The creation of exploration and storage rights
- Licensing by the Minister of Economy, Trade and Industry
- Operator contributions to post-closure monitoring
- Project plan approvals and authority to require modification or cancellation of plans

Existing approval process for applying for and obtaining regulatory approval for CCS projects

Offshore CCS projects in Japan are regulated under the Carbon Dioxide Storage Business Act, with project developers also required to obtain environmental approvals under the Marine Pollution Prevention Law, which empowers the MOE to administer the approvals process. The MOE may also approve permits for operations involving the disposal of CO_2 streams within the seabed, ordering the submission of reports on CO_2 storage under the seabed and conducting inspections. The MOE has also published guidelines for the safe operation of CCS demonstration projects, which set out standards to be followed, from a safety and environmental perspective when implementing a large-scale CCS demonstration project.

The application process for a permit to dispose CO_2 streams in the seabed requires project operators to comply with a variety of information requirements, including attaching a preliminary assessment document for Dumping Waste Under the Seabed (PADDWUS).

However, due to the absence of a comprehensive CCS-specific regulatory framework, the respective responsibilities of project operators and regulators are not clearly defined and may vary across different stages of the project lifecycle. Nevertheless, overall responsibility for the project remains with the project operator.

With regard to the CCS Business Act, METI's Long-Term CCS Roadmap has outlined how various aspects of a CCS value chain should be regulated. Among these, the CCS Roadmap provides for "Storage Business Rights" which are described as "the right to exclusively use underground structures (reservoirs) for CO_2 storage under certain conditions and in certain areas (reservoirs) under the supervision of the government". Storage business rights are also required to be subject to mortgage (Ministry of Economy Trade and Industry (METI), 2023).

Under the new CCS Business Act, Japan has established a licensing framework for the grant of CO_2 storage site exploration and injection by METI. The Act provides that METI is able to designate "specified zones" for areas with existing or potential CO_2 reservoirs, and issue guidelines for each of these zones. Business operators wishing to conduct CO_2-related activities in these zones must apply for a licence through the tender process. METI will then select the most suitable applicant for each zone. Prior to undertaking any activity authorised by a licence, the operator is required to submit an implementation plan for approval (Misato Fukushima & Hiroyasu Konno, 2024).

The Marine Pollution Prevention Law's permit system has been transferred to the CCS business act and will have the relevant provisions deleted once the new business act comes into force on May 22nd 2026 (Nishimura and Asahi, 2024).

Comprehensive application of the legal framework across all aspects of a CCS project

As discussed previously, Japan has not established integrated CCS-specific legislation addressing the various stages of a CCS project. Table 10 provides a brief overview of the current regulatory landscape and the extent to which it addresses key elements of the CCS project life cycle.

Table 10. Key considerations in Japan's CCS legal and regulatory framework

Classification of CO_2	✓	CO_2 is defined within the Marine Pollution Prevention Law as "gas that is mostly occupied by CO_2 and meets the standard specified by government ordinance". CO_2 stored within the seabed must comply with this definition and requires approval from the Ministry of Environment. Further specifications for CO_2 are provided in subsidiary regulations enforcing the Marine Pollution Prevention Law, namely that the gas must be collected through the method of isolating CO_2 from other substances using the chemical reaction of amine and carbon dioxide. A 99% CO_2 purity level is required from gas collected from such a process.
Ownership regime for sub-surface	✗	There is no ownership regime governing the sub-surface in relation to CO_2 storage activities in Japan. The CCS Business Act designates specified areas where geological storage may occur through the allocation of licenses and permits.
Design standards for CCS projects	✓	Design standards for CCS projects are not specified, with the exception of pipelines for transporting Gas. Standards for both onshore and offshore pipelines are prescribed within various Gas production legislation, including aspects such as size and technical and construction standards.
Transboundary movement of CO_2	✓	Japan has not officially ratified the 2009 amendment to the London Protocol. However, in 2024, the Japanese parliament approved acceptance of the 2009 amendment to the London Protocol, kickstarting the process of officially ratifying it.
Surface access and reclamation	✗	There is currently no specific legal framework for CCS activities in continental areas. However, there are general safety considerations that may apply to CCS project facilities, pertaining to activities such as drilling, completion, and the plugging and abandonment of CO_2 injection and storage wells, and they fall under the purview of the Mine Safety Act.
Leakage provisions	✓	There are no extensive provisions relating to CO_2 leakage. However, if the operator of a CCS project neglects to implement required corrective actions, the competent authority will intervene and carry out the necessary corrective measures at the expense of the operator.
Transport of CO_2	✓	Existing laws and regulations govern the use of pipelines and safety requirements for CO_2 transportation. The Ship Safety Act also specifies rules for ship transportation and accumulation of dangerous matters which may be relevant to the ship transport of CO_2. The CCS Business Act provides for the operation and safety of CO_2 pipelines in the context of CCS projects. Operators of CO_2 pipelines are required to notify METI about their business by providing detailed information regarding operations.

Monitoring and verification requirements	✓	There are ongoing monitoring and verification requirements in place under the regulation and discretion of the MOE. The holder of a permit for the storage of CO_2 streams beneath the seabed is also obligated to conduct ongoing monitoring of environmental conditions at the storage site and subsequently provide the monitoring findings to the MOE. The CCS Business Act requires continuous monitoring of CO_2 in the storage site reservoir during operations and up until the METI approves the abolition of storage business operations.
Storage and siting	✓	CO_2 storage site selection is subject to the ultimate decision of the MOE (specifically the Minister), who designates a CO_2 storage site under the seabed as a registered area or suitable site. Under the CCS Business Act, METI is empowered to designate an area where CO_2 storage operations may be conducted, as a “specified zone” and create implementation guidelines for conducting CO_2 storage activities within such zones.
Closure	✓	The project proponent’s obligations are ongoing, with no established closure regime. Furthermore, the holder of a permit for CO_2 stream storage under the seabed must monitor the status of pollution at the storage site and report monitoring results to the MOE. Under the CCS Business Act, METI must approve a closure plan submitted by a CO_2 storage operator seeking to cease injection operations. A variety of conditions have been established for obtaining approval for closure, including, among others, that the CO_2 stored in the reservoir has stabilised and is anticipated to remain stabilised into the future and the storage operator has contributed funds to JOGMEC to cover the costs of monitoring and maintenance of the CO_2 storage site.

Siting of projects and the Environmental Impact Assessment framework

Japan does not impose EIA requirements for the various stages of a CCS project. However, general requirements under Japan's environmental legislation may apply, as with any large project. Furthermore, applications for permits in respect of proposed CCS sites must be accompanied by a PADDWUS, which is used to survey impacts on the marine environment caused by CO_2 stream dumping.

Other risk mitigation and management measures include managing and mitigating the risks of pollution at a storage site and submitting monitoring plans together with a permit application for exploring CO_2 storage sites. The Ministry of Environment also has the power to order a report on CO_2 storage under the seabed and to conduct inspections for the purpose of ensuring compliance with laws and regulations.

Stakeholder and public consultation

Current regulations do not include provisions for communicating with stakeholders or requiring public consultation for CCS activities. Consequently, there are also no notification requirements for these activities under existing Japanese law.

Liability

There is currently no specific consideration or provision for liability issues related to post-closure and long-term storage obligations and breaches in CCS projects in Japan. However, under the Marine Pollution Prevention Law, those undertaking sub-seabed CO_2 sequestration activities are required to take corrective actions in the case of CO_2 leakage in the post-closure phase. They must also promptly inform the MOE if CO_2 migration or marine environmental impacts exceed the expected assessment range and continue monitoring until they align with original estimates. Overall, liability for CCS projects generally remains with the project proponent, even after project completion.

Under the new CCS Business Act, when the METI Minister publicly announces approval of the termination of storage business operations at a CO_2 storage site (referred to as a Notified Storage Site), the storage rights for that site are transferred to JOGMEC. JOGMEC will monitor items, as outlined by a subsequent ordinance, to ensure that the CO_2 in the Notified Storage Site is stored securely and will continue to manage the site thereafter. However, it is unclear from this the scope and extent of liabilities that are whether the transfer of storage rights to JOGMEC also includes the transfer of liabilities related to the storage site's management and CO_2 containment.

2.4.3 LEGAL ISSUES FOR CONSIDERATION

Japan's domestic legal and regulatory framework for CCS is currently at its infancy stage, with regulations focusing on the issuance of permits for the purpose of protecting the marine environment from the adverse impacts of sub-seabed storage activities. To facilitate commercial deployment of CCS however, several legal issues need to be considered for the development of a specific CCS framework in Japan, especially in addressing existing gaps in the legal and regulatory framework, such as liability, transboundary movement of CO_2, monitoring and reporting and closure obligations.

In preparation for promoting the domestic deployment of the technology, the government has passed the new CCS Business Act.

2.5 Malaysia

Malaysia's emissions profile and dependency upon fossil fuels for both industry and domestic energy generation is similar to other nations within the South-East Asia region. While there isn't a recent readily available national energy forecast for Malaysia, the US EIA's International Energy Outlook 2023 has estimated the energy use of the Asia Pacific region outside of Japan, South Korea, Australia, New Zealand, China, and India to be 70.8 EJ in 2040 and growing to 83.2 EJ in 2050 (US Energy Information Administration, 2023).

The country's updated NDC, submitted in early 2026, proposes an absolute reduction in GHG emissions of 15–30 $MtCO_2$-e by 2035 from the peak level (expected between 2029 and 2034). This comprises an unconditional reduction of up to 20 $MtCO_2$-e, with a further 10 $MtCO_2$-e reduction, conditional upon the provision of climate finance, technology transfer, and capacity-building support from international sources. Malaysia has also committed to achieving net zero emissions by 2050. To achieve its targets, the government has developed several sectoral policies, plans and programmes to drive its mitigation agenda. Mitigation efforts are focused on the energy, industrial processes and product use, waste, land use, land-use change and forestry, and agriculture sectors. The role of CCUS is emphasised, and reference is made to the recent establishment of a legal framework to enable the deployment of CCUS (UNFCCC, 2026).

2.5.1 CCS-RELATED POLICY LANDSCAPE

Several studies have emphasised the role CCS may play in mitigating the significant emissions from the nation's resource and power sectors, as well as the CO_2 content of its remaining natural gas reserves. The technology's potential was initially recognised by the government in the 12th Malaysia Plan 2021–2025, released in September 2021, which highlights the necessity for CCUS for the world's fourth-largest liquefied natural gas (LNG) producer (Government of Malaysia, 2021). Since then, progress made on CCUS projects, and the development of hubs/clusters indicate both support from the government and commitment from commercial interests and industry to progress CCUS projects at scale in Malaysia.

Malaysia has been engaged in consultations at the federal and state levels with input from the corporate sector to align the relevant policy and regulatory frameworks since 2021. Malaysia's net zero and NDC commitments have likely played a role in its intention to set up a domestic ETS (International Carbon Action Partnership (ICAP), 2023b). In 2021 the Ministry of Environment and Water released a report titled 'National Guidance on Voluntary Carbon Market Mechanisms' in 2021 (Ministry of Environment and Water & Government of Malaysia, 2021).

In December 2022 Malaysia launched of the Bursa Carbon Exchange, the world's first VCM platform that is also Shariah-compliant (Bursa Malaysia Berhad, 2023; International Carbon Action Partnership (ICAP), 2023b). In March 2024, the first verified credits from a domestic project (the Kuamut Rainforest Conservation Project) were traded on the BCX (Saptakee, 2024b). Malaysia plans to introduce a National Carbon Market Policy and launch an emission trading scheme as part of its 13th Malaysia Plan, in a move towards formalising the country's carbon market infrastructure (Carbon Pulse, 2025).

National commitments and CCS

Malaysia's National Energy Policy 2022-2040 (NEP) also identifies CCUS as a key emerging technology for Malaysia's oil and gas sector (Government of Malaysia, 2022). In line with its policy commitments, the Malaysian government, building upon its foundations and connections into the well-established oil and gas industry, is also positioning itself to be a CCUS leader in South-East Asia. The state-owned company, Petronas, plans to create clusters to share infrastructure and achieve economies of scale, with an eye to becoming a regional CO_2 storage hub. The company's approach could generate new revenues for Malaysia and facilitate the capture of CO_2 from smaller sources.

The National Energy Transition Roadmap (NETR), released in 2023, outlines a plan to develop three CCUS hubs – two in Peninsular Malaysia and one in Sarawak – with a combined storage capacity of up to 15 Mtpa by 2030. It further envisions the development of three additional carbon capture hubs and a total CO_2 storage capacity ranging from 40 to 80 Mtpa by 2050 (Ministry of Economy of Malaysia, 2023).

The government is also supporting CCS through tax incentives:

- Companies conducting in-house CCS activities can benefit from a 100% Investment Tax Allowance (ITA) on qualifying capital expenditure for 10 years, full import duty and sales tax exemptions on CCS equipment until 2027, and tax deductions for pre-commencement expenses within five years. Malaysia is also negotiating transboundary CO_2 export and import agreements and promoting local CO_2 utilisation in industry.

- Companies providing CCS services can receive the same ITA benefits, along with a 70% tax exemption on statutory income for 10 years, and similar import duty and sales tax exemptions on CCS equipment (IEA, 2025).

Malaysia's National Industry Master Plan (NIMP), released in 2023, is a comprehensive industrial policy initiative aimed at the manufacturing and manufacturing-related service sector (Ministry of Investment Trade and Industry Malaysia, 2023a). The plan's purpose is to serve as a reference for investors and provide strategic direction for industrial development over a seven-year timeframe, until 2030. The NIMP recognises the key role that manufacturing has played in Malaysia's industrial development and growth. It outlines key trends that will need to be considered for future growth, namely geopolitical movements, digitalisation, and sustainability. It refers to Malaysia's value proposition stressing its strategic location, commitment to education, an English-speaking population, strong rule of law, natural resources, and high-quality infrastructure (Ministry of Investment Trade and Industry Malaysia, 2023b).

The NIMP includes 4 missions. The 3rd mission is titled "Push for net-zero", which specifically mentions CCUS within its objectives (Ministry of Investment Trade and Industry Malaysia, 2023c). The NIMP commits several government ministries to actioning the plan for CCUS activities, as well as highlighting the following specific activities:

- Develop a CCUS framework and the governance mechanisms for industry development, through a Cluster-based approach

- Roll out the first CCUS cluster in East Coast Malaysia, targeting hard-to-abate sectors

- Strengthen current carbon management regulations and introduce a carbon tax to encourage the use of CCUS

- Explore government-to-government (G2G) bilateral agreements to facilitate collaboration between countries.

In October 2024, the Ministry of National Resources and Environmental Sustainability (NRES) announced an updated National Climate Change Policy 2.0, an umbrella policy that introduces a framework for Malaysia's transition to a low-carbon economy. The policy includes all climate initiatives and provides guidelines for governance, low-carbon development, adaptation, climate financing and cross-border collaborations. The National Climate Change Bill (RUUPIN) was expected to be tabled in Parliament after the presentation of the 2026 Budget, but it remains pending at the time of this report (NRES, 2024).

In October 2025, the Ministry of Investment, Trade, and Industry released Malaysia's Steel Industry Roadmap 2035, outlining 15 decarbonisation strategies for the industry across three phases: stabilisation from 2025 to 2027, transformation through 2035, and full decarbonisation by 2050. The roadmap proposes, among other things, the establishment of an ASEAN-wide database on steel production capacity and utilisation and a harmonised decarbonisation pathway with common green steel standards (Lai, 2025).

Project announcements

Petronas has two CCS projects in development – Kasawari and Lang Lebah. The Kasawari CCS Project reached a positive final investment decision in October 2022. Located offshore from Sarawak and linked to the Kasawari Gas Development, the project is in construction phase, and operation to reduce CO_2 emission from high CO_2 gas resources is expected to commence in 2026 (Global CCS Institute, 2025).

Petronas is also developing three offshore CO_2 storage sites (Northern Lawit cluster, Eastern M3 cluster, and Southern Duyong cluster) aiming to geologically store domestic and international CO_2 (Mardhiah, 2025). Development partners include Mitsui, TotalEnergies, Japan Petroleum Exploration Co. Ltd., Kawasaki Kishen Kaisha Ltd., Mitsubishi, Japan Gas Line Co. Ltd., and Chigoku Electric Power.

Malaysia is actively pursuing collaboration with other countries on cross-border CCS, and to this end has signed an MoU with Singapore in 2025 and has entered a partnership with Japan on “decarbonisation through technology”. Petronas has signed more than 20 MoUs across nine countries on cross-border transportation and storage (Iso, 2025).

2.5.2 ASSESSMENT OF LEGAL AND REGULATORY FRAMEWORK

The Malaysian government has previously highlighted the development of law and regulation as an important precursor in the deployment of the technology and has actively participated in several international initiatives aimed at removing regulatory obstacles. In 2022, Malaysia’s largest state, Sarawak, became the first in the country to enact legislation to regulate CCS, with the introduction of the Land Code (Carbon Storage) Rules 2022 (Sarawak CCS Rules) and amendments to the Sarawak Land Code. This development supported efforts by Petronas to develop a CCS hub in the state of Sarawak.

Malaysia enacted the CCUS Bill in March 2025, and released the associated Carbon Capture, Utilization and Storage (Offshore Permit and Licensing) Regulations 2025 (CCUS Regulations) in August. The CCUS Regulations entered into force on 1 October 2025. The CCUS Act also established the Malaysia Carbon Capture, Utilization and Storage Agency (MyCCUS) under the Ministry of Economy, to administer the Act, advise the government on the implementation of the Act, and enforce all subsidiary legislation (Malaysia Ministry of Economy, n.d.). In addition, CCS projects may be subject to planning and environmental laws. The CCUS Act and CCUS Regulations apply to CCUS projects in Peninsular Malaysia and the Federal Territory of Labuan.

On 10 October 2025, Petronas CCS Ventures Sdn Bhd (PCCSV) was granted an Offshore Assessment Permit under the new CCS Regulations, for assessment of CO_2 storage potential in the Duyong area, offshore Peninsular Malaysia. The Duyong CCS hub is being developed by PCCSV, TotalEnergies and Mitsui (Petronas, 2025).

The following sections analyse Malaysia’s legal and regulatory regime in greater detail, including the Sarawak CCS Rules, to identify the extent to which projects may be facilitated under that framework.

Existing approval process for applying for and obtaining regulatory approval for CCS projects

Peninsular Malaysia

The CCUS Regulations contain detailed procedures for the granting of offshore assessment permits and storage licenses, and requirements for data to be included in applications (Government of Malaysia, 2025a). This includes:

- Financial guarantees, risk assessments.
- Environmental management plans.
- MMV and reporting.
- Post-closure obligations of operators.

The first step in the storage permitting process is for the prospective offshore storage operators to apply to MyCCUS for an Offshore Assessment Permit. An Offshore Assessment Permit gives the permit holder the sole right to undertake geological assessment in the offshore area specified in the permit within a period of three years, or a longer period granted by MyCCUS. A permit holder must apply for an Offshore Storage License before the expiry date of the Offshore Assessment Permit, as the permit automatically lapses at the expiry date.

No storage operations can be carried out without the granting of an Offshore Storage License. An application for an Offshore Storage License must be accompanied by proof that the proposed offshore storage operator has sufficient financial security to cover the costs of all obligations, liabilities and risks associated with the storage operation, closure of the site and post-closure activities. The CCUS Regulations set out a list of plans that must be included in the application for an Offshore Storage License, which includes injection, monitoring, site closure, and post-closure plans, among others.

The CCUS Regulations include annual (or more frequent, at the discretion of MyCCUS) reporting obligations for operators, that include:

- Results of the monitoring carried out during the period and technology used.
- Quantities, properties and composition of the CO_2 streams delivered and injected during the reporting period.
- Proof of making available and maintaining the financial security set by MyCCUS.
- Any other information required by MyCCUS.

At the end of the operating/injecting period, an operator may submit a request to MyCCUS to commence storage site closure and submit a final post-closure plan. When MyCCUS has approved the final plan and is satisfied that all obligations for site closure, as specified in the Offshore Storage License, have been complied with, it will issue a Storage Site Closure Certificate. A storage operator remains obligated to perform monitoring and remediation activities following the closure of the storage site, until this obligation is transferred to the government.

All operator obligations under the CCUS Regulations will be transferred to the government upon request from the storage operator, after submitting a report, demonstrating compliance with the following conditions:

- A storage site has been closed, and a Storage Site Closure Certificate has been issued.
- All available proof, including monitoring results submitted to MyCCUS, indicates that the stored CO_2 will be completely and permanently contained.
- A minimum period of at least ten years has lapsed since the issuance of a Storage Site Closure Certificate, or longer period if MyCCUS is not satisfied that permanent containment can be proven.
- All financial obligations have been met.
- Decommissioning, as per the final post-closure plan, is complete.
- Any damage to the seabed and subsoil of the area surrounding the storage site has been remediated.

When the Agency is satisfied that all conditions have been met, it will issue a certificate to the offshore operator to document the transfer of obligations.

Sarawak

In Sarawak, CCS activities are regulated by the Director of Lands and Surveys, the Ministry of Energy and Environment Sustainability and the State Planning Authority. CCS projects will be required to obtain a “carbon storage licence” to develop and operate a project under the Sarawak CCS Rules. A carbon storage licence may be obtained by any petroleum operator, any person undertaking any industrial activity or any storage user who desires to use the storage site, regardless of whether the CO_2 to be injected by the person is obtained within or outside Sarawak. An application for a storage licence must be obtained at the preliminary stages of a project, before appraisal and exploration activities and include information such as the location, area plan and audited financial statements.

Furthermore, the Sarawak CCS Rules establish a storage user permit which enables a storage user (an entity who is not the holder of a carbon storage licence) to use the site. The application for a storage user permit has detailed requirements, including a requirement to submit a storage development plan which includes various details about the stakeholders and nature of the project.

Comprehensive application of the legal framework across all aspects of a CCS project

Table 11 provides a brief overview of the current regulatory landscape and the extent to which it addresses key elements of the CCS project life cycle.

Table 11. Key considerations in Malaysia's CCS legal and regulatory framework

Classification of CO_2	✓	Malaysia's CCUS Act 2025 (Laws of Malaysia act 870 carbon Capture, Utilization and Storage Act 2025, 2025 defines a CO_2 stream as "overwhelmingly" consisting of CO_2, and no waste or other matter may be added into the CO_2 stream for the purpose of disposing of the waste or other matter. This is aligned to the definition set out in the London Protocol. The Act makes it an offence to import CO_2 from outside Malaysia if the CO_2 stream does not comply with the carbon dioxide stream acceptance criteria. In Sarawak, atmospheric CO_2 is classified as "scheduled gases" along with any other greenhouse gases, where the reduction of emissions capture or storage is needed to mitigate effects of global climate change.
Ownership regime for sub-surface	✓	The CCUS Act is silent on ownership and access rights to pore space in sub-surface geological reservoirs into which CO_2 can be injected. However, under various other laws, ownership of resources or land is allocated to the state or state entities. Examples of this include the Petroleum Development Act 1974 which grants Petronas the exclusive rights to explore, exploit and obtain petroleum, whether onshore or offshore; and the Continental Shelf Act 1966, that vests all rights to the exploration of the continental shelf and the exploitation of its natural resources in Malaysia, with the federal government having the right to exercise these rights. In Sarawak, where scheduled gases (such as CO_2) are permanently stored in storage sites on state land, they are treated as a fixture and part of the state land, and the state government shall become the owner of such gases. As there are various ownership rights, clarity is needed regarding ownership of the sub-surface geological pore space for the purpose of CCS projects in Malaysia.

Design standards for CCS projects	✓	The CCUS Act (Article 5) makes provision for the application of "prudent practices" and defines this as: *"... any practice, method, measure and standard generally followed by the global carbon capture, utilization and storage industry during the applicable period in relation to carbon capture, transportation, utilization and storage, and including... any standard issued by any recognised body at the national or international level."* The country's existing environmental legislation has established pollution licences that must be obtained for activities that may result in pollution of land and water, while secondary regulations and standards may be established for activities coming under the purview of Malaysia's environmental legislation. CCS projects may be required to comply with the conditions of a pollution licence and standards established by regulation that may in turn require projects to be designed and constructed in an environmentally safe manner. General safety standards under occupational health and safety legislation may also be applicable to CCS projects.
Transboundary movement of CO_2	✗	Malaysia has not ratified the London Protocol. Where the nation engages in transboundary CO_2 export and import activities with countries that have ratified the Protocol, Malaysia would need to comply with the provisions of the London Protocol by virtue of the other party's obligations under the provisional application of the 2009 amendment.
Surface access and reclamation	✓	For Peninsular Malaysia – see Ownership regime for sub-surface above. In Sarawak however, the establishment of a storage user permit enables a third party to seek to store CO_2 in a CO_2 storage site that is subject to a carbon storage licence.

Leakage provisions	✓	The CCUS Regulations (Government of Malaysia, 2025b) make provision for the following information to be submitted as part of the application for an offshore storage license: • "a description of measures to prevent leakages, unintended migration or other irregularities in the storage site; • a proposed corrective measures plan and contingency procedures to be implemented in the event of any leakage or significant irregularity;" Operators have an obligation in terms of the license to notify MyCCUS immediately of any event of leakage or significant irregularities, and to implement the corrective measures plan as approved. The amount of financial security required from an operator will be assessed by MyCCUS to determine if the assessed risk of leakage is sufficiently covered. Operators are obliged to update the monitoring plane when the assessed risk of leakage changes. Transfer of obligations the State post-closure may only occur if an operator has proven, based on all the available evidence, that the stored CO_2 will be completely and permanently contained. In Sarawak, general rules regarding notification of leakages and taking corrective actions apply to CCS projects.
Transport of CO_2	✓	The CCUS Regulations provide that any person transporting CO_2 obtained through carbon capture, by road, railway, water, pipeline or by any other means, must be registered with MyCCUS and comply with existing transportation laws. The requirement for 'prudent practices' is also included for CO_2 transportation. In Sarawak, a licensee is authorised to install pipelines for the transport of CO_2 and at a storage site.
Monitoring and verification requirements	✓	Under the CCUS Regulations, operators have the obligation to monitor the injection facilities, the storage complex, the carbon dioxide plume and the surrounding environment in accordance with the monitoring plan, which is required as part of the application for an offshore storage license. This plan is required to be updated throughout the project lifetime, as required by MyCCUS. Operators are obliged to report the results of monitoring activities and technology employed to MyCCUS at least once a year. In Sarawak, a storage development plan, submitted with an application for a storage permit, must include a proposed monitoring and maintenance plan. Conditions relating to monitoring and maintenance, reporting, and notification of leakages may be imposed as part of the grant of a storage permit.

Storage and siting	✓	Under the CCUS Act, a prospective storage operator must apply to MyCCUS for an Offshore Assessment Permit. The application must indicate the area that is intended for offshore geological assessment, which may include more than one storage complex. The granting of an Offshore Assessment Permit gives the permit holder the sole right to undertake geological assessment in the offshore area specified in the permit within a period of three years, or a longer period granted by MyCCUS. Approval for storage and siting activities will also be required from the MNRE's Department of Environment (DOE). The DOE has released guidance on EIAs, which emphasises that EIAs should prioritise the issue of site suitability and ensure that sites are developed and managed in an environmentally safe manner. The Sarawak CCS Rules provide for various locations for siting CO_2 storage sites, including decommissioned petroleum sites, deep saline aquifers, coal seams, and areas deemed suitable and safe by the State Planning Authority.
Closure	✓	The CCUS Act refers to 'prescribed conditions' that an operator has to meet before a Closure Certificate will be issued. The Act also lists remaining responsibilities of the operator that continue post closure, that include monitoring of the storage site and reporting of results; executing corrective and remediation measures; and any other prescribed activities. In Sarawak, where CO_2 is permanently stored in storage sites, the CO_2 is treated as a fixture and part of the state land, and the state becomes the owner of the stored CO_2. Storage operators are required to make financial contributions to cover post-closure activities that will be undertaken by the state government after the transfer of responsibilities for the storage site.

Siting of projects and the Environmental Impact Assessment framework

In addition to the requirements included in the CCUS Act for the granting of an Offshore Storage License, (as indicated above), an application for such license must be accompanied by proof that the proposed offshore storage operator has sufficient financial security to cover the costs of:

- All obligations, liabilities and risks associated with the storage operation.
- Closure of the site and post-closure activities.
- Obligation to pay MyCCUS for the costs specified in the regulations.

The amount and form of financial security shall be determined by the applicant and approved by MyCCUS. Under Malaysia's Environment Quality Act 1974, for example, an EIA must be prepared in consultation with the Department of Environment, which involves both a preliminary EIA and a detailed EIA for major projects with the potential to significantly impact the environment. Further requirements under the EIA process include providing additional information on proposed changes and obtaining approval for EIAs from the Department of Environment to proceed with wider project approvals from other relevant federal or state government agencies.

Approval for storage and siting activities will also be required from the MNRE's Department of Environment. The DOE has released guidance on EIAs, which emphasises that EIAs should prioritise the issue of site suitability and ensure that sites are developed and managed in an environmentally safe manner.

CCS project construction and development will also be required to comply with additional obligations under Malaysia's planning and construction laws, at both the federal and state level. The federal Department of Environment will determine, as part of its EIA review, whether the project is consistent with local zoning requirements. However, the ultimate decision will be made by state and local authorities.

In Sarawak, project operators are required to make financial contributions to cover post-closure activities that will be undertaken by the government after the transfer of responsibilities for the storage site. Approval for storage licence is dependent on the State Planning Authority being satisfied of the suitability of the storage site area under the licence for exploration and development and that the project operator possesses adequate technical competence to undertake such activities. Licences may be revoked due to non-compliance with licence conditions.

Stakeholder and Public Consultation

Public participation is built into Malaysia's legal framework under environmental and planning legislation. While there are no CCS-project-specific requirements, planning legislation requires state authorities to ensure that adequate opportunities are provided to the public to make representations regarding the structural plans of projects.

Environmental frameworks also incorporate public participation during environmental impact assessments for projects, through requirements to hold local hearings with the public when preparing detailed EIAs. The public can also access the results of EIAs at any time.

Liability

The CCUS Act established the Post-Closure Stewardship Fund, that is administered by MyCCUS. The Fund consists of funds provided by the government for the purposes of the CCUS Act; any injection levy paid by offshore storage operators to MyCCUS; and investment returns. These funds are earmarked to cover post-closure costs, after site stewardship and liability have been transferred to the government.

All obligations related to the stewardship of the site will transfer to the government once the operator has complied with the following conditions:

- storage site has been closed, and a Storage Site Closure Certificate has been issued.
- All available proof indicates that the stored CO_2 will be completely and permanently contained.
- A minimum period of at least ten years has lapsed since the issuance of the Closure Certificate.
- Any financial obligations.
- Decommissioning is complete.

When MyCCUS is satisfied that all conditions have been met, it will issue a certificate to the offshore operator to document the transfer of obligations.

The state of Sarawak, through the establishment of the Sarawak CCS Rules, requires project operators to comply with a range of post-closure obligations, as discussed previously. Among these, a storage user is required to monitor the storage site post-closure in accordance with a monitoring plan, comply with reporting and notification requirements and ensure corrective measures in the face of any risks, up until the storage permit is cancelled. However, the Sarawak CCS Rules provide that the licensee or storage user is not relieved from liabilities for activities conducted prior to closure. The termination of a storage permit is conditional on the project operator satisfying the state planning authority that the CO_2 injected is safely and permanently contained within the storage reservoir, the storage site is sealed, and injection facilities have been appropriately decommissioned, through available evidence. A CO_2 storage site operator is also required to provide financial security to cover the costs that will be incurred by the government after the transfer to the government of obligations relating to the management of the CO_2 storage site.

Where CO_2 is permanently stored in geological storage sites, the CO_2 is treated as a fixture and part of the state land, and the state becomes the owner of the stored CO_2.

2.5.3 LEGAL ISSUES FOR CONSIDERATION

The Act and Regulations provide a critical foundation for projects to be permitted and developed in the country. This increases certainty for project developers and investors alike.

Although the Sarawak CCS Rules establish an integrated regulatory framework for CCS projects, their application is limited to the state of Sarawak.

The development of CCS-specific legislation at the sub-national level is typically complementary to or based upon a national or federal framework, as seen in examples in the United States, Australia and Europe. An arrangement of this nature provides a level of certainty and consistency to the operation of CCS projects from a national perspective. It is therefore notable that the Sarawak Rules and the CCUS Act and Regulations do not follow this pattern. The CCUS Regulations apply to Peninsular Malaysia and the Federal Territory of Labuan only and do not extend to the states of Sabah and Sarawak.

Despite plans to develop a CCS hub that sources CO_2 captured from within and outside the state of Sarawak, Malaysia is not a party to the London Protocol, nor has it developed national legislation to address the transboundary movement of CO_2.

2.6 South Korea

South Korea has established ambitious emissions reduction targets to comply with its obligations under the Paris Agreement, which include commitments to achieve a 40% reduction in net GHG emissions by 2030 and 53%-61% by 2035, compared to 2018 levels; and to reach carbon neutrality by 2050. The current NDC specifically mentions the development and commercialisation of CCUS technologies to achieve 41% of abatement by 2050, versus a ‘no transition’ pathway (Republic of Korea, 2025). With the country’s energy sector dominated by fossil fuel sources, South Korea is facing the challenge of balancing its domestic energy needs with its commitments to combat climate change. For example, South Korea aims to increase the share of renewable energy sources and accelerate the share of nuclear power generation (S&P Global, 2023). This strategy reflects revisions to the 2030 targets of both the industrial and power production sector, which reduced the burden of the industrial sector and led to a higher target for emissions reductions from the power sector.

The US EIA’s International Energy Outlook 2023 has estimated South Korea’s energy use to be holding steady at 15 to 15.1 EJ between 2040 and 2050 (US Energy Information Administration, 2023).

Korea enacted the Framework Act on Carbon Neutrality and Green Growth for Coping with Climate Crisis (the Carbon Neutrality Act) in 2021. Pursuant to Article 10 of the Act, South Korea published its first National Basic Plan for Carbon Neutrality and Green Growth (National Basic Plan) in 2023, setting a reduction target of 11.2 million tons by 2030 from CCUS technologies (Government of South Korea, 2023). In 2024, South Korea’s Constitutional Court ruled that portions of the Carbon Neutrality Act were unconstitutional. The court found that the government’s framework lacked sufficient credibility and specificity in its legal commitments. The court mandated that a revised and more robust legal framework be delivered by March 2026 (Seoul Vision 2030, 2026).

In January 2024, South Korea established a comprehensive legal and regulatory framework dedicated to enabling the various models and applications of CCS projects that industry is preparing to develop. The Act on Carbon Dioxide Capture, Transportation, Storage and Utilization was enacted pursuant to the Korean government's National Basic Plan, which commits to developing CCS-specific legislation addressing business, safety, and certification of CCUS projects (Presidential Committee on Carbon Neutrality and Green Growth 2050 Korea, n.d.).

CCS features as a core emissions reduction component across several of South Korea's national climate change mitigation strategies and action plans. Apart from the National Basic Plan, CCUS has also been designated as one of the Ten Major Technologies for Carbon Neutrality Technology Innovation in South Korea's 2050 Carbon Neutral Promotion Strategy. In furtherance of these commitments, CCS-related developments are gaining momentum in South Korea with multiple project announcements and cooperation agreements between the nation's leading energy and industrial companies to assess opportunities for and develop various applications of CCS technologies.

Business models involving transboundary CO_2 storage activities, are an emerging area of focus amongst South Korea's industry stakeholders. The formation of multiple consortiums within South Korea's private sector in the past year, to explore the opportunities associated with transboundary CO_2 storage in the region, is evidence of this new approach (Global CCS Institute, 2023a).

2.6.1 CCS-RELATED POLICY LANDSCAPE

South Korea launched a precursor to the current emissions trading scheme in 2012. Called the Target Management System, it was mandated by a 2010 law called the Framework Act on Low Carbon and Green Growth (Framework Act on Low Carbon and Green Growth, 2010; NDC Partnership, 2013). The country launched the current domestic ETS, the Korea Emissions Trading Scheme (KETS), in 2015. Currently in Phase 4 (2026–2035), the details of this phase were defined in the Fourth Basic Plan, adopted in December 2024, to align with the 2021 Carbon Neutral Framework Act.

While CCS activities were not excluded under the KETS in its first phase from 2015 to 2017, they do not appear to be included currently (International Carbon Action Partnership (ICAP), 2023e; International Emissions Trading Association (IETA, 2022; Jong Ik Yoo & Korea Research Institute on Climate Change, 2018). It is a mandatory market covering almost 75% of Korean GHG emissions from emitters in several sectors including airlines, transportation, power, and heavy industry amongst several others. The allowances are granted through a mix of free allocation and auctioning with intermediaries being able to participate since 2021 (International Carbon Action Partnership (ICAP), 2023e).

The CCUS Act of 2024 authorises subsidies and loans for R&D, permission to invest in climate-response funds, certain national/local tax reductions, and preferential access/fees for public property and waters for demonstrations; it also enables cluster designation with government subsidies for eligible CCUS projects across capture, transport, storage and utilisation (Kim & Chang, 2024).

2.6.2 ASSESSMENT OF LEGAL AND REGULATORY FRAMEWORK

The CCUS Act of 2024, entered into force in February 2025, is comprehensive and provides a legal basis for CCUS business to operate. The law specifies that CO_2 and products made from it will not be considered waste under the provisions of the Waste Management Act. The current regulatory framework for CCS in South Korea remains under-developed. Much of the detail relating to compliance with, and implementation of, specific obligations remain in need of clarification through supporting regulations. The regulation of CCS is largely under South Korea's environmental legislation. South Korea has also ratified the 2009 amendment to the London Protocol and has deposited a notification of provisional application with the IMO.

The following sections will consider South Korea's existing legal and regulatory regime in greater detail to identify the extent to which projects may be facilitated under the current framework.

Existing approval process for applying for and obtaining regulatory approval for CCS projects

The CCUS Act of 2024 establishes a permitting model for CO_2 storage site exploration and injection activities. The Act provides that a business entity can obtain the approval of the Ministry of Trade, Industry and Energy (MOTIE) to conduct:

- Exploration for the discovery of CO_2 storage sites within an onshore or offshore area nominated by the business entity that applied for such exploration activities pursuant to specified application criteria
- CO_2 storage activities within a candidate site upon satisfying specified application criteria
- CO_2 transport business activities pursuant to specified application criteria

It must be noted that MOTIE has been dissolved in the latter half of 2025, and its portfolio reorganised into two newly established ministries, namely the Ministry of Trade, Industry and Resources (MOTIR) and the Ministry of Climate, Energy and Environment (MCEE). It is expected that CCUS will fall within the jurisdiction of MCEE.

Comprehensive application of the legal framework across all aspects of a CCS project

Table 12 provides a brief overview of the current regulatory landscape and the extent to which it addresses key elements of the CCS project life cycle.

Table 12. Key considerations in South Korea's CCS legal and regulatory framework

Classification of CO_2	✓	The CCUS Act does not directly discuss the purity of CO_2 streams. The Management of Marine Garbage and Contaminated Marine Sediment Act and its enforcement decree discuss the purity of CO_2 streams (Republic of Korea, 2024). The CCUS Act provides that CO_2 captured or utilised in products and materials is excluded from waste legislation, unless mixed with waste, in which case waste laws apply. Byproducts from CO_2 utilisation that are no longer needed are considered waste.
Ownership regime for sub-surface	✗	South Korea has no ownership regime for sub-surface pore space for storage of CO_2.
Design standards for CCS projects	✓	Under the CCUS Act, while specific standards for the design and construction of CCS projects are not mandated, the government may promote standardisation to improve the quality of CCS technologies. CO_2 storage operators may be recommended to adopt such standards. The CCUS Act also addresses safety standards, requiring operators to establish safety management regulations before installing or operating CO_2 transportation pipelines. These regulations must cover aspects like emergency response plans and safety management systems, with government approval required. Existing industrial standards under other applicable laws, such as pipeline legislation, may still apply to CCS activities where relevant.

Transboundary movement of CO_2	✔	South Korea has ratified the London Protocol and the 2009 amendment to the London Protocol, which enables transboundary CO_2 export activities. However, South Korea's domestic regulatory framework does not currently enable transboundary CO_2 export and import activities. Discussions relating to the regulation of transboundary issues are currently underway. The CCUS Act provides definitions for CO_2 capture, transport and storage. These definitions cover these processes both domestically and internationally, indicating that transboundary CCS activities may be facilitated.
Surface access and reclamation	✖	There is no CCS-specific regime for surface access and reclamation in existing legislation.
Leakage provisions	✔	The CCUS Act requires storage permit applications to contain details relating to the management of CO_2 leakage from CO_2 storage sites. The Act requires operators who become aware that stored CO_2 has leaked during operations, to immediately notify the Minister of Trade, Industry, and Energy. CO_2 leakage would also be addressed through existing laws related to waste management, recycling, radioactive waste, and hazardous substances.
Transport of CO_2	✔	The CCUS Act requires CO_2 transportation businesses to obtain approval from MOTIE for their operations. Additionally, maritime CO_2 transport requires registration with the Ministry of Oceans and Fisheries (MOF) under the Maritime Transportation Act. For pipeline transport, businesses need to secure approval for safety management regulations, appoint safety managers, and ensure regular inspections before installing and operating pipelines. Existing regimes relevant to transportation and pipelines may be extended to the transport of CO_2 for CCS.
Monitoring and verification requirements	✔	The new CCS Act requires a business with a permit for CO_2 storage to create and execute a monitoring plan both before and after the closure of a CO_2 storage site. The entity must also comply with CO_2 leakage prevention measures and conduct regular safety inspections.
Storage and siting	✔	The CCUS Act provides for the siting of CO_2 storage projects in areas requested by exploration permit applicants, mining areas where mining rights have lapsed and seabed mining areas where natural gas seabed mining right has expired under the Act of Development of Seabed Mineral Resources. The Act also requires exploration permit applicants to submit a detailed exploration plan, equipment specifications, geological and seismic investigation plans, and other required documents. Although there are no explicit requirements, siting and CO_2 storage requirements for a CCS project may be subject to general obligations under various existing environmental and resource management laws. As South Korea has ratified the London Protocol, the requirements relating to CO_2 storage in sub-seabed geological formations are likely to be applicable to a project.

Closure	✓	The CCUS Act provides for a closure regime for CO_2 storage sites. For example, the Minister of Trade, Industry and Energy can order the closure of a CO_2 storage site in several cases: if the storage capacity is full and no further storage is possible, upon a closure request from the storage operator, due to natural disasters or CO_2 leakage, or other circumstances specified by Presidential Decree. The storage operator is responsible for closure costs. The closure process, including methods and procedures, will be outlined by a subsequent Presidential Decree. After closure, the operator must restore the site to its original state according to specified standards and obtain approval from the Minister for restoration. Before closing a CO_2 storage site, the storage operator must also develop a monitoring plan and obtain approval from the Minister of Trade, Industry, and Energy. This plan must include monitoring for at least 15 years after the site's closure, as specified by Presidential Decree. The CCUS Act does not discuss the transfer of liabilities nor financial mechanisms to cover the cost of ongoing site monitoring.

Siting of projects and the Environmental Impact Assessment framework

South Korea's current legal framework does not regulate the capture, transport, and storage in a comprehensive or uniform manner. While certain laws such as the High-Pressure Gas Management Law and the Urban Gas Management Law require permits for pipeline installation or modification, it remains unclear whether CO_2 falls under the definition of "high-pressure gas."

However, the CCUS Act provides for the siting of capture, transport and storage facilities in the context of CCS operations. The Act provides for the siting of CO_2 storage projects in areas requested by exploration permit applicants, mining areas where mining rights have lapsed and seabed mining areas where natural gas seabed mining right has expired under the Act of Development of Seabed Mineral Resources. It also requires exploration permit applicants to submit a detailed exploration plan, equipment specifications, geological and seismic investigation plans, and other required documents.

This process is similar to requirements stipulated under existing mining laws, which mandate the submission of exploration plans to MOTIE prior to commencing exploration activities, with mining licenses required for extraction. Undersea-related explorations are subject to approval by the same ministry under the Submarine Mineral Resource Development Law, contingent on factors such as funding, business plans, and equipment.

In terms of risk assessment and management responsibilities, project operators are required to conduct a risk assessment of leakages in respect of offshore activities. South Korea's Environmental Impact Assessment Act is likely to be relevant to CCS projects, while the Ministry of Environment will likely play a role in relation to environmental management, monitoring, mitigation, and risk management of offshore CO_2 storage, given its overarching responsibilities in this area.

Stakeholder and public consultation

Public engagement requirements for CCS projects are not addressed in South Korea's existing legal framework for similar activities. CCS projects could however be included under the Environmental Impact Assessment Act of 2017 since it covers public consultation and public hearings for projects.

Liability

South Korea's legal framework is silent with regard to post-closure responsibilities for a CCS project. Strict liability provisions apply in general for any damage caused by activities leading to accidents involving dangerous substances.

2.6.3 LEGAL ISSUES FOR CONSIDERATION

Although South Korea has passed legislation establishing a regulatory framework for CCS operations, the regime remains in need of further clarification through supporting regulations. In the absence of clarifying regulations, the legal and regulatory framework for CCS does not provide the regulatory certainty that project operators require to proceed with deployment. In light of South Korea's ambitions to facilitate transboundary CO_2 storage activities in particular, key elements of a transboundary CCS value chain need to be addressed within regulations covering the full lifecycle of a CCS project, including post-closure site care and maintenance, and liability provisions.

2.7 Thailand

Similar to many other nations in the region, Thailand is facing the challenge of facilitating a clean energy transition from an economy highly dependent upon fossil fuels across many sectors. In its updated NDC submitted to the UNFCCC in November 2025, the country committed to both reducing its GHG emissions by 47% by 2035 compared to 2019 levels and reaching net-zero by 2050 (NDC partnership, 2025). The new NDC targets five key sectors: energy and transport, industry, agriculture, waste management and forestry (LULUCF).

While there isn't a recent readily available national energy forecast for Thailand, the US EIA's International Energy Outlook 2023 has estimated the energy use of the Asia Pacific region outside of Japan, South Korea, Australia, New Zealand, China, and India to be 70.8 EJ in 2040 and growing to 83.2 EJ in 2050 (US Energy Information Administration, 2023).

In 2015, Thailand released its first Climate Change Master Plan for the period 2015-2050, and this document remains an important indicator of the country's approach to addressing the challenges of mitigation and adaptation (Office of Natural Resources and Environmental Policy Thailand, 2015). Alongside the updated NDC, Thailand also established the National Energy Plan framework, building upon Thailand's commitment to net-zero and introducing sectoral plans and policies aimed at achieving these ambitions (Nation Thailand, 2024).

2.7.1 CCS-RELATED POLICY LANDSCAPE

Without the deployment of technologies such as CCS, Thailand faces a significant challenge in addressing the impact of its dependency upon fossil fuel from the perspective of climate change mitigation. Climate and energy policies have, to some extent, recognised the potential role that CCS may play in achieving the country's mitigation objectives.

CCS was originally highlighted in Thailand's Climate Change Master Plan as part of its strategy focused upon mitigation and low carbon development. The plan proposed that feasibility studies on CCS in the power production sector be conducted, as part of efforts to address mitigation in the wider power generation and energy supply sectors. More recently, CCS/CCUS was mentioned in Thailand's updated NDC as a solution it was currently exploring to mitigate GHG emissions (NDC partnership, 2025).

It is anticipated that the forthcoming National Energy Plan will also highlight the role of CCS in meeting the nation's objectives for carbon neutrality. Thailand's revised Long-Term Low Greenhouse Gas Emission Development Strategy (LT-LEDS), which was submitted to the UNFCCC in November 2022, includes formal mention of CCUS and its potential role in supporting decarbonisation of the nation's energy sector (Office of Natural Resources and Environmental Policy and Planning & Ministry of Natural Resources and Environment, 2022). The government highlights that domestic CCS is expected to commence by 2040, with power plants and cement production as prime targets for the technology's deployment.

Recent project announcements, and increased emission reduction efforts are likely to result in far greater levels of activity in the coming years. In this regard, state-owned PTT Exploration and Production Public Company Limited (PTTEP) highlighted its ambitions to undertake transnational CCS activities in the Lang Lebah field in offshore Malaysia in late 2023. The state-owned company is also progressing the first CCS project in the Arthit gas field in the Gulf of Thailand, with FID reached in September 2025 and operations expected to commence in 2028 (PTTEP, 2025).

National commitments and CCS

In November 2025, Thailand submitted an updated NDC to the UNFCCC, aiming for a 47% reduction in net GHG emissions compared to 2019 levels, by 2035, and to achieve net zero by 2050. The updated NDC mentions CCS/CCUS as a promising solution to mitigate GHG emissions and notes that efforts are underway to evaluate the feasibility thereof (Thailand Department of Climate Change and Environment, 2025). The foundations for an ETS were established in December 2025, when the Thai Cabinet approved the draft Climate Change Act which introduced it alongside other carbon pricing mechanisms such as a carbon tax, a regulated carbon credit market and a Carbon Border Adjustment Mechanism (CBAM) (ICAP, 2025). The ETS is expected to become operational in 2027.

2.7.2 ASSESSMENT OF LEGAL AND REGULATORY FRAMEWORK

Although Thailand introduced a national CCS governance framework in January 2026 which approved guidelines to advance CCS and established clear institutional responsibilities for the development of CCS (PRD, 2026), the country does not currently have a CCS-specific regulatory framework. However, its regulatory framework for oil and gas may potentially be relevant to CCS projects. The permitting and operation of CCS projects will also be subject to wider laws, regulations and requirements. It is likely that the following will be applicable:

- The Land Code,
- Regulations of the Industrial Estate Authority of Thailand,
- Factory licensing requirements,
- The Petroleum Act (where CO_2 is the byproduct or waste from a petroleum project),
- Environmental Impact Assessment (EIA) requirements.

It should be noted that in March 2023, Thailand's Cabinet tasked the Department of Mineral Fuels (DMF) with developing a regulatory framework for CCS activities and to investigate and ensure that CCS-specific regulations are consistent with Thailand's laws. The proposed regulatory framework developed by the DMF will amend Thailand's Petroleum Law to enable the direct regulation of CCS activities in Thailand. One aspect of the proposed legislation pertains to the definition of carbon-related activities, which covers exploration for carbon storage areas and the injection of carbon into such sites. Furthermore, the Petroleum Law Amendment introduces licensing requirements for CCS activities. The adoption of this amendment promises to establish a comprehensive regulatory framework for conducting CCS operations in Thailand. Nevertheless, whilst the draft amendments have been completed by the DMF, the specific timeline for enforcing this law remains uncertain as approval will need to wait for a new elected government (Bangkok Global Law, 2026).

Pending the introduction of this legislation, the following sections will examine the extent to which Thailand's existing framework enables a CCS project to proceed.

Existing approval process for applying for and obtaining regulatory approval for CCS projects

As part of the Thai cabinet approved national CCS governance framework referenced earlier, the Department of Climate Change and Environment (DCCE) has been designated as the central coordinating authority for CCS policy and legal development. In addition, the DMF was appointed as project owner for pilot projects within the framework of Thailand-Japan cooperation and tasked with overseeing exploratory drilling and geological surveys in the Upper Gulf of Thailand (PRD, 2026). However, whilst this represents a start, Thailand does not yet have an operational regulatory framework governing CCS projects. As such, there is no separate pathway to obtain approval for projects. In the absence of a CCS-specific process, it is likely that Thailand's existing and robust oil and gas permitting process will provide the basis for projects to proceed within the country. Approvals are generally in the form of a concession granted by the Cabinet on a sealed bid basis to the applicant offering the terms most favourable to the government.

General application requirements include demonstrating the applicant's technical competence and financial capacity and the potential benefit of the project to the community. Foreign project proponents are also required to obtain foreign business licences to operate projects in Thailand. Under this process, foreign project proponents are required to meet potentially onerous permitting requirements that are known to involve substantial effort and time.

It is the responsibility of the Department of Mineral Fuels and Ministry of Energy (MOE) to regulate oil and gas projects, and it is likely that these agencies will be involved if CCS projects were to proceed in Thailand.

Despite the potential for CCS projects to proceed under the permitting process for oil and gas, there are no defined roles for project operators and regulators with regard to CCS operations. In the absence of such clarity, the permitting pathway for CCS is under-developed and inadequate to facilitate CCS activities.

Comprehensive application of the legal framework across all aspects of a CCS project

As Thailand does not have an integrated legal and regulatory framework that governs CCS projects, many aspects of the CCS project lifecycle remain unaddressed and there is considerable uncertainty for project operators regarding compliance requirements for various activities. Table 13 provides a brief overview of the current regulatory landscape and the extent to which it addresses key elements of the CCS project life cycle.

Table 13. Key considerations in Thailand's CCS legal and regulatory framework

Classification of CO_2	✗	The Petroleum Law amendment draft classifies "carbon" as "CO_2 in the state of gas or supercritical fluid generated as a by-product or captured from other sources and transported to storage". However, the amendment has yet to be enacted and has an uncertain timeline. There is no express definition of CO_2 within existing legislation.
Ownership regime for sub-surface	✗	Sub-surface ownership issues in the context of CCS projects are not clarified. Existing oil and gas legislation vests ownership of hydrocarbons in the sub-surface with the Thai state, which may hold implications for CCS projects. Under Thailand's mining legislation, mining activities are authorised only pursuant to a licence, implying that minerals belong to the state.
Design standards for CCS projects	✓	Although there are no CCS-specific design standards, it is likely that CCS projects would be subject to existing laws regulating the transport of fuels via pipelines.
Transboundary movement of CO_2	✗	Thailand has not ratified the London Protocol and there is no legislation in place for the safe transboundary movement of CO_2.
Surface access and reclamation	✓	While there are no CCS-specific provisions, surface access and reclamation may be regulated on substantially the same basis as oil and gas activities under the PA or mining activities under the Minerals Act.
Leakage provisions	✓	There are no current specific regulations on leakage from CCS projects in Thailand. However, the Petroleum Law amendment draft includes carbon license conditions for carbon businesses who must have "remedial measures in the event of carbon leakage, movement or other irregularities". Thailand's environmental legislation also enshrines the polluter pays principle, which holds the project operator responsible for compensating any harm or damage, including injury or property damage, resulting from project-related leakage or contamination.
Transport of CO_2	✗	There are no CCS-specific regulatory requirements applicable to CO_2 transport. However, Thailand possesses comprehensive laws on the transportation of hazardous goods that may be potentially relevant to CO_2 transport.

Monitoring and verification requirements	✗	There are no CCS-specific legislation in Thailand regarding monitoring and verification of CCS projects or the provision of public information about such projects, but existing regulatory frameworks may be immediately relevant to CCS projects. In particular, monitoring and verification may be required as part of general environmental impact assessment frameworks.
Storage and siting	✓	There are no specific storage and siting provisions in Thailand for the storage of CO_2 or selection of sites. In the absence of specific provisions, existing requirements under oil and gas frameworks may be extended to CCS projects.
Closure	✓	Thailand does not currently have any specific closure regime obligations for CCS operators or provisions that address liability during the post-closure period. Under the Petroleum Law amendment draft, the carbon business license imposes technical conditions for the closure of a carbon storage site. Post-closure, operators are required to continue monitoring and surveillance of the storage site until storage operations are complete, facilities are fully decommissioned and a "security for liability transfer" has been provided to the DMF. Responsibility and long-term liability is then transferred over to the DMF. Under existing legislation, there are requirements to decommission oil and gas facilities and concessions that may be applicable to CCS projects, however, these are limited and do not extend to reclamation.

Siting of projects and the Environmental Impact Assessment framework

Thailand's environmental legislation does not currently require an EIA to address the various stages and activities of a CCS project. However, as the activities bear similarities to oil and gas exploration and production activities, which do necessitate an EIA, CCS projects may be required to comply with the same requirements. In addition, Carbon businesses, as part of the Petroleum Act draft amendments, may be subject to EIAs.

The general objective of environmental legislation in Thailand is to protect and mitigate the risk to the environment. The EIA reports submitted to the regulator must contain details of the operations' structures and activities, an assessment of these activities' environmental impacts and proposed environmental protection measures. These requirements are not specific to CCS projects and are inadequate in addressing their unique considerations and potential environmental impacts.

Stakeholder and public consultation

No specific stakeholder and public consultation requirements are applicable to CCS projects. However, such processes are built into Thailand's environmental impact assessment framework.

Liability

There is no closure regime applicable to CCS projects in Thailand. General obligations under oil and gas legal frameworks to decommission facilities may apply, however, these do not clearly define the project proponent's reclamation obligations for projects of this nature. Similarly, responsibilities and liability during the post-closure phase of a CCS project remains a critical gap that is not addressed in Thailand.

Under the Petroleum Act draft amendments, liability of a CCS project only transfers from a carbon business operator to the DMF after a three-year liability transfer security is deposited and all carbon storage infrastructure removed.

2.7.3 LEGAL ISSUES FOR CONSIDERATION

Thailand's legal regime remains inadequate for supporting the deployment of CCS projects at a commercial scale, or to facilitate regional CO_2 transport and storage. Current environmental and licensing regimes do not address many of the critical aspects of the CCUS project lifecycle. Further regulation will likely be necessary to ensure storage, siting and liability for damages arising from CCS are addressed in a comprehensive manner.

Increased commercial interest in the technology and the advancement of projects ultimately places a greater emphasis on the development of the national regulatory regime. The proposed new amendment to the Petroleum Act is Thailand's response to the growing momentum for the technology; however, the timeline for the law to enter into force is still uncertain.

2.8 Vietnam

As a party to the UNFCCC and the Paris Agreement, Vietnam has submitted an NDC that includes a commitment (strengthened from previous years) to make an unconditional 15.8% reduction of GHG emissions compared to business as usual by 2030. A conditional commitment to a 43.5% reduction of GHG emissions compared to business as usual by 2030 was also submitted, subject to the country receiving international support through bilateral and multilateral cooperation as well as through any new mechanisms developed under the Paris Agreement (Socialist Republic of Vietnam, 2022).

While there isn't a recent readily available national energy forecast for Vietnam, the US EIA's International Energy Outlook 2023 has estimated the energy use of the Asia Pacific region outside of Japan, South Korea, Australia, New Zealand, China, and India to be 70.8 EJ in 2040 and growing to 83.3 EJ in 2050 (US Energy Information Administration, 2023). Vietnam has committed to achieving net zero emissions by 2050, a target that has been enshrined in legislation since July 2022.

2.8.1 CCS-RELATED CLIMATE POLICY LANDSCAPE

International studies have highlighted the considerable potential for deploying CCS in Vietnam, in the context of the nation's rapid growth and anticipated increase in energy use and emissions, which will see continued reliance on fossil fuels. Vietnam also possesses significant storage potential and completed assessments suggest there are considerable storage resources when compared to national emissions.

Notwithstanding the nation's potential, Vietnam has yet to develop a formal policy commitment towards deploying the technology. In 2005, in partnership with two Japanese companies, Vietnamese/Russian joint venture Vietsovpetro proposed the first CCS/enhanced oil recovery (EOR) project under the Kyoto Protocol's Clean Development Mechanism (CDM). Although ultimately the project was not approved, the country proved an early mover in the discussion surrounding the inclusion of the technology within the CDM.

I. More recently, there has been some indication of desire to deploy the technology. At COP26, Vietnam communicated its aim to conduct research on technologies and implement solutions for CCS in certain fields. The nation proposed projects to "trial the application of coal gasification, carbon capture and storage at underground coal seams outside the dyke of Yinggehai-Song Hong Basin" (Prime Minister of Vietnam, 2022).

II. In 2022, Japan and Vietnam renewed the MoU signed between the two countries in 2007 and expanded its scope to include collaboration on joint business opportunities in CCS/CCUS projects. Based on this revised MoU, studies were conducted by Japan to investigate the feasibility of CCS/CCUS projects in Vietnam. This was followed by another MoU between the two in 2023, where it was agreed to go forward with additional CCS/CCU feasibility studies, and the signing of a Joint Study Agreement (JSA) in 2024 to promote private-sector-led CCS projects in Vietnam (JOGMEC, 2024), culminating in

ENEOS Xplora signing an MoU on cooperation with JOGMEC and Petrovietnam to launch a CCS project in the country (ENEOS Xplora, 2025).

III. In January 2026, the Vietnamese government issued Decree 29/2026/ND-CP, finalising the legal foundations for its domestic carbon market and establishing a regulatory framework that allows the trading of GHG quotas and carbon credits (Vietnam News, 2026). This builds off the country's launch of an emissions trading scheme's pilot phase in June 2025 aimed at decarbonising the iron & steel, cement and thermal power industries (Reuters, 2025). In February 2026, the ETS' total GHG allowance cap and number of covered entities was established by the Vietnamese Prime Ministers' approval of Decision No.236/QD-TTg (ICAP, 2026).

Although references have been made for the need to adopt and use low-carbon fuel sources and new technologies employing low emissions, Vietnam is yet to make explicit reference to CCS in any of its major national climate or energy policies.

2.8.2 ASSESSMENT OF LEGAL AND REGULATORY FRAMEWORK

Vietnam has not yet developed CCUS-specific legislation. The following sections examine Vietnam's current legal and regulatory frameworks and their readiness to facilitate CCS activities.

Existing approval process for applying for and obtaining regulatory approval for CCS projects

The regulatory framework for large infrastructure projects in Vietnam is fragmented and not adequate for addressing the unique aspects of a CCS project. As various pieces of legislation may be applicable, there is no clarity as to which government department would be involved in permitting or overseeing the regulation of CCS projects.

At present, it is likely that the environment-focused government agencies would be involved in the approval of CCS projects. The Ministry of Industry and Trade (MOIT) may also be involved as it is primarily responsible for regulating power, energy, oil and gas exploitation activities in Vietnam. In addition, the MOIT is also responsible for oil and gas industry safety standards and practices; including, but not limited to, safety issues related to the siting of natural gas pipelines.

However, the Ministry of Natural Resources and Environment, the Ministry of Construction and MOIT have all been tasked with research on technologies and implementing solutions for CCS in certain fields, suggesting that these agencies are likely to be involved in the regulation of CCS.

In the absence of CCS-specific legislation in Vietnam, there is no standardised approvals process for CCS projects. Various legal regimes are likely to apply depending on the nature of the project operator. If the project operator is a foreign investor, for example, an Investment Policy Decision and/or an Investment Registration Certificate must be obtained from local authorities. Where projects involve land use, investors must apply for a Certificate of Land-Use Rights. However, there is little guidance under the current framework for potential CCS project operators.

Comprehensive application of the legal framework across all aspects of a CCS project

Vietnam's current framework does not regulate CCS projects and there remains considerable uncertainty about the aspects of the CCS project lifecycle. Table 14 provides a brief overview of the current regulatory landscape and the extent to which it addresses key elements of the CCS project life cycle.

Table 14. Key considerations in Vietnam's CCS legal and regulatory framework

Classification of CO_2	✓	CO_2 is regarded as a dangerous substance and there are strict requirements regarding its transportation via inland waterways and roads.
Ownership regime for sub-surface	✗	Ownership of the sub-surface in the context of CCS is not clarified. Property law and land rights legislation only define use rights of surface land in Vietnam. Sites may be expropriated by the state for use in the public interest.
Design standards for CCS projects	✗	There are no design standards for CCS activities that apply in respect of general mining activities, or health and safety specific laws for drilling and mining activities.
Transboundary movement of CO_2	✗	The transboundary movement of CO_2 is not addressed in Vietnamese law. Vietnam has not ratified the London Protocol.
Surface access and reclamation	✗	Not clarified under Vietnamese law. General land rights legislation provides that users "must use land for proper purposes in accordance with land parcel boundaries". It is unclear how this provision applies in the context of CCS.
Leakage provisions	✗	Leakage and irregularities associated with CO_2 storage activities are not dealt with under existing law. General environmental protection legislation regulates the discharge of wastes and the prevention of pollution; CCS projects may be required to comply with obligations established under existing environmental frameworks.
Transport of CO_2	✗	As CO_2 is regarded as a dangerous substance, the transport of CO_2 via both inland waterways and road is strictly regulated. Compliance with a host of safety and licensing obligations is required under the current framework. Nevertheless, these provisions do not support the transportation of CO_2 within the context of CCS projects and serve to impose restrictions.
Monitoring and verification requirements	✗	There are no specific monitoring and verification provisions in relation to CCS activities.
Storage and siting	✗	There are no specific provisions for storage and siting of CCS activities.
Closure	✗	There are no specific provisions for a CCS closure regime to deal with post-closure responsibilities and liabilities.

Siting of projects and the Environmental Impact Assessment framework

Although there is no regulatory framework specific to CCS, the nation's environmental legislation may hold obligations that are applicable to potential CCS operations in Vietnam. Mitigation and risk management responsibilities, in the context of the environment, are found in the Law on Environmental Protection 2020 and its 2025 amendments (NANOEN, 2026). The legislation requires the submission of an EIA report, which outlines monitoring and reporting obligations aimed at mitigation and risk management of the environmental effects of the proposed activity. Project proponents are required to consider how projects may harm the environment, any measures to be adopted to avoid and mitigate the project's impact, and the payment of compensation in the event of environmental pollution. Once an EIA Report has been approved, the operator must comply with any environmental protection activities that are requested by the authorities. The 2025 amendments to the EIA framework gave more responsibility to People's Committees at commune-level, giving them the authority to appraise and issue environmental permits for certain project types.

Stakeholder and public consultation

There are no provisions outlining public participation or consultation requirements for CCS projects in Vietnam. The Law on Environmental Protection 2020, however, requires projects subject to EIAs, which would likely include future CCS projects, to undertake consultation procedures with affected local communities. Project operators are required to prepare project-specific environmental management plans that must be published on Vietnam's national environment database.

Liability

A regulatory regime for the closure of CCS projects has not been established in Vietnam. Current risk assessment frameworks for activities with the potential to cause environmental damage and remediation provisions are based on environmental protection objectives. Compensation and costs are calculated where environmental damage occurs as a consequence of project activities. The current model is focused upon addressing environmental harm after its occurrence, rather than proactively managing and assessing risks associated with activities such as CCS operations.

Vietnamese laws also hold land use rights holders accountable for any damage resulting from their land use, with potential sanctions including civil, administrative, or criminal penalties for individuals. A framework for post-closure activities and the management of liability remains a critical gap in the country's regulatory framework for CCS.

2.8.3 LEGAL ISSUES FOR CONSIDERATION

Vietnam's legal and regulatory framework for CCS is inadequate and there is no guidance or clarity from the government as to how a CCS project would be implemented in the country. In the absence of CCS-specific legislation, it is likely that existing legislation governing environmental protection, mining operations, the treatment of wastewater and environmental damage may be applicable to CCS operations. An assessment of Vietnam's legal and regulatory environment, however, reveals that these frameworks do not adequately address all aspects of the CCS project lifecycle.

CCS-specific issues and requirements such as the classification of CO_2 for storage, property rights, monitoring and reporting and provisions to address potential instances of leakage from storage sites are yet to be addressed. The administrative arrangements may also prove complex for regulating a project, by virtue of the number of regulatory agencies likely to be involved.

Several of these existing regulatory frameworks, however, do include obligations for operators, including a requirement to undertake an environmental impact assessment, or to pay damages for environmental damage and remediation. As such, there may be opportunities to expand them to explicitly include CCS operations.

2.9 Singapore

Singapore submitted an updated version of its original NDC in November 2022 that highlights the nation's intention to reduce emissions to around 60 $MtCO_2e$ in 2030, after peaking its emissions earlier. Singapore will also aim to achieve net zero emissions by 2050. In February 2025 the country submitted its second NDC which outlined its goal of reducing emissions to between 45 and 50 $MtCO_2e$ in 2035 (NCCS, 2025).

The country has focused its mitigation efforts across several key sectors, in particular on the reduction of fossil fuel use in power generation. In this sector, the government has supported the shift towards the greater use of gas and highlights the percentage of natural gas used in electricity generation has increased from 19% to about 94% between 2000 and 2025 (EMA, 2025a). An increased focus on reducing the use of fuel oil and the more widespread deployment of solar PV are also important initiatives. In the industry sector, a strong focus upon energy efficiency is driving emissions reductions.

2.9.1 CCS-RELATED POLICY LANDSCAPE

The government of Singapore has emphasised the role of low-carbon technologies in achieving its emission reduction and net zero targets. In its 2020 Long-Term Low-Emissions Development Strategy, Singapore identifies investment in CCS as one of four key avenues for achieving national emissions reduction goals (National Climate Change Secretariat Singapore, n.d.). Furthermore, the National Climate Change Secretariat (NCCS), together with the country's Economic Development Board, commissioned a study in 2021, to examine the role of CCUS in addressing the emissions of the energy and chemicals sectors in Singapore. More recently, under its 2035 NDC, Singapore highlighted CCS's potential role in supporting decarbonisation in hard-to-abate sectors as well as in the waste and power sectors. The updated NDC also includes an abatement target of 2 Mtpa of CO_2 through CCS by 2030 (NCCS, 2025).

Under the Green Plan 2030, Singapore is also developing its position as a centre for carbon exchanges to facilitate carbon trading, and as a centre of expertise and service delivery for initiatives associated with CCUS projects (Government of Singapore, n.d.). The plan includes the financing of low-carbon development, low emissions, and emissions reduction projects, consultancy, assessment, reporting, and verification within South-East Asia and the broader international community.

In March 2025, the government announced it would be aiming to launch a CCS pilot at its waste-to-energy plants by 2026 (Economic Development Board, 2025a). In addition, in July 2025, the Energy Market Authority selected three power generation companies as winners of their 2024 grant call to conduct CCS feasibility studies and investigate post- and pre-combustion capture solutions (EMA, 2025). As part of the 2024 grant call, the Singaporean government also announced that it was developing a CCS project to aggregate CO_2 emissions on Jurong Island for overseas storage. Phase 1 of the project is expected to commence around 2030. The government will work with the lead developer S Hub, a consortium comprising Shell and ExxonMobil, to study the viability of developing a cross-border CCS project from Singapore. This includes evaluating the technical feasibility of aggregating CO_2 emissions in Singapore and collaborating with international partners to study potential CO_2 storage sites. The Economic Development Board has detailed plans to realise at least 2.5 million tonnes of carbon captured by 2030 through this project (EDB, 2024).

While the government has implemented a carbon tax on high emitters since 2019, with a planned ramp up to up to S$50-80/tonne CO_2e by 2030, CCS as a mitigation technology will still require further incentives and support (National Climate Change Secretariat Singapore, 2024). The carbon price increased from S$5/$tCO_2$-e in 2019 to S$25/tCO_2-e in 2024 and is set to increase to S$45/$tCO_2$-e in 2026 (Singapore Ministry of Sustainability and the Environment, 2024).

Singapore is also presently progressing options to provide services around CCUS projects, both to address national emissions liability and emissions reduction commitments, and to enhance the nation's role as a hub/cluster for CCUS projects in the South-East Asian region.

In October 2022 Singapore and Australia signed the Singapore-Australia Green Economy Agreement (Australian Government Department of Foreign Affairs and Trade, n.d.). The agreement builds upon earlier commitments, including the Low Emissions Solutions MOU, and will target a cooperative approach between the two nations towards supporting the transition to net zero emissions. The arrangement and the text of the agreement contain positive signals for collaboration around CCUS activities. The Agreement references the technology specifically in the "Principles of Green Economy Cooperation."

Singapore has also signed a Letter of Intent (LOI) with Indonesia to conduct cross-border CO_2 transport between the two countries (Ministry of Trade and Industry Singapore, 2024). Negotiations to formalise the LOI into a legal binding instrument are currently underway, with an additional MoU signed in June 2025 to deepen CCS collaboration between the two (Economic Development Board, 2025). Further action on cross-border CO_2 transport was taken in January 2025, with the signing of an MoU with Malaysia to collaborate on transboundary CCUS. The two countries also agreed to facilitate information sharing on CCS (Allen & Gledhill, 2025). In addition to Malaysia and Indonesia, Singapore has MoUs in place with Brunei, with whom it agreed to cooperate on CCS and explore potential cross-border CO_2 transport and storage opportunities (Shell Singapore, 2022).

2.9.2 ASSESSMENT OF LEGAL AND REGULATORY FRAMEWORK

Although CCS plays a critical role in Singapore's long-term emissions reduction strategy, the country does not currently have a legal and regulatory framework specific to CCS. Existing environmental, gas and marine pollution laws may provide a potential framework for regulating CCS activities, however, the current regime is under-developed across many aspects of the CCS project lifecycle.

As Singapore lacks suitable domestic CO_2 storage locations, its CCS deployment strategy includes plans to work with foreign countries to allow for the export of CO_2 for storage5F5F[4] (Norton Rose Fulbright, 2025). To this end, the CCS Programme Office has been recently set up and will be housed under the Energy Market Authority (Energy Market Authority of Singapore, 2024). In collaboration with the Ministry of Trade and Industry, the CCSPO is advancing bilateral discussions with potential store countries for the nation's CO_2 with MoUs already signed with Indonesia and Malaysia.

The following sections consider Singapore's existing legal and regulatory regime in greater detail to identify the extent to which projects may be facilitated under the current framework.

Existing approval process for applying for and obtaining regulatory approval for CCS projects

For the capture, transport and temporary storage of CO_2, Singapore has not established a separate approvals pathway for CCS projects. However, CCS projects may be required to obtain relevant permits and permissions complying with general environmental pollution control legislation, including air and water pollution control regulations. CCS project operators are likely to be required to comply with obligations under legislation that currently does not explicitly mention CCS but may have potential application due to the nature of activities covered.

There are various other legislative regimes that are relevant to CCS, including legislation governing environmental protection and management, the safety, technicalities and economics of gas transport, and the discharge of harmful substances at sea to environmental management practices, including monitoring and reporting of GHG emissions annually and land acquisitions and transfers. A plethora of regulatory agencies oversee and administer these legal regimes, and it is likely that CCS activities will trigger the regulatory oversight of these bodies, such as the Ministry of Sustainability and the Environment,

4 Singapore could also consider introducing legislative measures to enable the deduction of post-combustion or process-captured CO_2 from the carbon tax liabilities of entities, as well as from the country's overall carbon inventory. The Carbon Pricing Act, in effect since 2019, would need to be amended to incorporate such provisions.

the Energy Market Authority, the Maritime and Port Authority, the Singapore Land Authority, among others.

The responsibilities of the project operator and regulator are not clearly defined within Singapore's legal framework, due to the absence of CCS-specific regulatory pathway. However, the project operator will be responsible for obtaining all of the necessary approvals and licences for all stages of a CCS project under the various legal regimes highlighted, while the regulatory agencies highlighted previously will be responsible for granting the necessary approvals and permits.

Comprehensiveness application of the legal framework across all aspects of a CCS project

Under the current laws and regulations, there are no comprehensive laws that uniformly and systematically regulate the capture of CO_2. Although various existing laws regulate CO_2 as a greenhouse gas, it is not in the context of CCS. Key issues relating to the CCS project lifecycle such as permanence, liability for leakage, and processes and responsibilities relating to monitoring and closure are also not addressed within the current regulatory model. Table 15 provides a brief overview of the current regulatory landscape and the extent to which it addresses key elements of the CCS project life cycle. Note, there is a lack of suitable CO_2 storage sites in Singapore and therefore a legal and regulatory framework for CCS is unlikely to cover domestic CO_2 storage.

Table 15. Key considerations in Singapore's CCS legal and regulatory framework

Classification of CO_2	✓	CO_2 is defined as a greenhouse gas under environmental legislation and the Carbon Pricing Act.
Ownership regime for sub-surface	✗	There is no ownership regime for sub-surface storage of CO_2. However, landowners own the underground sub-surface up to 30 meters under the Singapore Height Datum (a standardised benchmark for measuring the elevation of land relative to sea level), unless otherwise specified in the title.
Design standards for CCS projects	✗	No specific standards have been prescribed for the design and construction of CCS projects. However, conditions may be imposed under environmental legislation to serve environmental protection and pollution prevention objectives, including requiring the project operator to install and operate equipment in a certain manner, carry out tests and monitoring, and prohibiting the use of certain equipment.
Transboundary movement of CO_2	✗	Singapore is not a party to the London Protocol. If exporting CO_2 to a country that is a party to the London Protocol and has ratified its 2009 amendment to Article 6, Singapore would need to comply with the requirements under the London Protocol by virtue of the importing party's obligations.
Surface access and reclamation	✗	There is no CCS-specific regime for surface access and reclamation in existing legislation.

Leakage provisions	✗	There are no specific provisions for leakage arising from CCS projects; however, the leakage of CO_2 would be treated as pollution of the environment under existing legislation.
Transport of CO_2	✓	There are no specific provisions applicable to CO_2 transport activities. However, Singapore's existing gas transportation, service and supply regime under the Gas Act has the potential to be extended to the transportation of CO_2 for CCS.
Monitoring and verification requirements	✓	Under existing environmental legislation, a project operator may be required to install suitable monitoring equipment or systems to monitor the quality or quantity of the emissions or discharge of CO_2. Compliance with Singapore's Environmental Protection and Management Act 1999 is heavily monitored by the Director-General of Environmental Protection.
Storage and siting	✗	Not applicable.
Closure	✗	As there is no CCS-specific piece of legislation, there is no specific closure regime.

Siting of projects and the Environmental Impact Assessment framework

Singapore currently lacks a comprehensive framework to assess the environmental impact of each stage of a CCS project. However, development projects are generally required to undergo an evaluation process of the development's potential impact on the environment, human health and safety and traffic. Development projects situated close to sensitive nature reserves are subject to further environmental impact requirements and more detailed environmental studies. Planning approvals are also contingent upon meeting the regulatory standards imposed by the National Environmental Agency, which administers the Environmental Protection and Management Act and the Environmental Public Health Act.

The Environmental Protection Management Act also generally mandates pollution control studies and that project operators of large projects submit a proposal for implementation of measures to prevent, reduce or control pollution of the environment. Further, a project operator is required to self-monitor emissions and discharge as well as keep a proper record of monitoring results to be submitted as required. Lastly, project owners are required to take out insurance policies for any liabilities or damages that may be prescribed under the regulations.

Stakeholder and public consultation

CCS-specific public engagement and notification requirements are absent in Singapore. However, Singapore's regulatory authorities regularly hold public consultations or closed group consultations on significant projects. In October 2024, a public consultation on Singapore's decarbonisation journey was launched, inviting comments on the decarbonisation measures it will undertake (NCCS, 2024). Furthermore, Singapore has also conducted public consultation exercises for major projects that have the potential to impact the environment or nearby communities, with regulatory authorities notifying the affected public.

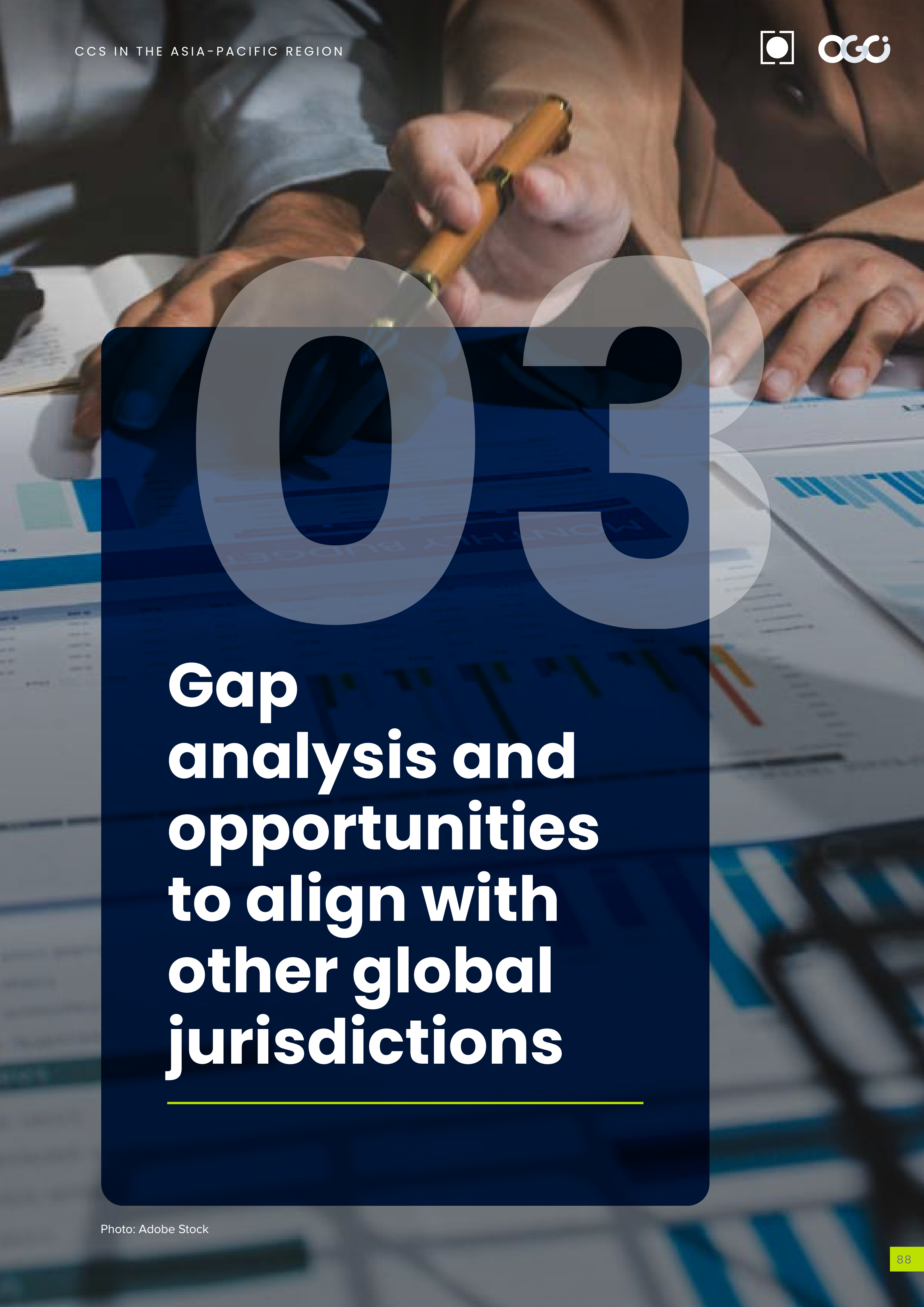
Liability

Singapore's legal and regulatory framework does not address the closure phase of a CCS project or liability issues that may arise from CCS activities. However, liability may be imposed under the Gas Act, which provides that it is an offence to wilfully, recklessly or negligently undertake any act or permit any act which damages or is likely to damage any submarine gas pipeline or associated infrastructure. Furthermore, accidental releases of stored CO_2 could also be considered pollution, and the project operator could be liable for an offence under Singapore's environmental legislation.

2.9.3 LEGAL ISSUES FOR CONSIDERATION

There are no comprehensive laws that uniformly and systematically regulate CCS in Singapore. A key component missing in the current regulatory landscape is a clear permitting or licensing framework delineating the requirements or criteria for obtaining authorisation to undertake CCS-related activities. Permanence requirements such as site characterisation and assessment, liability for leakage, and processes and responsibilities relating to monitoring and closure are also not addressed within the current regulatory model. Singapore is not a party to the London Protocol.

In the context of the nation's plans to develop a CCS hub, it is likely imperative that Singapore expedites the process to establish a regulatory pathway for safely conducting CO_2 capture and transport/export activities within its domestic legal framework. Singapore may also be required to ensure a robust framework that establishes adequate permanence requirements for CO_2 exported from Singapore for storage overseas.



03

Gap analysis and opportunities to align with other global jurisdictions

Photo: Adobe Stock

3 Gap analysis and opportunities to align with other global jurisdictions

The preceding sections provided an assessment of the legal and regulatory regimes of nine jurisdictions within the APAC region for facilitating CCS activities. A key takeaway from the assessment is that across the region, with the exception of a few notable examples, legal and regulatory frameworks to facilitate CCS projects are largely absent. The development of legislation remains a key priority for many countries in the context of recent ambitious project deployment objectives.

Table 16 provides a summary of the gaps in each jurisdiction when considering the assessment criteria developed by the Institute to determine the comprehensiveness of a national legal and regulatory framework for facilitating CCS activities.

Where gaps are identified, the table also provides recommendations for addressing these gaps with the objective of how each jurisdiction can develop or enhance their frameworks to facilitate the widespread and secure deployment of CCS projects, including those involving regional transport and storage activities.

Table 17 provides an overview of the gaps and opportunities for policy frameworks within each jurisdiction. Gaps and recommendations are discussed within the context of the policy assessment criteria developed by the Institute to provide a holistic understanding of the policy environment within each jurisdiction.

Table 16. Legal and regulatory gaps and opportunities

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
Existing approval process for applying for and obtaining regulatory approval for CCS projects		
Australia	• With the exception of the state of Victoria, regulatory roles and responsibilities, where they overlap between the Commonwealth and subnational levels, are not clarified. • The approval of onshore CCS projects is not consistent across Australia as multiple frameworks impose differing obligations.	• Clarify regulatory roles and responsibilities of the various Commonwealth and state agencies involved in the approval and regulation of CCS projects in states such as Western Australia, South Australia and Queensland, and in the Northern Territory. • Achieve consistency in the approval of CCS projects and project requirements across all Australian jurisdictions by mirroring Commonwealth legislation and publishing regulatory guidance on navigating the myriad approval processes involved under the various overlapping legislative regimes.
Japan	• Regulatory approval for CCS projects currently falls within the purview of environmental legislation and does not impose specific obligations in respect of the various unique aspects of a CCS project. • The responsibilities of project operators and regulators are not clearly defined, especially at different stages of the project lifecycle. • The new CCS Business Act provides for the permitting of CCS operations across various stages. However, the detail regarding the implementation of this permitting scheme is yet to be clarified.	• Implement specific legislation or enhance existing legislation to establish a separate approval pathway for projects. • Clarify regulatory roles and responsibilities at all stages of a CCS project lifecycle. • Establish supporting regulations clarifying permitting criteria for CO_2 storage site exploration and injection operations.

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
Indonesia	• Although Indonesia has established a separate pathway for the approval of CCS projects, Interactions with wider environmental and other legislation that will be applicable to the CCS process and the regulatory authorities overseeing the implementation of such legislation are not sufficiently clarified. • There is a lack of clarity regarding coordination between the agencies assigned with implementing Indonesia's newly established legal framework for CCS.	• The current framework, while adequate for permitting CCS projects, should clarify how wider environmental and resource legislation interacts with its provisions. • The current framework should also clarify the regulatory roles and responsibilities of state agencies overseeing the implementation of such legislation in the context of CCS projects. • Provide guidance on the regulatory functions and relationships between the various state agencies responsible for administering Indonesia's new CCS-specific legal framework. • Regulatory and institutional capacity to implement Indonesia's new framework should be improved.
Malaysia	• A comprehensive CCUS Act and accompanying CCUS Regulations have been established. The Act and Regulations cover CCS projects in Peninsular Malaysia and the Federal Territory of Labuan. • In Sarawak, CCS projects are regulated under the Sarawak CCS Rules.	• The interaction between the Sarawak CCS Rules and the obligations imposed by environmental and wider national legislation is not clear.
South Korea	• South Korea's current regulatory landscape is insufficient for approving CCS projects. Although the new CCS Act establishes a permitting pathway for exploration and operation of CO_2 storage sites, the details pertaining to the implementation of permitting pathways and exact permitting requirements remain in need of further clarification through supporting regulations. • Since the dissolution of MOTIE, the MCEE seems to be responsible for CCS regulation, but the permitting process of CCS projects is unclear.	• Improve clarity on application requirements and supplement new permitting pathways established under the new CCS Act with supporting regulations that clarify application criteria • Provide clarity regarding the allocation of roles and responsibilities of various permitting authorities in accordance with the new permitting pathway established under the new CCS Act for both onshore and offshore CO_2 storage sites.

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
Thailand, Brunei, Singapore, Vietnam	• Thailand, Brunei, Singapore and Vietnam currently have not established a separate pathway for the approval of CCS projects. • Regulatory roles and responsibilities in relation to the approval and regulation of CCS projects have not been clarified across all four jurisdictions.	• Determine a clear pathway for the approval of CCS projects within regulatory frameworks. • Allocate and clarify the roles and responsibilities for the approval and regulation of CCS amongst the relevant regulatory agencies. • The relevant ministries and regulatory agencies should Issue guidance, including national protocols, informing project operators about compliance with various obligations under CCS-specific legal and regulatory regimes. • Establish clear timelines for the approval of applications for permits to conduct CCS activities.
Comprehensiveness of the legal framework across all aspects of a CCS project		
Australia	• Provisions dealing with closure and the transfer of liability for CO_2 stored are inconsistent across the Commonwealth and states and territories. Several states and territories, such as New South Wales, the Australian Capital Territory, and the Northern Territory, also currently lack CCS-specific legislation. • Provisions regulating certain activities across the CCS project lifecycle need to mirror the Commonwealth framework, particularly where such activities, such as CO_2 transport, straddle Commonwealth and state boundaries.	• Australia has now enacted legislation implementing its obligations under the 2009 amendment to the London Protocol enabling transboundary CO_2 export activities into Australian waters. However, the new legal provisions do not clarify roles and obligations where they interact with CCS activities conducted in state waters. Further regulatory guidance on this aspect is required. • Australia should also take steps to ensure that where certain activities, such as CO_2 transport, straddle both Commonwealth and state boundaries, or where they cross state boundaries, the regulatory roles and responsibilities of each jurisdiction is clarified.

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
Japan	• In advance of the new CCS Business Act's entry into force, Japan's current CCUS permitting model is not aimed at promoting CCS as a low-carbon technology, but is rather primarily focused on protecting the marine environment from any adverse impacts of sub-seabed storage activities. • Consequently, the current framework does not facilitate the large-scale deployment of CCS activities, including regional CO_2 transport and storage models. • As Japan is actively pursuing CO_2 export for overseas storage, the lack of provisions dealing with transboundary CO_2 movement activities in Japan remains a key gap in the country's framework. However, recent steps taken to formally ratify the London Protocol amendment are encouraging. • In the case of offshore CO_2 storage activities in Japan, the current framework does not provide clarity on key aspects such as ownership of sub-surface pore space, long-term liability and site closure requirements. • Under the new CCS Business Act, Japan has established a licensing framework for the grant of CO_2 storage site exploration and injection by the METI, but details regarding the implementation of this framework are yet to be clarified.	• Although the new CCS Business Act is intended to facilitate large-scale and commercial deployment of CCS, various novel aspects of a CO_2 storage project such as security of tenure for storage sites, ownership of the pore space, site closure and long-term liability require further clarification through supporting regulations. • Finalise the official ratification of the 2009 amendment to the London Protocol or enable the provisional application of the 2009 amendment of the London Protocol to facilitate transboundary CO_2 storage activities. • Clarify regulatory roles and responsibilities in relation to domestic and transboundary CO_2 storage value chains.

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
Indonesia	• Indonesia's new framework regulating CCS activities is comprehensive across the CCS project lifecycle. The new legislation, however, remains fragmented and the interaction between the various instruments may be clarified further through supplementary guidance.	• Clarify interactions between the various legal pathways to conduct for CCS in Indonesia. • As Indonesia is not a Party to the London Protocol, enter into appropriate government-to-government agreements with neighbouring countries to facilitate cross-border CO_2 trade, clarifying aspects such as CO_2 stream criteria, transportation modes and requirements, permitting responsibilities and liabilities. • Clarify obligations of project operators involved in cross-boundary CCS operations within domestic legislation. • Clarify project operator and regulator's roles and responsibilities in respect of in-country CO_2 transport.
Malaysia	• The CCUS Act and CCUS Regulations provide a comprehensive legal and regulatory regime under which projects in Peninsular Malaysia and the Federal Territory of Labuan can be permitted. • Although the Sarawak CCS Rules establish a comprehensive regulatory framework for CCS activities in the state of Sarawak, key elements remain unaddressed such as the classification of CO_2, ownership of the pore space and transboundary CO_2 storage activities. • The interaction of the Sarawak CCS Rules with national legislative requirements in relation to various issues that arise from the nature of CCS activities, such as CO_2 transport and pore space ownership is also unclear.	• Take steps to ratify the 2009 amendment to the London Protocol or enable provisional application of the 2009 amendment to the Protocol in order to facilitate transboundary CO_2 movement and storage activities. • Clarify regulatory roles and responsibilities in respect of cross-border CO_2 transport and storage activities within domestic legislation. • Clarify the interaction of the Sarawak CCS Rules with other national or state legislative requirements relating to activities such as CO_2 transport and pore space ownership.

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
South Korea	• South Korea's new CCS Act establishes comprehensive and integrated regulatory requirements addressing the various phases of the CCS project lifecycle. Key issues such as siting, closure, and long-term monitoring are addressed. The framework, however, is silent regarding the allocation, scope and extent of post-closure responsibilities, transfer of liabilities and financial mechanisms.	• Although key aspects of the CCS project lifecycle have been addressed under the new CCS Act, these provisions largely establish a framework for conducting activities and ensuring compliance with obligations under key phases of the project lifecycle. Further details must be promulgated to provide greater clarity and certainty to project operators regarding compliance with and implementation of regulatory requirements applicable to aspects such as permitting CCS operations, site characterisation, MRV, closure and post-closure activities and transfer of liability.
Thailand, Brunei, Singapore, Vietnam	• All 4 jurisdictions lack comprehensive regimes addressing the novel and unique aspects of the CCS project lifecycle. • Thailand, Brunei, Singapore and Vietnam have not ratified the 2009 amendment to the London Protocol or taken steps to enable provisional application of the 2009 amendment enabling transboundary CO_2 storage activities although major regional transport and storage models are being contemplated.	• Developing comprehensive CCS specific legislation is key to the widespread deployment of CCS within these jurisdictions. It is noteworthy that in Thailand, regulatory developments are underway. • It is also critical that domestic frameworks are developed to facilitate and remove barriers to transboundary CO_2 storage activities, particularly where CO_2 export or import is contemplated.
Siting of projects and the Environmental Impact Assessment framework		
Australia	• Although Australia possesses a comprehensive EIA process applicable to CCS projects at both the Commonwealth and state levels, with the exception of the state of Victoria, the interaction of the EIA framework between the levels needs to be clarified further.	• In states and territories which are yet to establish comprehensive CCS-specific legislation, clarify the interaction of EIA frameworks where CCS projects straddle Commonwealth and state boundaries. • Clarify the interaction of the roles and responsibilities of regulators and agencies at both the Commonwealth and State levels in relation to CCS projects.

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
Japan	• EIA requirements are only applicable to offshore CO_2 storage activities and the current framework applies Japan's obligations under the London Protocol, which is underpinned by the objective of preventing marine pollution. • No further provisions from other domestic EIA legislation apply to CCS projects and the interactions of domestic frameworks with the Marine Pollution Prevention Law or the new CCS Business Act are not clarified.	• Adopt consistent and specific EIA legislative provisions applicable in the context of CCS projects in Japan.
Indonesia	• Indonesia's new CCS-specific legal regime mandates CCS projects to address environmental and social impacts per existing laws, likely bringing CCS activities under the purview of Indonesia's national EIA framework. However, clarity as to how CCS projects must comply with EIA requirements under the existing framework is not provided.	• Establish clear guidelines on integrating CCS projects with the national EIA framework (AMDAL process) to ensure transparency and compliance. • Clarify the interaction of various regulatory agencies when approving environmental impact assessment reports submitted by CCS project operators.
Malaysia	• The CCUS Regulations state that environmental laws must be adhered to prior, during, and post injection operations. Although Malaysia has not established specific environmental impact assessment requirements in the context of CCS projects, existing requirements under environmental legislation may still be applicable, as with any large project. • The Environment Quality Act 1974 requires an EIA to be prepared in consultation with the Department of Environment (DOE), which involves both a preliminary EIA and a detailed EIA for major projects with the potential to significantly impact the environment. CO_2 storage activities require approval from the DOE as part of broader project approvals. • In Sarawak, general rules regarding notification to authorities of leakages, and taking corrective actions apply to CCS projects.	• Clarify the application of national EIA requirements, risk mitigation and management requirements for CO_2 storage projects in Malaysia.

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
South Korea	• The CCUS Act provides for the siting of capture, transport and storage facilities in the context of CCS operations. The Act does not clarify requirements for EIAs. However, existing EIA frameworks, such as the Environmental Impact Assessment Act of 2017, are likely to be relevant.	• Establish clear guidance or regulations as to the application of environmental impact assessment or risk mitigation requirements to CCS projects. • Allocate environmental approval responsibilities to relevant regulatory agencies.
Thailand, Brunei, Singapore, Vietnam	• Although all four jurisdictions have their own environmental impact assessment and risk mitigation measures for large projects which may be extended to CCS projects, the application of these requirements are not clear.	
Stakeholder and public consultation		
Australia	• Extensive stakeholder consultation and public notification requirements across the various jurisdictions in Australia would apply to CCS projects, however, the requirements are not consistent, and the interactions of regulatory frameworks are not clear.	• Issue guidance on the interaction of environmental frameworks across the Commonwealth and state levels for stakeholders.
Japan, Indonesia, Malaysia, Thailand, South Korea, Brunei, Singapore, Vietnam	• Stakeholder consultation and public notification requirements in the context of CCS projects are absent across all jurisdictions. • However, general public consultation and notification requirements under existing environmental protection regimes may be extended to CCS projects. The interaction of these frameworks is unclear.	• Establish specific requirements for stakeholder consultation and public notification early in the permitting process for CCS projects and in particular, project models involving CO_2 imports to foster stakeholder confidence and smooth facilitation of projects.

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
Liability		
Australia	• The application of closure and long-term liability requirements, while extensive across the various jurisdictions, are inconsistent between them and further clarification as to the interaction of various frameworks is required.	• Further harmonisation of legislative requirements across the various jurisdictions is required to provide greater certainty.
Japan	• Until the CCS Business Act's entry into force, there is no specific consideration or provision for liability issues related to post-closure and long-term storage obligations and breaches in CCS projects. • Under the new CCS Business Act, provision is made for the storage rights relating to a closed CO_2 storage to transfer to JOGMEC. However, the scope and extent of liabilities transferred are not clarified.	• Clarify the issue of closure and allocation of long-term liability for CO_2 stored in the context of CCS projects within domestic legislation. The allocation of liability for CO_2 stored overseas also requires clarification.
Indonesia	• Upon fulfilling closure conditions, including verification of CCS activities and monitoring for risks, a contractor and storage permit operator's rights and responsibilities under a CCS contract are transferred to the state.	• Clarity is needed regarding the scope and extent of liabilities transferred to the state upon closure of a CO_2 storage site.
Malaysia	• The CCUS Act provides for the obligations related to a CO_2 storage site to be transferred to the government once prescribed conditions are met, or the prescribed period from the issuance of the Closure Certificate has lapsed. • In Sarawak, where CO_2 is permanently stored in storage sites, the CO_2 is treated as a fixture and part of the state land, and the state becomes the owner of the stored CO_2.	• Liability provisions for imported CO_2 need to be clarified.

	Gaps in existing legal and regulatory frameworks	Opportunities to align to with other global jurisdictions
Thailand, South Korea, Brunei, Singapore, Vietnam	• Issues relating to long-term stewardship and liabilities in the context of CCS projects are not clarified within the legal frameworks of all 6 jurisdictions. • The issue of liability is dealt with in draft regulation in Thailand. However, the bill faces an uncertain timeline. • General closure requirements under existing oil and gas legislation may apply, however, the application of these requirements is not clarified.	• Clarify the issue of closure and allocation of long-term liability for CO_2 stored in the context of CCS projects within domestic legislation. The allocation of liability for CO_2 stored overseas, or imported for storage, also requires clarification.

Table 17. Policy gaps and recommendations

Country	Gaps	Opportunities to align to with other global jurisdictions
Fiscal incentives		
Australia	• Carbon pricing is not regulated through a formal mechanism, however the ACCU Scheme has a market price. • Australia instituted a carbon tax in 2011 and revoked it in 2014.	• Support CCS with public finance and fiscal incentive policies like tax relief.
Japan	• Japan introduced a carbon tax in 2012 that is applied as a surcharge on existing petroleum and coal taxes	• Supplement the carbon tax that was implemented in 2012 with other strong fiscal incentive policies, like tax relief.
Malaysia	• Malaysia's introduced an Investment Tax Allowance in 2023 for companies that conduct CCS activities or provide CCS services.	• Malaysia plans to implement a carbon tax from 2026, in the iron, steel, and energy industries. This will support the safeguarding of Malaysia's exports against the EU's CBAM that is now in force.
South Korea	• Tax incentives are in place for carbon-neutral technologies, including CCUS and hydrogen. Tax credit rates were increased in 2024.	• Continue to provide fiscal support aligned with best practice..
Indonesia	• Indonesia's carbon tax is under consideration.	• Implement strong fiscal incentive policies. • Supplement carbon taxes with strong fiscal incentive policies like tax relief that include CCS projects. • Current best practice includes tax relief like the 45Q tax credit program in the United States.

Country	Gaps	Opportunities to align to with other global jurisdictions
Singapore	• Singapore's carbon tax was implemented in 2019.	• Implement strong fiscal incentive policies. • Supplement carbon taxes with strong fiscal incentive policies like tax relief that include CCS projects. • Current best practice includes tax relief like the 45Q tax credit program in the United States.
Thailand, Brunei, Singapore, Vietnam	• These countries do not have a formal fiscal incentive policy in place that supports CCS or action on climate change that could be broadened to support CCS.	• Implement strong fiscal incentive policies. • Supplement carbon taxes with strong fiscal incentive policies like tax relief that include CCS projects. • Current best practice includes tax relief like the 45Q tax credit program in the United States.
Public finance		
Australia	• Carbon Capture Technologies Program launched in 2025. • The CarbonNet project in Victoria has R&D components that received government funding support. • Carbon capture is not included under the Clean Energy Finance Corporation Act.	• Expand/extend Australia's clean hydrogen and carbon capture investment grants. • Include carbon capture under the Clean Energy Finance Corporation Act. • Augment private sector support for R&D through fiscal incentives or public finance. • Support covered facilities under the SGM to deploy technologies that will contribute to achieving declining emissions baselines.
South Korea	• Under the CCUS Act, subsidies and loans are made available for R&D projects, including eligible CCUS projects. This support needs to be expanded to support commercial deployment of CCUS.	• The government has made funding available for emissions reduction and offset projects through 2030. CCUS could potentially benefit from this programme.

Country	Gaps	Opportunities to align to with other global jurisdictions
Japan	• Funding under NEDO's JPY2 trillion Green Innovation Fund, which supports multi-year decarbonisation demonstrations	• Extend the financial support from METI, NEDO, and JOGMEC to more industry-led projects.
Indonesia, Malaysia, Thailand, Brunei, Singapore, Vietnam	• These countries do not have a formal public finance policy in place that supports CCS.	• Support CCS through a dedicated grant or loan program.
Market mechanisms		
Australia	• The ACCU scheme currently does not provide sufficient incentive to scale up CCS, due to the current costs of CCS being much higher. • The ACCU Scheme currently only incentivises the least-cost abatement technologies. As such, only certain types of CCS applications, such as CCS applied to natural gas processing, which is known as a cheaper application of the technology, may benefit.	• Continue support for ACCUs and the Safeguard Mechanism. • Complement ACCUs through the introduction of a tax credit or subsidy, to encourage deployment of CCS beyond low-cost applications.
Japan	• While formal market mechanisms exist in these countries, or are in the process of being developed, it remains important to ensure that CCS activities are not excluded from their scope.	• Ensure CCS is included in Japan's GX-ETS
Indonesia	• While formal market mechanisms exist in these countries, or are in the process of being developed, it remains important to ensure that CCS activities are not excluded from their scope.	• Ensure CCS is included in the ETS that Indonesia established in 2023 by establishing a clear methodology to generate credit from CCS projects.
Malaysia	• While formal market mechanisms exist in these countries, or are in the process of being developed, it remains important to ensure that CCS activities are not excluded from their scope.	• Ensure CCS is included in Malaysia's national ETS that is under consideration.

Country	Gaps	Opportunities to align to with other global jurisdictions
Thailand	• While formal market mechanisms exist in these countries, or are in the process of being developed, it remains important to ensure that CCS activities are not excluded from their scope.	• Ensure CCS is included in Thailand's national ETS that is under consideration.
South Korea	• While formal market mechanisms exist in these countries, or are in the process of being developed, it remains important to ensure that CCS activities are not excluded from their scope.	• Ensure CCS in includes in Korea's ETS, operational since 2015. • Continue support for the Republic of Korea Offset Credit Mechanism.
Singapore	• While formal market mechanisms exist in these countries, or are in the process of being developed, it remains important to ensure that CCS activities are not excluded from their scope.	• Ensure Singapore's Carbon Markets Programme includes CCS.
Vietnam	• While formal market mechanisms exist in these countries, or are in the process of being developed, it remains important to ensure that CCS activities are not excluded from their scope.	• Ensure CCS is included in Vietnam's ETS, launched in 2025. Policies were announced in 2022 with other technical considerations to be developed in 2023.
Brunei	• Formal market mechanisms do not exist in Brunei.	• Formal market mechanisms could be established that include CCS.

<table>
<tr><th>Country</th><th>Gaps</th><th>Opportunities to align to with other global jurisdictions</th></tr>
<tr><td colspan="3">Institutional strength and government support</td></tr>
<tr><td>Australia</td><td>Australia has legislated and regulates CCS at both the national and state levels. A centralised/national approach to regulating all aspects of the CCS value chain can provide consistency to all sub-national jurisdictions while demonstrating regional leadership.
Australia currently lacks an economy-wide CCS deployment roadmap.
The Government mentions CCS through a variety of different avenues: laws, white papers, and policy documents to name a few.</td><td>Continue support for CCS through the following:
Australia’s federal body (Climate Change Authority) and publications on the potential of carbon sequestration.
Australia’s Net Zero by 2050 Plan.
Australia’s Future Gas Strategy.
References to meeting emissions targets in the updated Safeguard Mechanism.
Amendments to the National Greenhouse and Energy Reporting Act through the Safeguard Mechanism.
The Climate Change Authority refers to CCS.
Australia’s Long-Term Emissions Reduction Plan.
Develop an economy-wide CCS deployment roadmap with clear timelines, targets and milestones.</td></tr>
<tr><td>Japan</td><td>Japan has CCS demonstration projects and while there is support for them, the country can benefit from formal support through legislation and regulation.
Japan includes CCS in its Long-term CCS Roadmap.
The Strategic Roadmap for Hydrogen and Fuel Cells document mentions CCS.</td><td>Continue support for Japan’s Green Growth Strategy for Carbon Neutrality in 2050 with mentions to CCUS and DACCS.</td></tr>
</table>

Country	Gaps	Opportunities to align to with other global jurisdictions
Indonesia	• Indonesia has an opportunity to coordinate national CCS policy around the 2023 and 2024 CCS regulations.	• Continue support for Indonesia's Ministry of Energy and Mineral Resources 2023 CCS regulations – MEMR 2/2023. PR 14 of 2024 and PR 16 of 2024 – that have synergies with CCS. • Ensure CCS is included in Indonesia's Net Zero by 2060 commitment – in discussion. • The Indonesian Government should continue support for the National Action Plan Addressing Climate Change mentions CCS (2007).
Malaysia	• Malaysia includes CCUS as a key pillar in its 2023 National Energy Transition Roadmap.	• Ensure CCS is included in Malaysia's Plan for emissions reduction; and that commitments are clear. • Ensure CCUS is included in the next NDC update.
South Korea	• South Korea included CCS in its National Basic Plan for Carbon Neutrality and Green Growth.	• Ensure CCS is included in South Korea's Net Zero by 2050 or sooner commitment.
Thailand	• While institutional support for actions to reduce emissions exists in these countries (Brunei needs to establish support), it is essential that CCS is not excluded.	• Continue support for Thailand's updated NDC that mentions CCS and expand support for CCS formally through policy, law, and regulation. • Formalise amendments to Petroleum Law to establish CCS regulatory framework.
Brunei	• While institutional support for actions to reduce emissions exists in these countries (Brunei needs to establish support), it is essential that CCS is not excluded.	• Establish support for CCS through formal institutional support.
Singapore	• While institutional support for actions to reduce emissions exists in these countries (Brunei needs to establish support), it is essential that CCS is not excluded.	• Ensure CCS is included in Singapore's Net Zero by 2050 Strategy/Policy.

Country	Gaps	Opportunities to align to with other global jurisdictions
Vietnam	• While institutional support for actions to reduce emissions exists in these countries (Brunei needs to establish support), it is essential that CCS is not excluded.	• Ensure CCS is included in Vietnam's NDC and national commitments.
Information sharing and international collaboration		
Australia	• These countries share information and collaborate through different fora, for example both are members of the IEAGHG and the Clean Energy Ministerial' s CCUS Initiative.	Continue support for: • Sharing of information and learnings from the CarbonNet project. • Participation in ISO/TC 265 carbon dioxide capture, transportation, and geological storage. • CCS being part of the Technology Investment Roadmap. • The ADB's Carbon Capture and Storage Fund established with Australia. • Membership of the Clean Energy Ministerial's CCUS Initiative. • Membership of the IEAGHG • The Regional Cooperation Initiative on Carbon Sequestration. • Australia and Singapore signed an MOU in 2020. Subsequently, Australia signed an MoU with South Korea in 2024. Cooperation extends to information sharing. • CCS-related MOUs have also been concluded in the private sector.

Country	Gaps	Opportunities to align to with other global jurisdictions
Japan	• These countries share information and collaborate through different fora, for example both are members of the IEAGHG and the Clean Energy Ministerial' s CCUS Initiative.	Continue support for: • Participation in ISO/TC 265 carbon dioxide capture, transportation, and geological storage. • Collaboration through the Global Clean Energy Action Forum funding for Clean Energy Technology Demonstrations. • Contribution to the Green Climate Fund. • Membership of the Clean Energy Ministerial's CCUS Initiative. • Membership of the IEAGHG. • Membership of the Asia CCUS Network.
Indonesia	• These countries contributes to ASEAN-wide CCS discussions through the Asean Centre for Energy (ACE). • CCS is mentioned only in the abbreviations list in Indonesia's 2012 Technology Needs Assessment.	Continue support for: • Membership of the Clean Energy Ministerial's CCUS Initiative. • Contributing to the Green Climate Fund. • Continue support as a participating country in ISO/TC 265 carbon dioxide capture, transportation, and geological storage (Malaysia). • Continue regional collaboration as Asia CCUS Network members. Continue pursuing MoUs with neighbouring countries to collaborate and cooperate on CCS-related knowledge sharing and technology transfer.

Country	Gaps	Opportunities to align to with other global jurisdictions
Malaysia	• These countries contributes to ASEAN-wide CCS discussions through the Asean Centre for Energy (ACE).	Continue support for: • Membership of the Clean Energy Ministerial's CCUS Initiative. • Contributing to the Green Climate Fund. • Continue support as a participating country in ISO/TC 265 carbon dioxide capture, transportation, and geological storage (Malaysia). • Continue regional collaboration as Asia CCUS Network members. Continue pursuing MoUs with neighbouring countries to collaborate and cooperate on CCS-related knowledge sharing and technology transfer.
Thailand	• These countries contributes to ASEAN-wide CCS discussions through the Asean Centre for Energy (ACE). • Thailand mentions CCUS in its updated NDC and in its LT-LEDS.	• Update dated references to CCS with the latest in the industry's learnings.
South Korea		Continue support for: • Participation in ISO/TC 265 carbon dioxide capture, transportation, and geological storage. • Collaboration through the Global Clean Energy Action Forum funding for Clean Energy Technology Demonstrations. • Contribution to the Green Climate Fund. • Membership of the Clean Energy Ministerial's CCUS Initiative. South Korea has an opportunity to update its guidance and collaborative efforts through extending regional partnerships.

Country	Gaps	Opportunities to align to with other global jurisdictions
Brunei	• These countries contributes to ASEAN-wide CCS discussions through the Asean Centre for Energy (ACE). • Brunei does not currently share information on CCS.	• Create opportunities to collaborate and to exchange information in the South-East Asian region.
Singapore	• These countries contributes to ASEAN-wide CCS discussions through the Asean Centre for Energy (ACE).	Continue support for: • Australia and Singapore signed an MOU in 2020. • Collaboration through the Global Clean Energy Action Forum funding for Clean Energy Technology Demonstrations. • Continue collaboration through the MoUs signed with Malaysia and Indonesia in 2025.
Vietnam	• These countries contributes to ASEAN-wide CCS discussions through the Asean Centre for Energy (ACE). • Vietnam contributes to ASEAN-wide CCS discussions through ACE.	• Create further opportunities to collaborate in the South-East Asian region and to exchange information.

04 Conclusions

Photo: Adobe Stock

4 Conclusions

The Institute's review of the legal and regulatory regimes in the APAC region demonstrates that there is considerable variation in the coverage and readiness of frameworks that would facilitate CCS. While the region includes jurisdictions with detailed legal and regulatory models for CCS, such as Australia, Malaysia, and Indonesia, in other nations, CCS-specific frameworks are largely absent, and significant gaps remain in existing regulatory frameworks in relation to key aspects of the CCS project lifecycle.

These gaps hold implications for the development and implementation of CCS activities both domestically and in the context of regional CO_2 transport and storage activities. Several countries are contemplating cross-border storage of CO_2 due to high domestic emissions, limited domestic storage potential, and geographic proximity to suitable storage sites in the territorial waters of neighbouring countries. This approach gives rise to a variety of key issues that require clarification within national regulatory frameworks.

The following sections offer some overarching conclusions for addressing the critical legal and regulatory gaps to facilitate CCS in the region, including considerations for regional CO_2 transport and storage activities.

4.1 Designing comprehensive national regulatory frameworks that address the novel aspects of the CCS project lifecycle

The review reveals that with the exception of Australia, Indonesia and more recently, Japan, Malaysia, and South Korea, all the jurisdictions surveyed have gaps in their existing regulatory frameworks relating to CCS. The gap analysis conducted in this report demonstrates that while existing frameworks address most of the key aspects related to CCS to some extent, the following issues remain in need of dedicated CCS-specific provisions:

- Clarification of pore space ownership
- Separate permitting pathway authorising CCS activities
- Classification of CO_2
- Site characterisation requirements
- Monitoring and verification
- Risk mitigation and management
- Authorisation of site closure
- Post-closure site care and monitoring
- Long-term liability

The lack of clarity on these issues is a considerable uncertainty that may serve to deter project operators from advancing investments in CCS. Furthermore, the lack of regulation across these aspects holds implications for assuring the safety, permanence and integrity of CO_2 storage operations. The following table highlights, at a high-level, options for addressing the key gaps identified.

Table 18. Options for addressing key regulatory gaps

Issue	Options for addressing gap
Pore space ownership	Clarify and define ownership rights over sub-surface geological formations and the pore space, potentially through legislation or regulatory amendments.
Separate permitting pathway authorising CCS activities	Develop site selection and characterisation requirements to ensure that CO_2 storage sites are suitable for the safe and permanent containment of CO_2. Consider the need for secondary guidance to assist project developers in their interpretation of these requirements.
Classification of CO_2	Determine how captured CO_2 is to be classified within domestic legal frameworks, and the necessity of excluding it from the scope of current waste management legislation.
Site characterisation requirements	Develop site selection and characterisation requirements to ensure that CO_2 storage sites are suitable for the safe and permanent containment of CO_2. Consider the need for secondary guidance to assist project developers in their interpretation of these requirements.
Monitoring and verification	Establish adequate monitoring and reporting procedures to ensure robust accounting verification and reporting of injection activities and the stored CO_2.
Risk mitigation and management	Develop adequate risk mitigation measures that incorporate strategies and contingency plans to address potential CO_2 leakage during the operational phase and after the closure of a project site.
Authorisation of site closure	Develop a procedure within the regulatory framework to formally authorise site closure.
Post-closure site care and monitoring	Develop regulatory provisions addressing long-term monitoring after site closure and require approval of these plans to ensure adherence to containment provisions.
Long-term liability	Consider how long-term liabilities are to be managed within a domestic regime and, in particular, whether a transfer to a government designated authority would be an option. Consider liability treatment in the case of cross-border CO_2 imports for local storage.

4.2 Regional transport and storage considerations

With government and industry across the ASEAN region increasingly pursuing opportunities to collaborate on regional CO_2 transport and storage projects, the resolution of legal and regulatory issues governing the operation of these activities will be critical. From an international law perspective, South Korea, Japan, the Philippines, New Zealand, China, and Australia are the only countries in the region who are Parties to the London Protocol. South Korea, Australia, and Japan are the only nations that have ratified the 2009 amendment to the London Protocol. To undertake projects that feature a transboundary component hosted by a Contracting Party to the Protocol, it will be essential for national governments in the region to ensure they comply with the provisional application requirements agreed by the Contracting Parties to the London Protocol in 2019.

National regulators and policymakers who are Contracting Parties to the Protocol will be required to support these projects, put into place the necessary agreements, and subsequently notify the International Maritime Organisation of their arrangements. To this end, the Contracting Party status of countries will determine which country has responsibility to ensure that an agreement/arrangement to conduct cross-border CO_2 transport and storage activities are compliant with the London Protocol. Figure 4 below provides an overview of the respective obligations of Contracting Parties and Non-Contracting Parties when undertaking the cross-border export of CO_2 in the context of the 2009 amendment to the London Protocol and the 2019 Resolution, accepting the provisional application of the 2009 amendment to the London Protocol (IEA, 2021).

Figure 4. Cross-border maritime CO_2 transport under the 2009 Amendment and 2019 Resolution for Provisional Application of the London Protocol (IEA, 2021)

		LP status of country receiving CO_2 for storage:	
		Contracting party	**Non-contracting party**
LP status of country capturing CO_2 for export:	**Contracting party**	CPs must establish agreements or arrangements, depositing formal declarations to the IMO detailing compliance with environmental conditions related to the composition of CO_2 streams, and CO_2 storage	Exporting CP must ensure that control conditions and permits as applicable to CPs. CP must ensure agreements or arrangements are maintained by the receiving country
	Non-contracting party	Receiving CP must ensure that exporting country demonstrates appropriate consideration of incidental associated substances in CO_2 stream, and treatment if needed. CP must ensure agreements or arrangements are maintained by the exporting country.	Not governed by the LP; may be subject to UNCLOS

Note: LP = London Protocol; CP = Contracting Party.
Sources: IEAGHG (2021); IMO (2013).

The Institute's analysis revealed that with the exception of Australia, Indonesia and Malaysia, none of the jurisdictions surveyed have clarified the issue of transboundary movement of CO_2 within their domestic legislation. As a Party to the London Protocol, Australia has thus far progressed legislation that implements its obligations under the London Protocol relating to the transboundary movement of CO_2,. Legal amendments introduced in 2023, establish a permitting pathway for CO_2 export and import activities in compliance with the Protocol. Indonesia, which is not a Party to the London Protocol, has enabled CO_2 storage permit holders and contractors to allocate up to 30% of total carbon storage capacity for foreign use, and has outlined requirements for the country to enter into bilateral agreements with other countries to conduct cross-border CO_2 transport. However, the practical implementation of these provisions is yet to be tested.

With efforts underway to conclude formal agreements to conduct transboundary CO_2 transport and storage operations between nations in the region, many issues relating to the transboundary movement of CO_2 will eventually need to be managed as part of the CCS permitting regime. These issues include but are not limited to bilateral agreements between nations, the allocation of liabilities for accidents and leakages, the reporting and accounting of transferred CO_2, transboundary environmental impacts, and dispute resolution mechanisms.

For regulators and policymakers in countries that are Parties to the London Protocol or have ratified the 2009 amendment to the Protocol, enacting domestic legislation implementing the 2009 amendment to the London Protocol's provisions remains a key priority. Another key measure for countries seeking to establish bilateral agreements for transboundary CO_2 transport and storage is to ensure that roles and responsibilities under such agreements are clearly defined within domestic legislation.

The increasing interest in conducting transboundary CO_2 transport and storage operations may also require the development of a consistent regional approach to regulation. To ensure smooth and efficient transboundary CCS value chains, regulators may consider developing harmonised regulatory frameworks, complemented by shared protocols and standards that coordinate and simplify the regulatory process for project developers and operators.

05

CO_2 storage of key countries in the Asia-Pacific region

Photo: Adobe Stock

5 CO_2 storage of key countries in the Asia-Pacific region

The APAC region has numerous suitable storage basins and abundant CO_2 storage resources which could help facilitate industrial decarbonisation across the region.

Nine nations were reviewed in detail: Australia, Brunei, Indonesia, Japan, Malaysia, Philippines, South Korea, Thailand, and Vietnam. Timor Leste, Lao, Myanmar, and Cambodia were not assessed due to a lack of data, and their storage potential has never been reviewed. Singapore does not have a storage basin within its borders. New Zealand and China were beyond the scope of work.

The study uses a portfolio approach to ensure the data is reported succinctly. In each of the nine nations, the following was summarised:

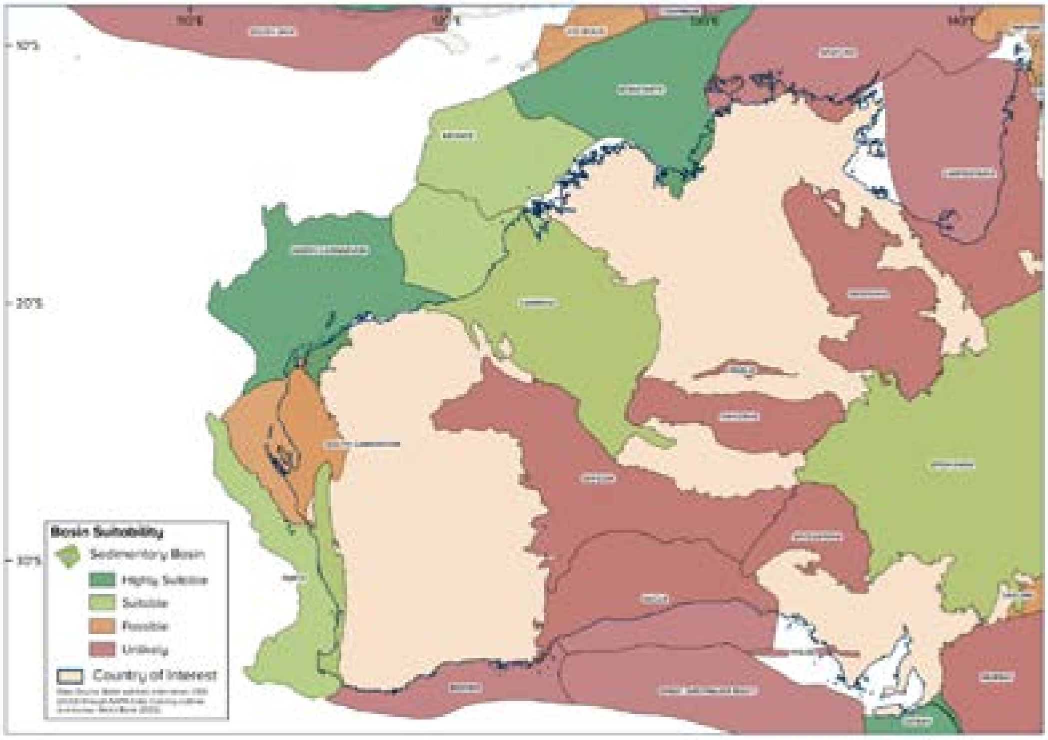
- The storage resources for hydrocarbon fields and saline formations (where data exists) are presented as tables and graphs.
- The basin suitability assessment is presented as a "traffic light" table for each key basin in the country with a supporting map.
- A summary of key formations and fields in the country, potential for mineral carbonation and prospects, barriers and issues to CCS deployment.

Finally, a series of potential future opportunities is presented.

The methodology of the storage resource calculation and suitability assessment are presented in the Appendix.

5.1 Northwest Shelf Australia

5.1.1 BASIN SUITABILITY MAP



5.1.2 BASIN RANKING

Basin	Geology	Subsurface Knowledge and Data Maturity	Storage Resource Knowledge	Accessibility	Overall
Bonaparte	Highly Suitable	Suitable	Suitable	Highly Suitable	Highly Suitable
Browse	Highly Suitable	Suitable	Suitable	Highly Suitable	Suitable
North Carnarvon	Highly Suitable	Highly Suitable	Suitable	Highly Suitable	Highly Suitable
Perth	Possible	Possible	Suitable	Suitable	Suitable
Onshore Canning*	Possible	Possible	Suitable	Suitable	Suitable
South Carnarvon	Possible	Possible	Possible	Suitable	Possible

Highly Suitable | Suitable | Possible | Unlikely

*Analysis applies to onshore Canning only. Offshore Canning has not been reviewed for offshore storage potential as data is limited.

5.1.3 STORAGE RESOURCES

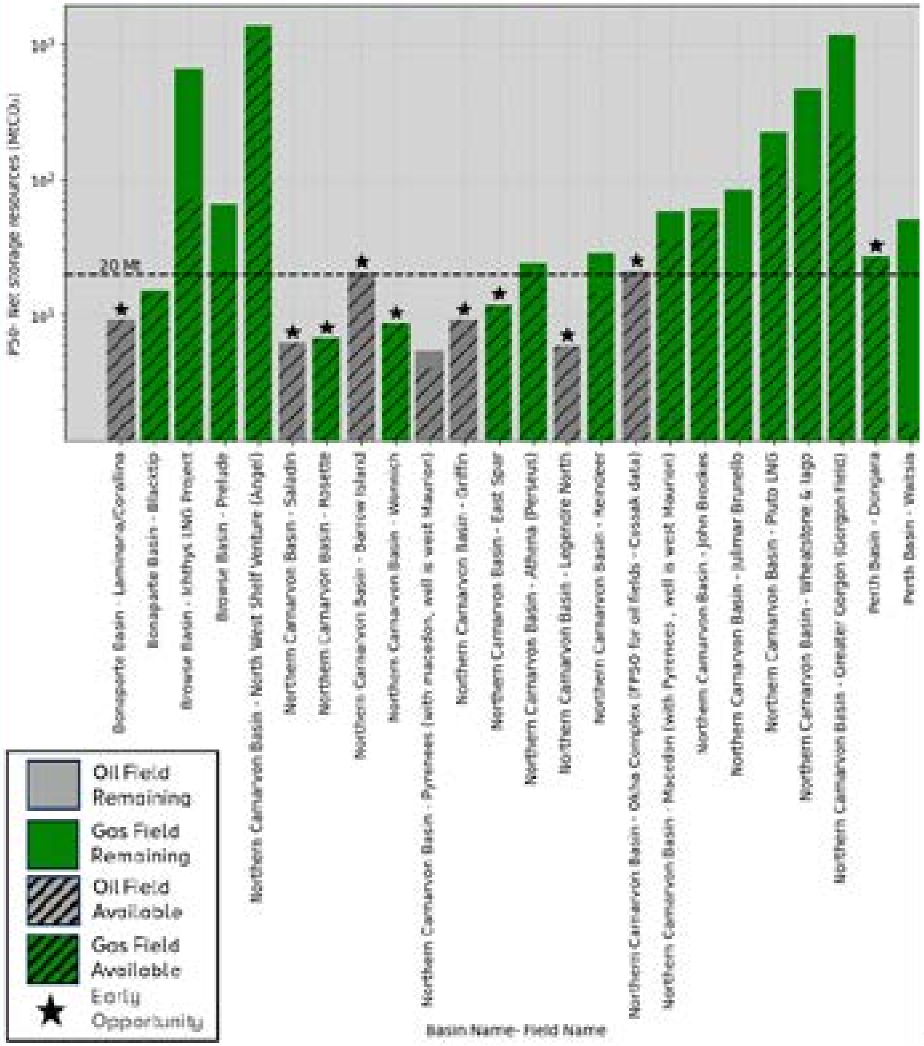
Estimated CO_2 Storage Resources in Hydrocarbon Fields

Basin	P50- Storage available ($MtCO_2$)	P50- Storage remaining ($MtCO_2$)	P50- Storage net ($MtCO_2$)
Bonaparte	23	1	24
Browse	95	626	721
Northern Carnarvon	1,823	1,777	3,600
Perth	29	50	79
Offshore Western Australia Total	1,970	2,454	4,424

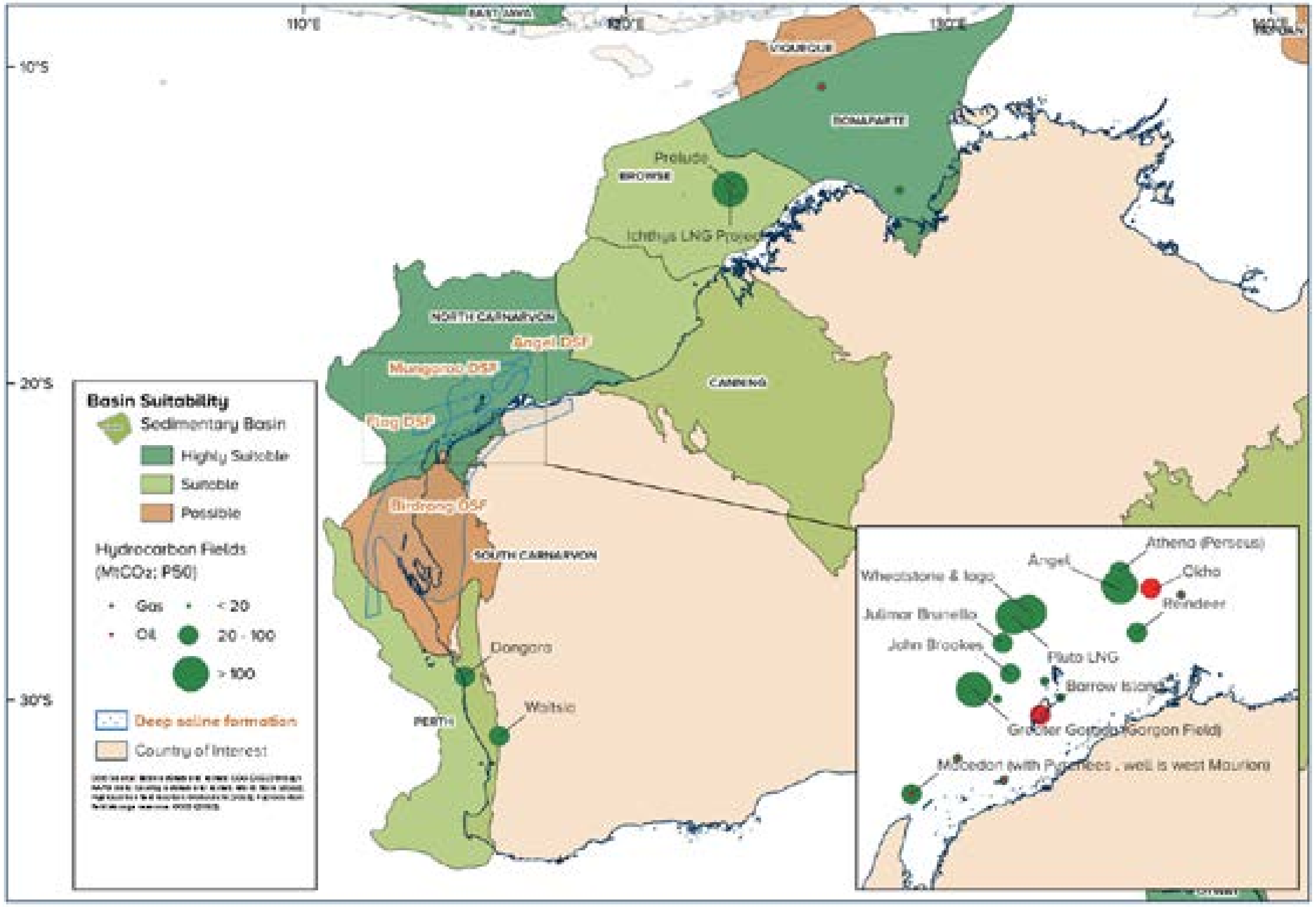
Estimated CO_2 Storage Resources in Selected Saline Formations of the Carnarvon Basin only (See Storage Resource Map for location)

Basin	Formation(s)	P90 ($GtCO_2$)	P50 ($GtCO_2$)	P10 ($GtCO_2$)
Carnarvon	Mungaroo	100	163	251
Carnarvon	Angel	0.6	2.1	5.3
Carnarvon	Flag Sandstone	0.5	1.7	4.1
Carnarvon	Birdrong Sandstone	0.2	0.6	1.5
Carnarvon Total		**101**	**167**	**262**

Estimated CO_2 Storage Resources in Hydrocarbon Fields
(See Storage Resource Map for location)



5.1.4 STORAGE RESOURCE MAP



Note: Only fields with greater than 20 $MtCO_2$ storage resources are labelled.

5.1.5 PUBLISHED STORAGE RESOURCE ESTIMATES

Resource Estimate ($GtCO_2$)		Focus of estimates	Source	Confidence in resource estimate
720		Australia-wide Hydrocarbon Fields and saline formations GEODISC program; 65 sites; Risked resource estimate	Bradshaw et al., 2004	High confidence. • Best practice field estimates method using hydrocarbon production values • Best practice volumetric calculation methodology used for saline formations • Data provided • Pessimistic approach to assumptions
55 (P50) Bonaparte 11 (P50) Browse 33 (P50) Canning (Onshore) 48.5 (P50) Northern Carnarvon 29 (P50) Perth		Hydrocarbon Fields and Saline Formations; National Carbon Mapping and Infrastructure Plan (Carbon Storage Taskforce)	Carbon Storage Taskforce, 2009	Moderate confidence. • Best practice field estimates method using hydrocarbon production values • Best practice volumetric calculation methodology used for saline formations • Limited data provided • Basin-wide assumptions used • Saline formations not individually calculated
0.5		Saline Formation Gage Sandstone Offshore Perth Basin (Vlaming) Dynamic Modelling Study Geoscience Australia	Wang et al. 2018	High confidence • Based on dynamic simulation • Uses subsurface seismic and well data • Data provided
12.29 (P90)	20.02 (P10)	Saline Formation Plover and Elang Formations Bonaparte Basin Volumetric analysis Geoscience Australia	Consoli et al., 2014	High confidence • Best practice volumetric calculation methodology used for saline formations • Data provided

5.1.6 COUNTRY SUMMARY

5.1.6.1 Summary of key storage formation and hydrocarbon field

Mungaroo Formation

The Mungaroo Formation comprises up to 3,000 m of Late Triassic clastic sediment in the Carnarvon Basin, northwest Australia. The deposits are fluvial-deltaic sandstones and mudstones and host more than 500 MMBO and 7.5 TCF of gas (Bishop, 1999). The Mungaroo Formation's porosity ranges from 28 to >30%, and permeability can be as high as 1,000 mD (Bishop, 1999), making it a suitable target for CO_2 storage. The Mungaroo Formation is estimated to hold more than 163 Gt (P50) of CO_2 storage resources in its saline formations.

Angel Field

The giant Angel gas field is situated at 80 m of water depth and was discovered in 1972 (Vincent and Tilbury, 1988). The field comprises marine sandstones of the Upper Jurassic Angel Formation and is sealed by claystones of the Early Cretaceous Barrow Group (Vincent and Tilbury, 1988). Porosity ranges from 14 to 20%, and permeabilities range from 150 to 727 mD (Vincent and Tilbury, 1988). The Angel Field is estimated to hold 1,154 Mt of available CO_2 storage resources and 221 Mt of remaining CO_2 storage resources for a total CO_2 storage resource base of 1,375 Mt.

5.1.6.2 Mineralisation

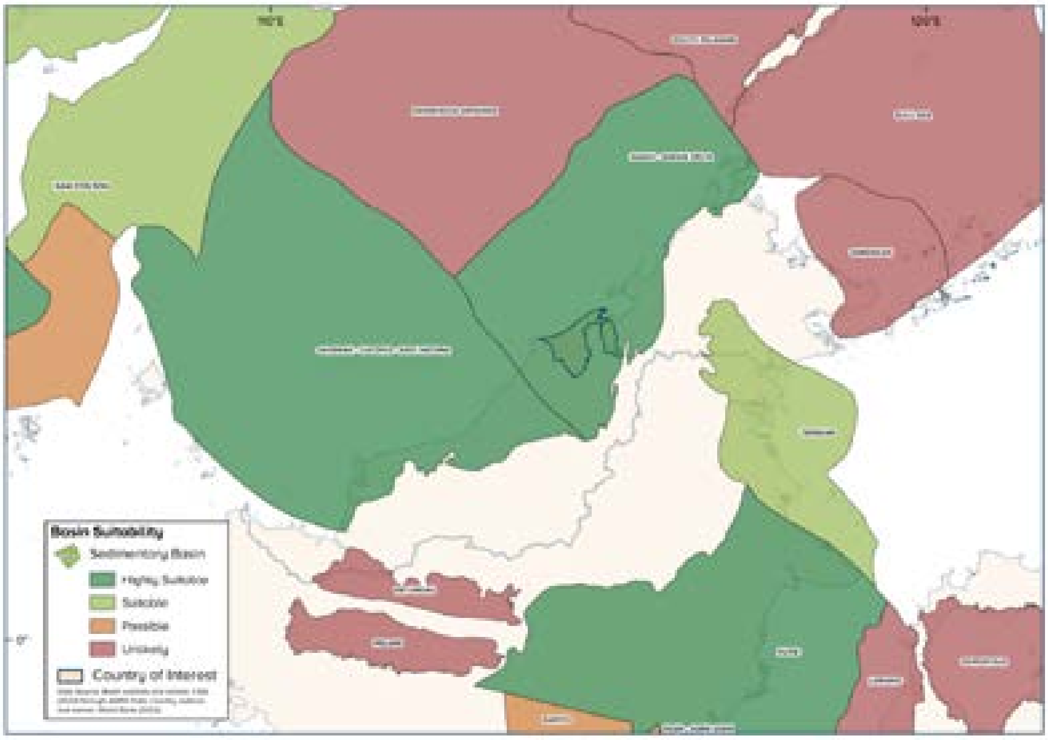
Australia has abundant mafic and ultramafic formations with potential for in-situ carbon mineralisation. However, compared with conventional CO_2 storage, their potential remains uncertain and would require detailed site-specific assessment, including fracture network characterisation and fluid flow analysis. Given the availability of oil and gas fields and saline aquifers near emission sources, conventional geological storage is likely to be the more practical option in Australia.

5.1.6.3 Summary of storage deployment prospects, barriers, and issues

- Very high prospects for CCS deployment along the Northwest Shelf (Western Australia and the Northern Territory).
- Multiple suitable and highly suitable basins along the Northwest Shelf.
- Gigatonne storage resources are available in hydrocarbon fields.
- Multiple CO_2 transport and storage CCS facilities are currently in development phases, with Chevron's Gorgon CCS currently operational.
- High-quality sedimentary formations in Australia offer more suitable options for permanent CO_2 storage, making in-situ mineralisation technology less advantageous.
- Sub-surface data is accessible to the public.
- A regulatory framework exists for offshore Australian waters, with active storage acreage available and an acreage release process (not onshore in Western Australia and the Northern Territory).

5.2 Brunei

5.2.1 BASIN SUITABILITY MAP



5.2.2 BASIN RANKING

Basin	Geology	Subsurface Knowledge and Data Maturity	Storage Resource Knowledge	Accessibility	Overall
Sabah-Baram Delta	Highly Suitable	Suitable	Suitable	Possible	Suitable

Highly Suitable
Suitable
Possible
Unlikely

5.2.3 STORAGE RESOURCES

Estimated CO_2 Storage Resources in Hydrocarbon Fields

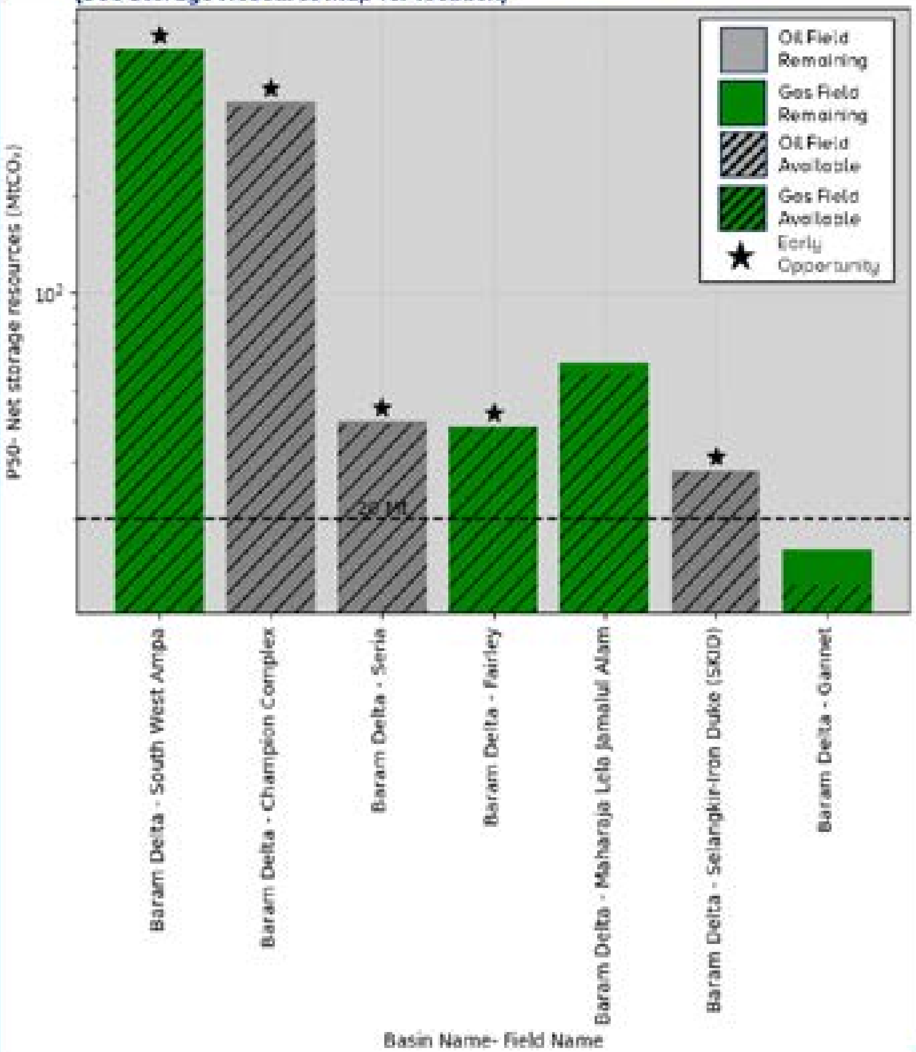
Basin	P50- Storage available ($MtCO_2$)	P50- Storage remaining ($MtCO_2$)	P50- Storage net ($MtCO_2$)
Baram Delta	1,128	23	1,151

Estimated CO_2 Storage Resources in Selected Saline Formations (See Storage Resource Map for location)

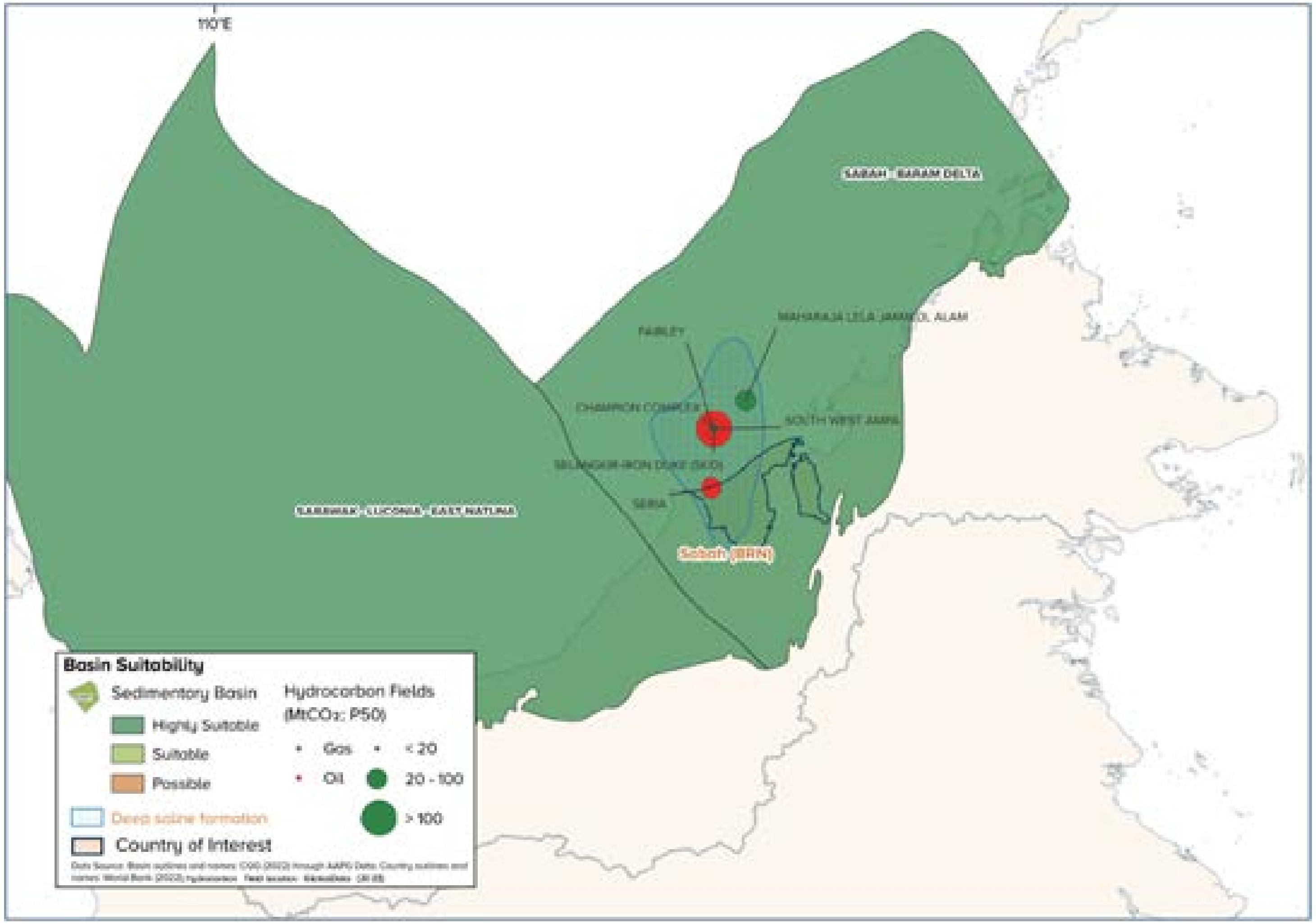
Basin	Formation(s)	P90 ($GtCO_2$)	P50 ($GtCO_2$)	P10 ($GtCO_2$)
Baram Delta (Brunei)	Baram Fluvial-Deltaic System sands	13	18	25

Estimated CO_2 Storage Resources in Hydrocarbon Fields

(See Storage Resource Map for location)



5.2.4 STORAGE RESOURCE MAP



Note: Only fields with greater than 20 $MtCO_2$ storage resources are labelled.

5.2.5 PUBLISHED STORAGE RESOURCE ESTIMATES

Storage Resource Estimate ($GtCO_2$)	Focus of estimates	Source	Confidence in resource estimate
0.5489	Hydrocarbon Fields and adjacent saline formation; Baram Delta Basin	APEC, 2010	Moderate confidence • Best practice field estimates method using hydrocarbon production values, but outdated • Best practice volumetric calculation methodology used • Data Provided

5.2.6 COUNTRY SUMMARY

5.2.6.1 Summary of key storage formation and hydrocarbon field

Baram Fluvial-Deltaic System Sands

The Baram Fluvial-Deltaic System comprises several sequences of Neogene clastic deposits ranging in thickness from 1,000 to 3,000 m offshore Brunei (Rijks, 2014). The Baram Fluvial-Deltaic System sands (Cycle V) feature porosities averaging 20% and permeabilities averaging 980 mD, making it a suitable target for CO_2 storage (CO_2CRC, 2010). The CO_2 storage resources of saline formations of Baram Fluvial-Deltaic System sands are estimated to be around 18 GtCO_2 (P50)

South West Ampa Field

The South West Ampa gas field is situated in less than 60 m of water depth and was discovered in 1963. The South West Ampa Field is assessed to possess only 0.3 Mt of remaining CO_2 storage resources, resulting in a total CO_2 storage resource base of 574 Mt. These data indicate a significant level of depletion in the field, making it a potential strong candidate for long-term commercial-scale CCS facilities in Brunei and the broader region. Nevertheless, a thorough field analysis is imperative to evaluate the impacts of geological complexities, such as reservoir compartmentalisation, on storage resources and injectivity.

5.2.6.2 Mineralisation

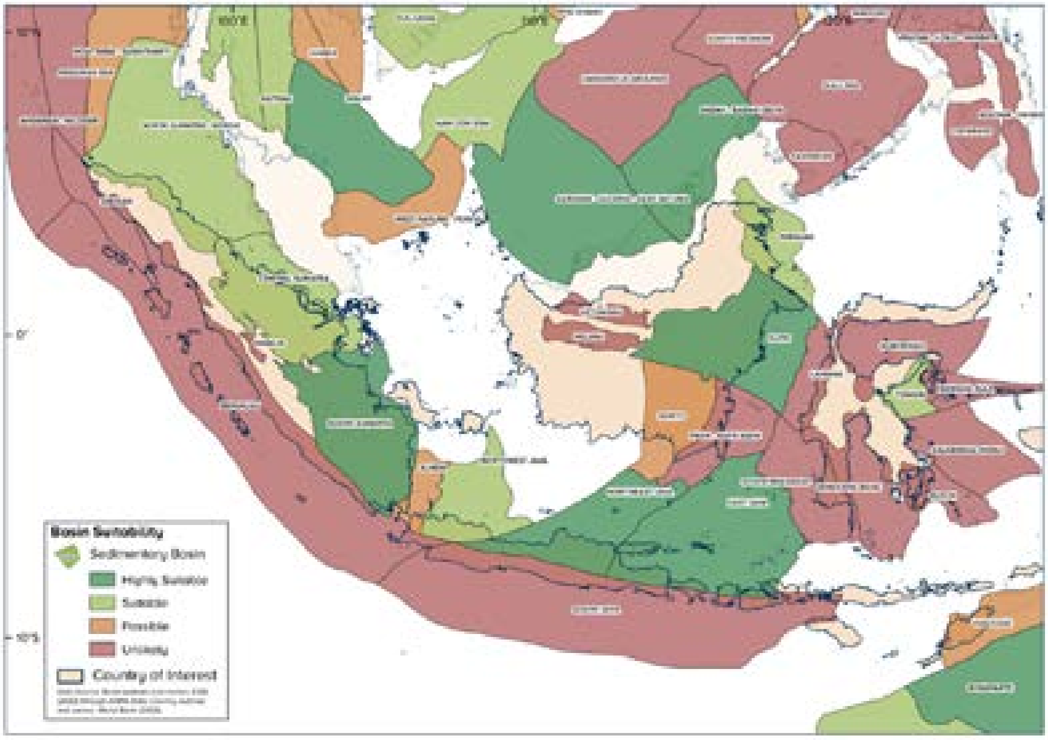
The geology of Brunei is predominantly characterised by sedimentary rocks, with several notable formations like the Setap, Belait, Miri, Seria, and Liang formations. The Global Lithological Map Database v1.0 also suggests the possibility of certain areas in Brunei containing mixed sedimentary rocks, potentially including mafic and ultramafic rocks. However, based on the limited information, the country lacks notable candidates for implementing in-situ carbon mineralisation technology.

5.2.6.3 Summary of storage deployment prospects, barriers, and issues

- Brunei hosts significant resources in hydrocarbon fields and saline formations in a highly suitable basin with limited domestic emissions.
- Detailed analysis of the South West Ampa Field and Champion Complex is essential for unlocking their CO_2 storage resources.
- Brunei could rapidly deploy CO_2 storage operations to enable a domestic CCS industry and the international import of CO_2. A CCS roadmap with CO_2 storage characterisation and detailed site scale assessment would support these opportunities.
- Brunei lacks a CCS-specific legal and regulatory framework and CCS-specific domestic policies or incentives.
- There are no active CCS facilities in Brunei.

5.3 Indonesia

5.3.1 BASIN SUITABILITY



5.3.2 BASIN RANKING

Basin	Geology	Subsurface Knowledge and Data Maturity	Storage Resource Knowledge	Accessibility	Overall
Banggai-Sula (Tomori)	Possible	Possible	Unlikely	Possible	Unlikely
East Java	Highly Suitable	Suitable	Highly Suitable	Highly Suitable	Highly Suitable
Kutei	Highly Suitable	Suitable	Highly Suitable	Highly Suitable	Highly Suitable
North East Java	Highly Suitable	Suitable	Suitable	Highly Suitable	Highly Suitable
Central Sumatra	Suitable	Suitable	Suitable	Suitable	Suitable
North Sumatra	Suitable	Suitable	Suitable	Suitable	Suitable
North West Java	Suitable	Suitable	Suitable	Suitable	Suitable
Sengkang	Suitable	Possible	Unlikely	Possible	Unlikely
South Sumatra	Highly Suitable	Suitable	Highly Suitable	Highly Suitable	Highly Suitable
Sunda (West Java)	Possible	Possible	Unlikely	Suitable	Possible
Tarakan	Possible	Suitable	Possible	Suitable	Suitable
West Natuna	Suitable	Possible	Unlikely	Possible	Possible
Salawati	Suitable	Possible	Possible	Possible	Suitable
Bintuni	Suitable	Possible	Unlikely	Possible	Possible

Highly Suitable Suitable Possible Unlikely

5.3.3 STORAGE RESOURCES (1/2)

Estimated CO_2 Storage Resources in Hydrocarbon Fields (See Storage Resource Map for location)

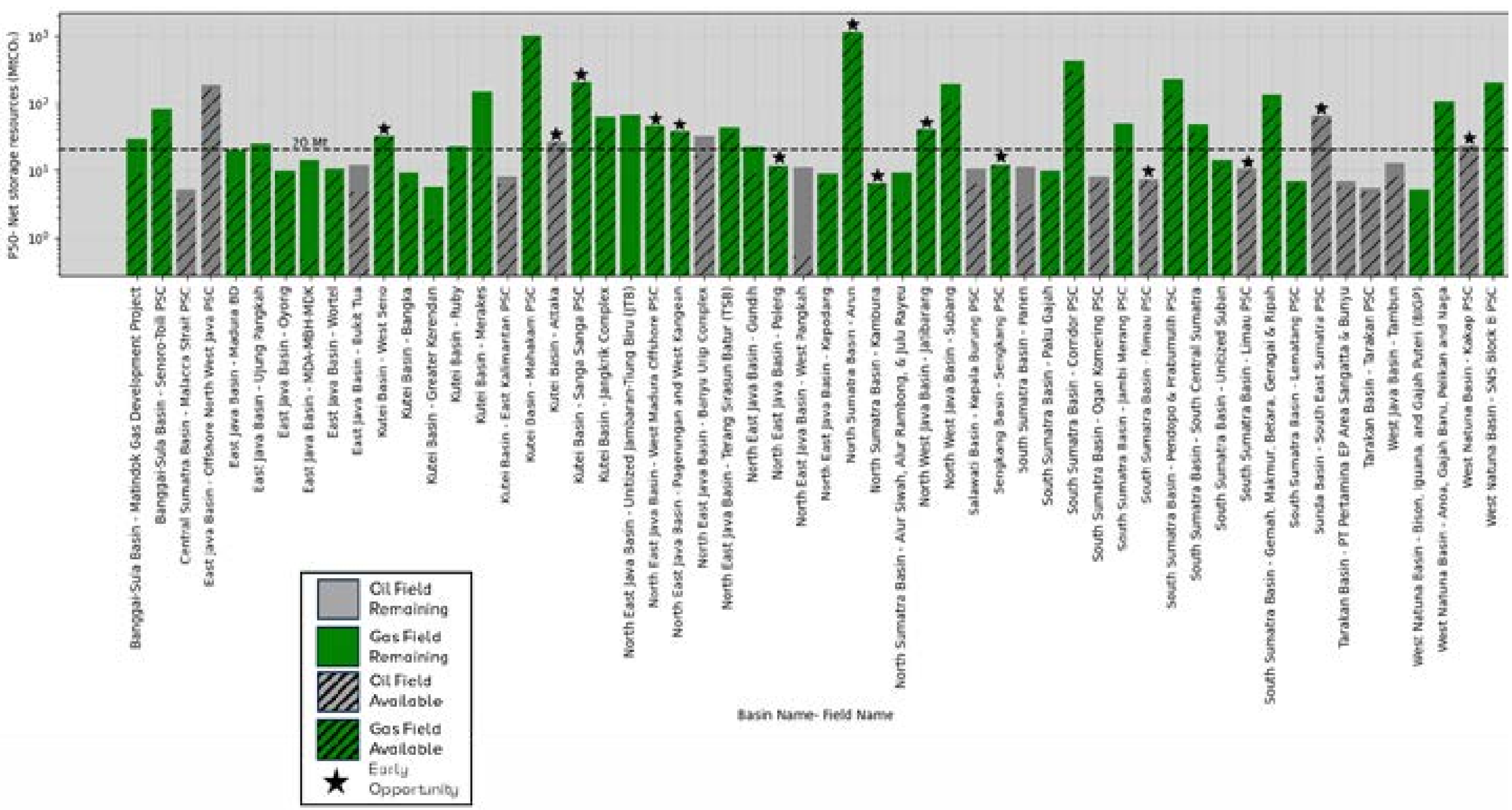
Basin	P50- Storage available ($MtCO_2$)	P50- Storage remaining ($MtCO_2$)	P50- Storage net ($MtCO_2$)
Banggai-Sula	53	58	111
Central Sumatra	4	1	5
East Java	211	62	273
Kutei	1,282	231	1,514
North East Java	161	119	281
North Sumatra	1,135	6	1,142
North West Java	146	84	230
Salawati	6	4	10
Sengkang	12	0	12
South Sumatra	624	331	956
Sunda	62	3	65
Tarakan	11	2	13
West Java	8	5	13
West Natuna	284	58	342
Indonesia Total	4,001	965	4,966

Estimated CO_2 Storage Resources in Selected Saline Formations (See Storage Resource Map for location)

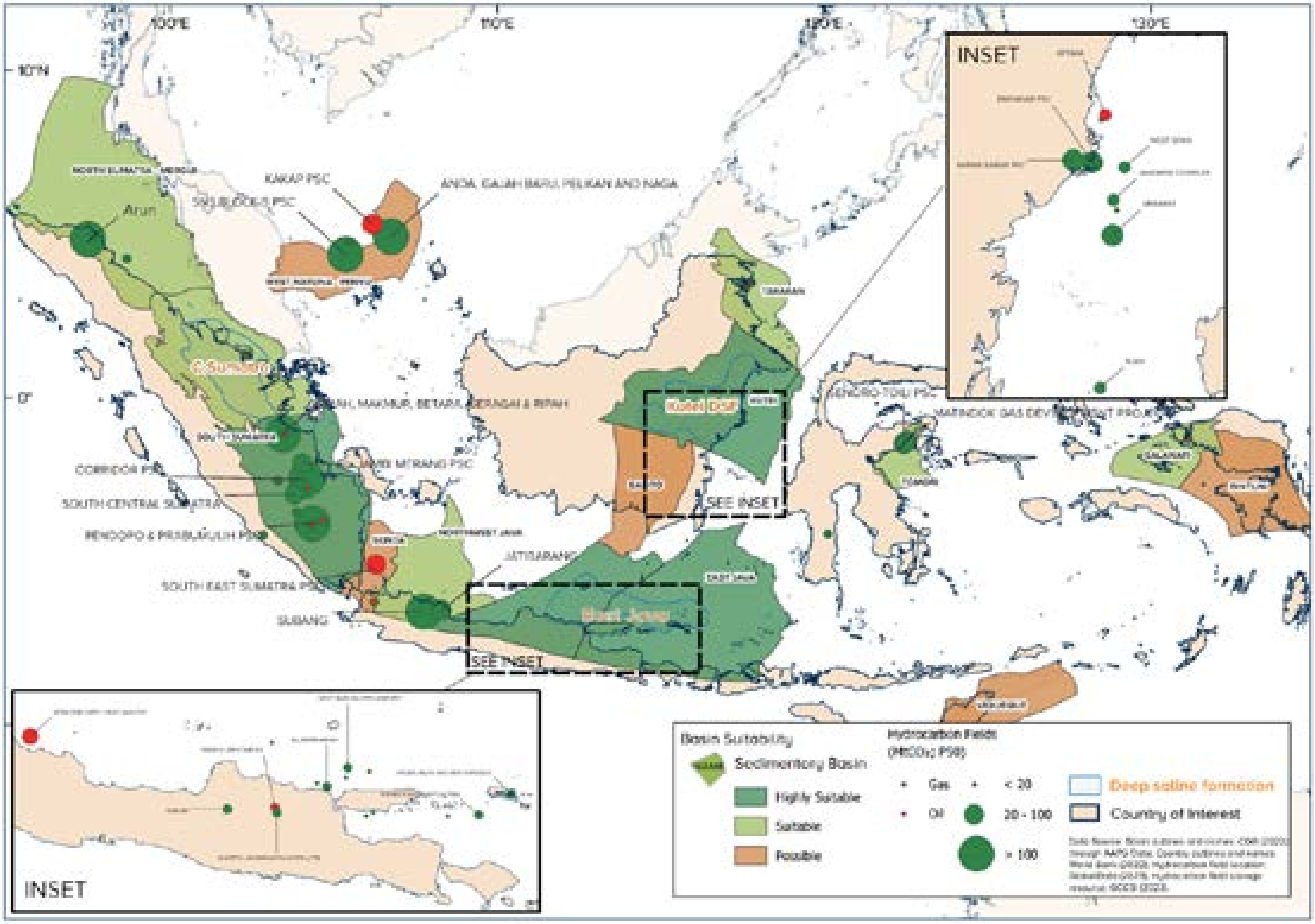
Basin	Formation(s)	P90 ($GtCO_2$)	P50 ($GtCO_2$)	P10 ($GtCO_2$)
Kutei	Balikpapan Group	23	35	53
East Java	Kujung	4	7	13
Central Sumatra	Beksak	5	6	9
Indonesia Total		**32**	**49**	**75**

5.3.4 STORAGE RESOURCES (2/2)

Estimated CO_2 Storage Resources in Hydrocarbon Fields
(See Storage Resource Map for location)



5.3.5 STORAGE RESOURCE MAP



Note: Only fields with greater than 20 $MtCO_2$ storage resources are labelled.

5.3.6 PUBLISHED STORAGE RESOURCE ESTIMATES

Storage resource estimates ($GtCO_2$)	Focus of estimates	Source	Confidence in resource estimate
4.421	Analysis from Bintuni, E. Natuna, NW Java, N/C/S Sumatra, and Kutei Basins	APEC, 2010	Moderate confidence • Best practice field estimates method using hydrocarbon production values, but outdated • Best practice volumetric calculation methodology used • Data Provided
0.6	Depleted fields from 60 sedimentary basins	Iskander et al., 2013	Low confidence • Best practice field estimates method using hydrocarbon production values, but outdated • Names of fields or data used not provided • Methodology assumptions not listed and data limited
8.6	Saline Formations and Depleted Fields of South Sumatra	Asian Development Bank, 2013	Low confidence • Hydrocarbon fields and saline formations not listed • Best practice field estimates method using hydrocarbon production values • Data used not provided • Volumetric calculation methodology had basin-wide assumptions • Efficiency factors were country-specific, not reservoir specific
1.420 - 2.041	EOR, Depleted Fields, and Saline Formations of S. Sumatra and W. Java	World Bank, 2015	Moderate confidence • Best practice field estimates method using hydrocarbon production values • Best practice volumetric calculation methodology used for saline formations • Names of fields, formations or data used not provided
13.519 - 15.723	Depleted Fields and Saline Formations of S. Sumatra and W. Java	Hedriana et al., 2017	Moderate confidence • Best practice field estimates method using hydrocarbon production values • Best practice volumetric calculation methodology used for saline formations • Names of fields, formations or data used not provided

5.3.7 COUNTRY SUMMARY

5.3.7.1 Summary of key storage formation and hydrocarbon field

Balikpapan Group

The Balikpapan Group comprises Miocene marine carbonate to deltaic clastic deposits up to 1,400 m thick, onshore and offshore east Borneo Island in the Kutei Basin (Marks et al., 1982). Balikpapan Group sands feature 7% to 25% porosities and permeabilities up to 4,718 mD, making it a suitable target for CO_2 storage (Musu et al., 2018). The Balikpapan Group sandstones are estimated to hold more than 35 Gt (P50) of CO_2 storage resources in its saline formations.

Mahakam PSC

The Mahakam PSC in Indonesia's Kutei Basin is one of the most prolific hydrocarbon-producing blocks in the country, producing roughly 19 TCF of gas and 1.5 billion barrels of oil (Herwin et al., 2018). The licence area comprises many fields, including the Bekapai oil field, discovered in 1972 and the largest gas field in Indonesia, Tunu Field, discovered in 1977 (Herwin et al., 2018). The Tunu Field is situated in shallow water (~5 m) and comprises Miocene fluvial-deltaic clastic sediments with porosities ranging from 8% to 30% and permeabilities ranging from 0.1 to >1,000 mD (Muhazir et al., 2008). The Mahakam PSC is estimated to hold 935 Mt of available CO_2 storage resources and 56 Mt of remaining CO_2 storage resources, for a total CO_2 storage resource base of 991 Mt.

5.3.7.2 Mineralisation

Indonesia's geography is dominated by volcanoes, resulting in the presence of multiple mafic and ultramafic formations across the country, including but not limited to:

- The Eastern Sulawesi ophiolite belt, located in the eastern part of Sulawesi Island, ranks among the three largest ophiolites in the world.
- Sulawesi ultramafic rocks are widely distributed throughout Sulawesi and can be found in various locations, including Barru, Pangkep, Malili, Soroako, and several other areas in East and Central Sulawesi.
- The Meratus Ultramafic Complex in South Kalimantan, Indonesia, covers an extensive area of approximately 2,500 square kilometres.
- The Sorong Ophiolite Complex, situated in West Papua, is one of South-East Asia's largest and most well-exposed ophiolite complexes.
- Volcanic arc in western Indonesia formed by the subduction of the Indian Plate beneath the Sunda Plate.

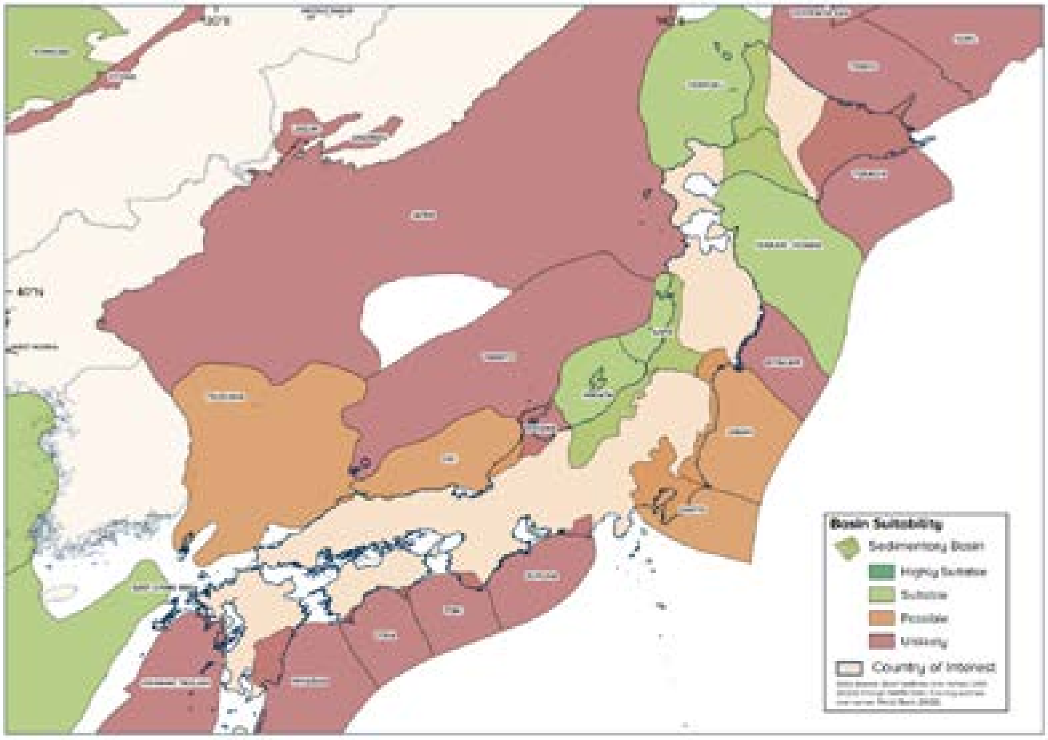
These widely distributed formations in Indonesia suggest the potential for in-situ carbon mineralisation technology, provided they feature open, well-connected, and complex fracture networks.

5.3.7.3 Summary of storage deployment prospects, barriers, and issues

- Indonesia is in the execution phase of the deployment of CCS, with multiple hydrocarbon companies progressing CCS facilities associated with natural gas development and hydrocarbon/ammonia production.
- Indonesia lacks a comprehensive national CO_2 storage resource atlas. Most CO_2 storage resource studies focus on storage in depleted hydrocarbon fields. More work is required to characterise storage resources in saline formations.
- The country now has a comprehensive national regulatory framework for CCS projects. The introduction of these regulations provides a strong indication that the government is supportive of CCS.
- Indonesia hosts eight commercial facilities and one pilot (Gundih) nationwide. Six of the eight CCS facilities (PAU Central Sulawesi, Sakakemang, Tangguh LNG, Sukowati, Balikpapan, Jatibarang) are vertically integrated. The Arun CCS Hub in Aceh will be designed as a multi-user storage site.

5.4 Japan

5.4.1 BASIN SUITABILITY



5.4.2 BASIN RANKING

Basin*	Geology	Subsurface Knowledge and Data Maturity	Storage Resource Knowledge	Accessibility	Overall
Joban	Suitable	Unlikely	Possible	Unlikely	Possible
Ishikari / Hidaka	Suitable	Unlikely	Suitable	Possible	Suitable
Kanto**	Suitable	Unlikely	Possible	Unlikely	Possible
Tempoku	Suitable	Unlikely	Possible	Unlikely	Suitable
Niigata	Possible	Possible	Suitable	Possible	Suitable
Akita	Suitable	Possible	Suitable	Possible	Suitable
Tsushima	Suitable	Unlikely	Possible	Possible	Possible
Oki	Suitable	Unlikely	Possible	Possible	Possible

Highly Suitable   Suitable   Possible   Unlikely

*Unlikely basins are not detailed in this assessment.
**Labelled as Kazusa Basin in "Estimated CO_2 Storage Resources in Hydrocarbon Fields"

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5.4.3 STORAGE RESOURCES

Estimated CO_2 Storage Resources in Hydrocarbon Fields

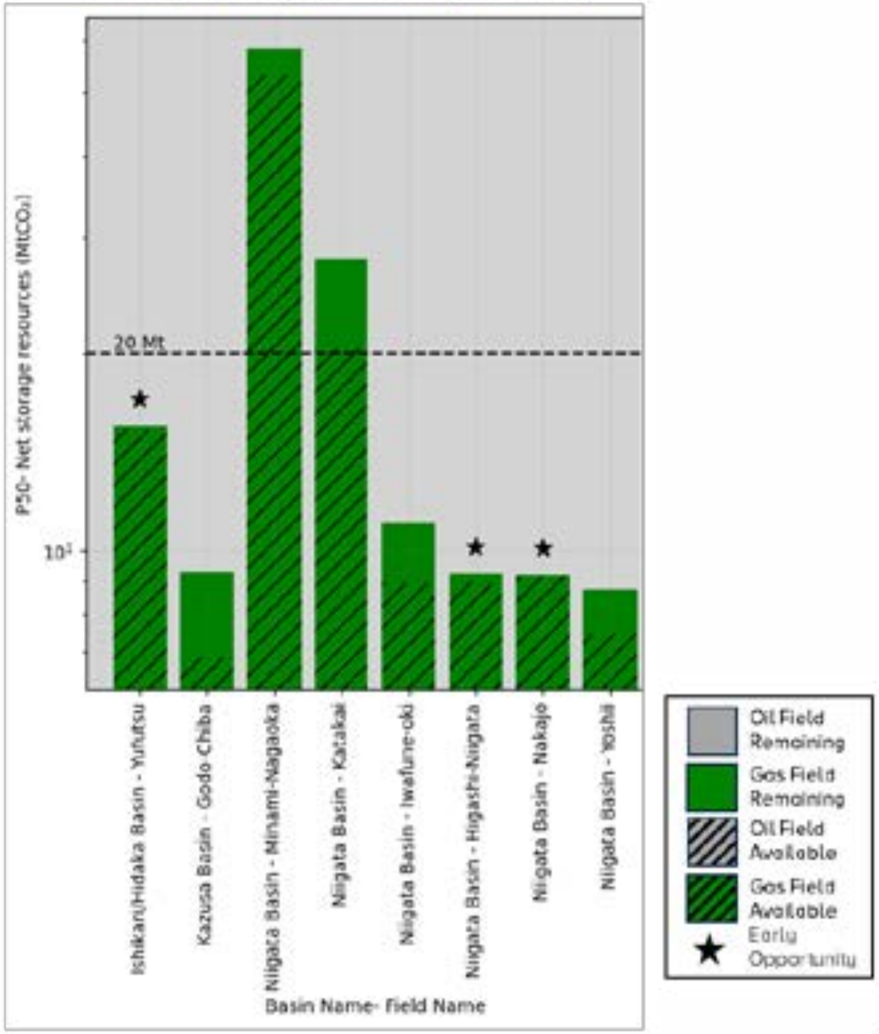
Basin	P50- Storage available ($MtCO_2$)	P50- Storage remaining ($MtCO_2$)	P50- Storage net ($MtCO_2$)
Ishikari/Hidaka	15	0	15
Kanto (Kazusa)*	7	2	9
Niigata Basin	108	17	125
Total	130	19	149

*Labelled as Kanto Basin in maps.

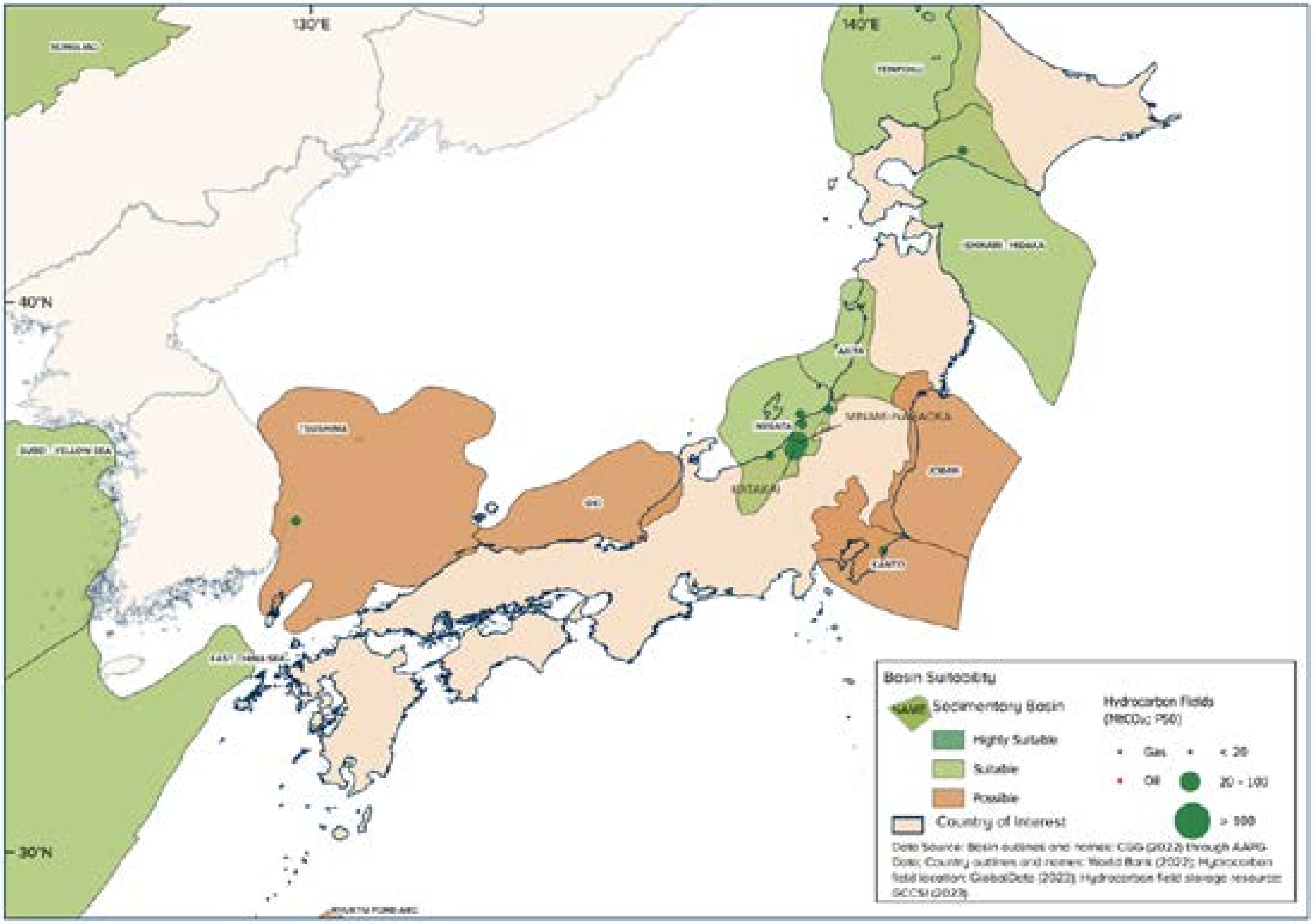
Estimated CO_2 Storage Resources in Selected Saline Formations

No saline formations were assessed due to a lack of reservoir property data

Estimated CO_2 Storage Resources in Hydrocarbon Fields (See Storage Resource Map for location)



5.4.4 STORAGE RESOURCE MAP



Note: Only fields with greater than 20 $MtCO_2$ storage resources are labelled.

5.4.5 PUBLISHED STORAGE RESOURCE ESTIMATES

Storage resource estimates ($GtCO_2$)	Focus of estimates	Source	Confidence in resource estimate
91.5	Depleted Fields, Saline Formations onshore and offshore	Tanaka et al., 1995	Low confidence • The methodology for volumetric calculations is not best practice • Assumptions listed • Data for facilities not provided for calculations
146.1	Depleted Fields, Saline Formations onshore and offshore	Takahashi et al., 2009	Moderate confidence • Best practice methodology for volumetric calculations • Data not provided for calculations of individual fields or formations • Assumptions listed
23.22*	Selected Saline formations (*estimated from published bubble chart, Fig. 4)	Ogawa et al., 2011	Moderate confidence • Best practice methodology for volumetric calculations • Limited data provided for calculations of individual formations • Assumptions listed

5.4.6 COUNTRY SUMMARY

5.4.6.1 Summary of key storage formation and hydrocarbon field

Minami-Nagaoka Field

The Minami-Nagaoka Field in Japan's Niigata Basin is the largest gas field in Japan, producing roughly 1.8 bcf of gas per day (INPEX, 2023). The field was discovered in 1979 and is located onshore in Niigata Prefecture (INPEX, 2023). The Minami-Nagaoka Field comprises a total thickness of 1,000 m of rhyolite (volcanic) formations and a gas column exceeding 800 m (Kikuchi et al., 1991; Fukuta, 1986). The field's porosities (10%-20%) and permeabilities are controlled by meso- and micro-vugs and secondary fractures, respectively (Fukuta, 1986). The Minami-Nagaoka Field is estimated to hold 53 Mt of available CO_2 storage resources, with 5.4 Mt remaining – a total CO_2 storage resource base of 58.5 Mt.

5.4.6.2 Mineralisation

Many mafic and ultramafic formations are widely distributed across Japan. Their widespread presence means some formations are conveniently located near suitable emission sources, reducing CO_2 transportation costs. Additionally, Japan's lack of knowledge of high-quality sedimentary formations for conventional CO_2 storage further highlights the potential of in-situ carbon mineralisation technology for deployment in the country.

Basalts in Japan are primarily associated with volcanic activity and are commonly found in volcanic islands and regions with active or extinct volcanoes. Their age varies depending on the specific location and geological setting. Some basalts found in active volcanic islands like Hokkaido or Kyushu could be as young as a few thousand years or even more recent due to ongoing volcanic activity. Being relatively young, these basalts are less weathered, indicating that their fracture networks are likely still open.

It's important to note that Japan's seismic and volcanic activity complicates implementing in-situ mineralisation technology. Managing pressure and injection rates is necessary to minimise and avoid risks of induced seismicity. Iceland's CarbFix operation, situated in a similarly seismically active region, demonstrates the feasibility of such management strategies.

A detailed evaluation is crucial to fully understand the potential and suitability of each formation for in-situ mineralisation technology. Among the essential steps are precise quantification of their mineralogical composition, thorough characterisation of their fracture networks and fluid flow properties, and comprehensive numerical modellings. With careful consideration of these factors, Japan can further explore the promising avenue of in-situ carbon mineralisation.

5.4.6.3 Summary of storage deployment prospects, barriers, and issues

- Japan has several suitable sedimentary basins for CO_2 storage, but their potential is largely unknown. In addition, many regions have limited storage potential due to their geologically active setting.

- Japan requires a detailed atlas for CO_2 storage supported by a sub-surface data acquisition programme. Japan lacks a comprehensive suite of sub-surface data that other nations with a mature oil and gas industry host.

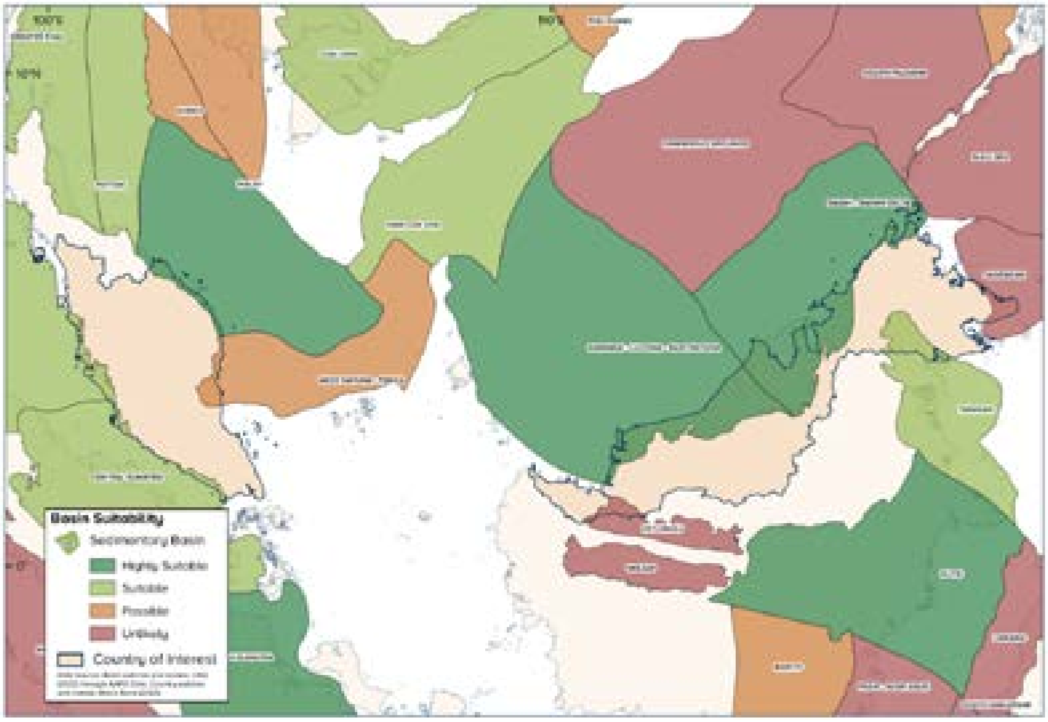
- Although Japan's storage potential is largely unknown, given the sheer scale of domestic emissions, the country will likely require the export of CO_2. Several projects, such as the JOGMEC Hubs (https://www.jogmec.go.jp/english/news/release/news_10_00036.html), have already been announced to export CO_2. The country has not ratified the London Protocol 2009 Amendment to enable the export of CO_2 for sub-seabed geological storage.

- The Japanese government's 2022 Long-Term CCS Roadmap includes a reference to the development of CCS-specific legislation, and the government is currently preparing draft legislation.

- The aforementioned JOGMEC Hubs is funding nine consortiums to establish hubs across Japan, each storing 1-3 Mtpa by 2030.

5.5 Malaysia

5.5.1 BASIN SUITABILITY



5.5.2 BASIN RANKING

Basin	Geology	Subsurface Knowledge and Data Maturity	Storage Resource Knowledge	Accessibility	Overall
Sabah-Baram Delta	Highly Suitable	Suitable	Suitable	Highly Suitable	Highly Suitable
Malay	Highly Suitable	Highly Suitable	Suitable	Possible	Highly Suitable
Sarawak	Highly Suitable	Highly Suitable	Suitable	Highly Suitable	Highly Suitable
West Natuna	Highly Suitable	Possible	Possible	Possible	Possible

Highly Suitable Suitable Possible Unlikely

5.5.3 STORAGE RESOURCES (1/2)

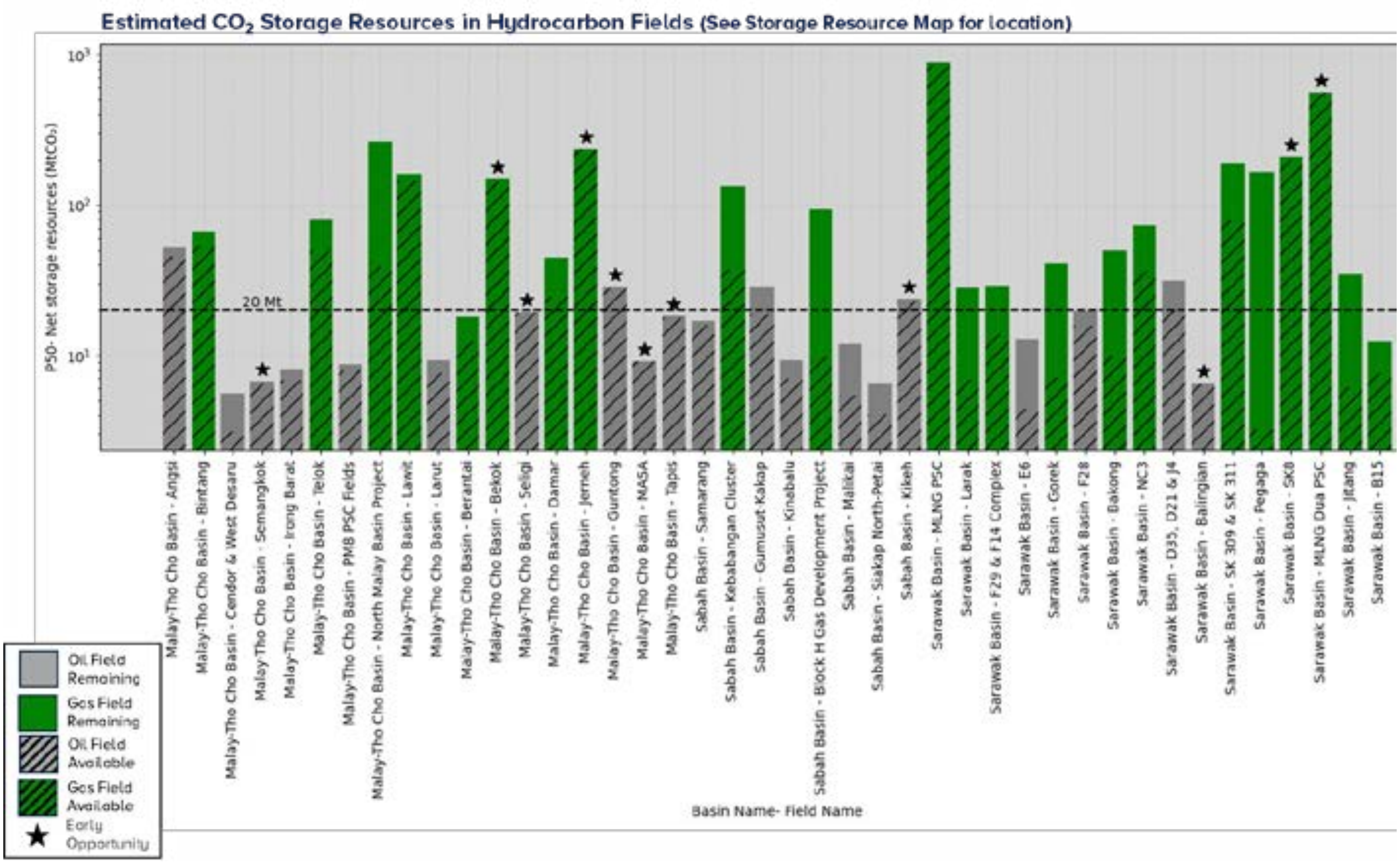
Estimated CO_2 Storage Resources in Hydrocarbon Fields

Basin	P50- Storage available ($MtCO_2$)	P50- Storage remaining ($MtCO_2$)	P50- Storage net ($MtCO_2$)
Malay-Tho Chu (Malaysia)	850	329	1,179
Sabah	121	203	323
Sarawak	1,803	533	2,336
Malaysia Total	2,773	1,065	3,838

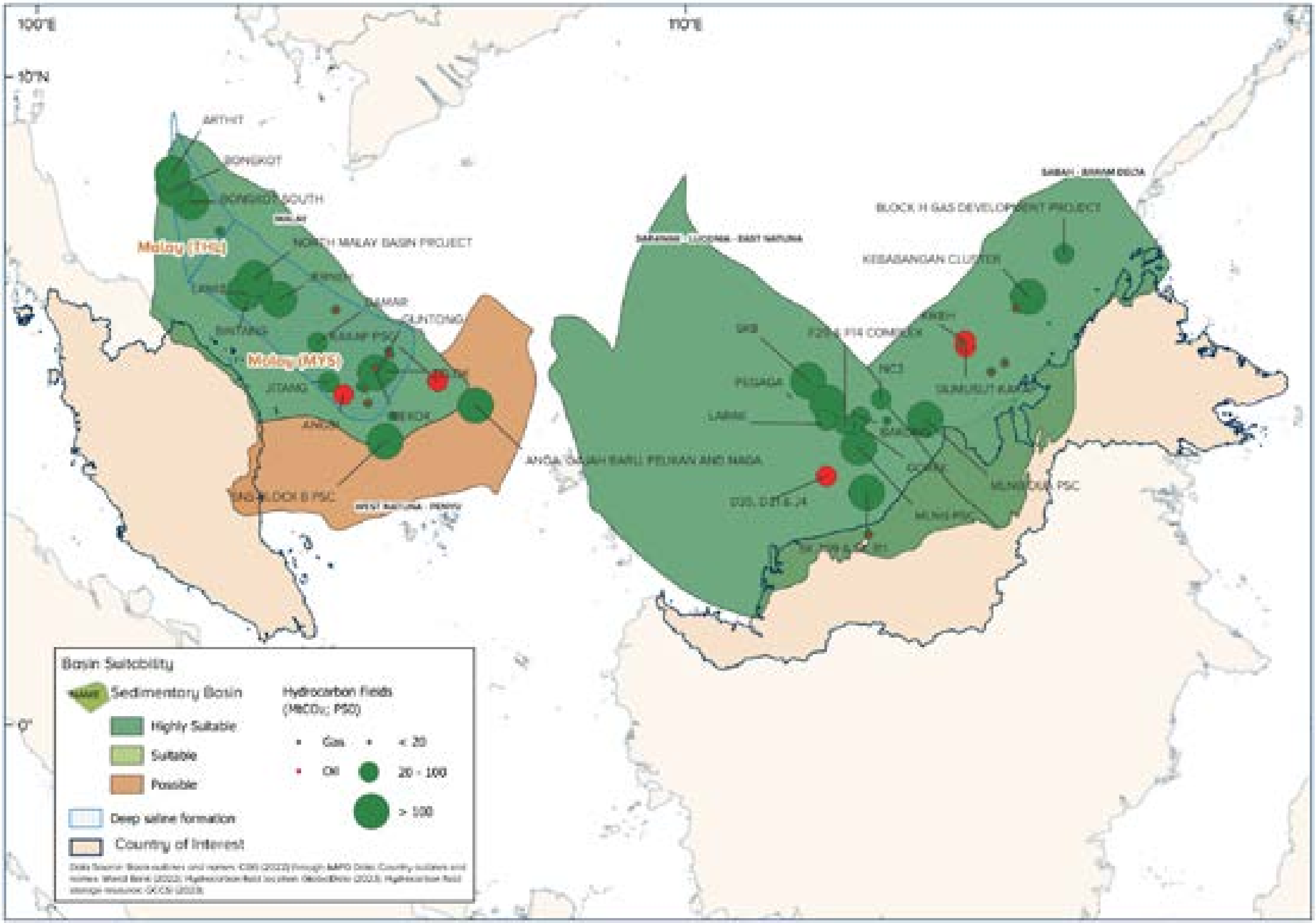
Estimated CO_2 Storage Resources in Selected Saline Formations (See Storage Resource Map for location)

Basin	Formation(s)	P90 ($GtCO_2$)	P50 ($GtCO_2$)	P10 ($GtCO_2$)
Malay-Tho Chu (Malaysia)	Sandstone below Upper Miocene intraformational seal	48	83	136
Sarawak	Carbonate below Middle-Upper Miocene regional marine shales	31	44	61
Malaysia Total		**80**	**127**	**197**

5.5.4 STORAGE RESOURCES (2/2)



5.5.5 STORAGE RESOURCE MAP



Note: Only fields with greater than 20 $MtCO_2$ storage resources are labelled.

5.5.6 PUBLISHED STORAGE RESOURCE ESTIMATES

Storage resource estimates ($GtCO_2$)	Focus of estimates	Source	Confidence in resource estimate
0.15	Malay Basin only (Groups D, E, H, K)	APEC, 2010 (Table 37)	Moderate confidence • Hydrocarbon production values used but outdated • Best practice volumetric calculation methodology used • Data Provided
140	Saline formations Malay and Central Luconia (Sarawak) basins	Junin and Hasbollah, 2016	Moderate confidence • Best practice field estimates method using hydrocarbon production values • Names of fields or data used not provided • Methodology assumptions not listed and input data limited
56 - 75 (P50)	Central Luconia Province only Sarawak Basin	Hasbollah and Junin, 2017	Moderate confidence • Best practice field estimates method using hydrocarbon production values • Names of fields or data used not provided • Methodology assumptions not listed and input data limited

5.5.7 COUNTRY SUMMARY

5.5.7.1 Summary of key storage formation and known (hydrocarbon) field developments for storage

Sandstone below the Upper Miocene intraformational seal

Sandstones below the Upper Miocene intraformational seal in the Malay Basin belong to the Bekok and Tapis Formations. The deposits are coastal plains and shallow marine sandstones (Armitage and Viotti, 1977; Ramli, 1998). Tapis Formation porosity ranges from 10 to 30%, and permeability ranges from 1 to 1,000 mD (Ramli, 1998), making it a suitable target for CO_2 storage. These formations are estimated to hold more than 83 Gt (P50) of CO_2 storage resources in their saline formations.

Jerneh Field

The Jerneh gas field is approximately 60 m of water depth and was discovered in 1969 (Fahmi, 2007). The field comprises coastal plain to tidal/shallow marine sandstones of the Upper Miocene seismic group D and E reservoirs (Bintang and Jerneh Formations, respectively) in the Malay Basin (Madon, 1994). Porosity ranges from 10 to 25%, and permeability can be up to 1,000 mD in Jerneh Field sandstones (Bishop, 2002; Madon, 1994). The Jerneh Field is estimated to hold 234 Mt of available CO_2 storage resources and 2 Mt of remaining CO_2 storage resources, for a total CO_2 storage resource base of 236 Mt.

5.5.7.2 Mineralisation

According to the Global Lithological Map Database v1.0, Malaysia has limited occurrences of mafic and ultramafic formations. Examples include the Mt. Kinabalu Ophiolite Complex in Mount Kinabalu, Malaysia, and alkaline basaltic lavas such as Kuantan basalt and Segamat basalt found in the Malay Peninsula.

Despite these formations, the abundance of oil and gas fields and saline aquifers in the country suggests that in-situ mineralisation technology may not hold potential compared to conventional CO_2 storage methods. These oil and gas reservoirs and saline aquifers could offer more suitable options for permanent CO_2 storage in Malaysia, making in-situ mineralisation technology less advantageous.

5.5.7.3 Summary of storage deployment prospects, barriers, and issues

- Malaysia hosts three highly suitable basins (including the Sabah Basin, which spans both Malaysia and Brunei) in the region. These basins contain significant resources in hydrocarbon fields and saline formations, although adjacent domestic emissions are relatively limited.

- Malaysia lacks a comprehensive national CO_2 storage resource atlas, with limited information on saline formations.

- The development of high CO_2 content gas fields in offshore Malaysia enables the development of CCS networks with natural gas processing as the anchor facility.

- While Malaysia features several basins highly suitable for CO_2 storage (Malay, Sarawak, Sabah), only one state (Sarawak) has a CCS-specific legal and regulatory framework.

- Beyond the offshore potential of the Sabah, Sarawak and Malay basins, there is limited opportunity for the cluster of emissions near Kuala Lumpur. The nation will unlikely seek storage in Indonesia even though prospective storage exists between 200-300 km away from the emissions sources. Accessing the Malay Basin's resources is the only likely potential for the KL cluster, which is a significant distance but the only plausible option for decarbonisation.

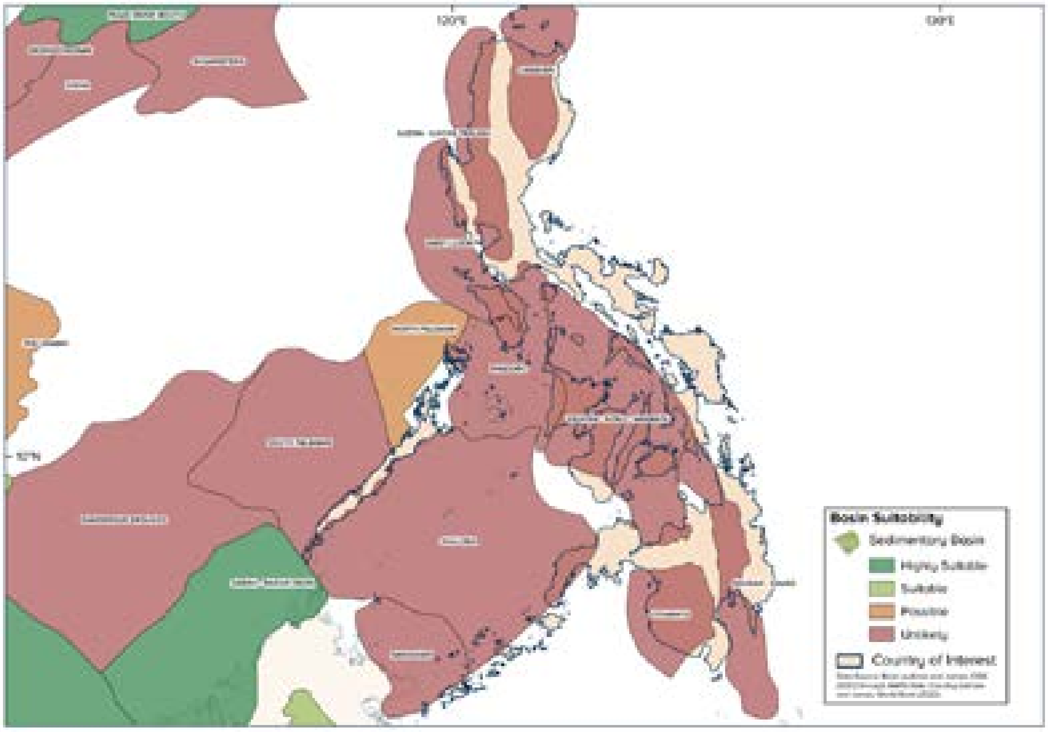
- Petronas is building the Kasawari and planning Lang Lebah CCS facilities in the Sarawak Basin. Both facilities are part of gas developments and will store reservoir CO_2 from high CO_2 fields and stored in depleted gas fields. Petronas is seeking agreements from international third parties from dedicated CO_2 transport and storage networks, such as the Korean Sheperd CCS consortium, which plans to capture CO_2 from industrial emissions in Korea for storage in Malaysian waters.

Japan Organization for Metals and Energy Security (JOGMEC) announced a total of nine consortiums to advance CCS deployment. Three of the consortiums focus on capturing of CO_2 in Japan and shipping to Malaysia for CO_2 storage.

See: https://www.jogmec.go.jp/english/news/release/news_10_00072.html

5.6 Philippines

5.6.1 BASIN SUITABILITY



5.6.2 BASIN RANKING

Basin	Geology	Subsurface Knowledge and Data Maturity	Storage Resource Knowledge	Accessibility	Overall
North Palawan	Possible	Possible	Possible	Unlikely	Possible
Sulu Sea	Possible	Unlikely	Unlikely	Unlikely	Unlikely
Luzon - Ilocos Trough	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely
West Luzon	Possible	Unlikely	Unlikely	Unlikely	Unlikely

Highly Suitable Suitable Possible Unlikely

5.6.3 STORAGE RESOURCES

Estimated CO_2 Storage Resources in Hydrocarbon Fields

Basin	P50- Storage available ($MtCO_2$)	P50- Storage remaining ($MtCO_2$)	P50- Storage net ($MtCO_2$)
North Palawan Basin (Malampaya Field only)	127	22	149

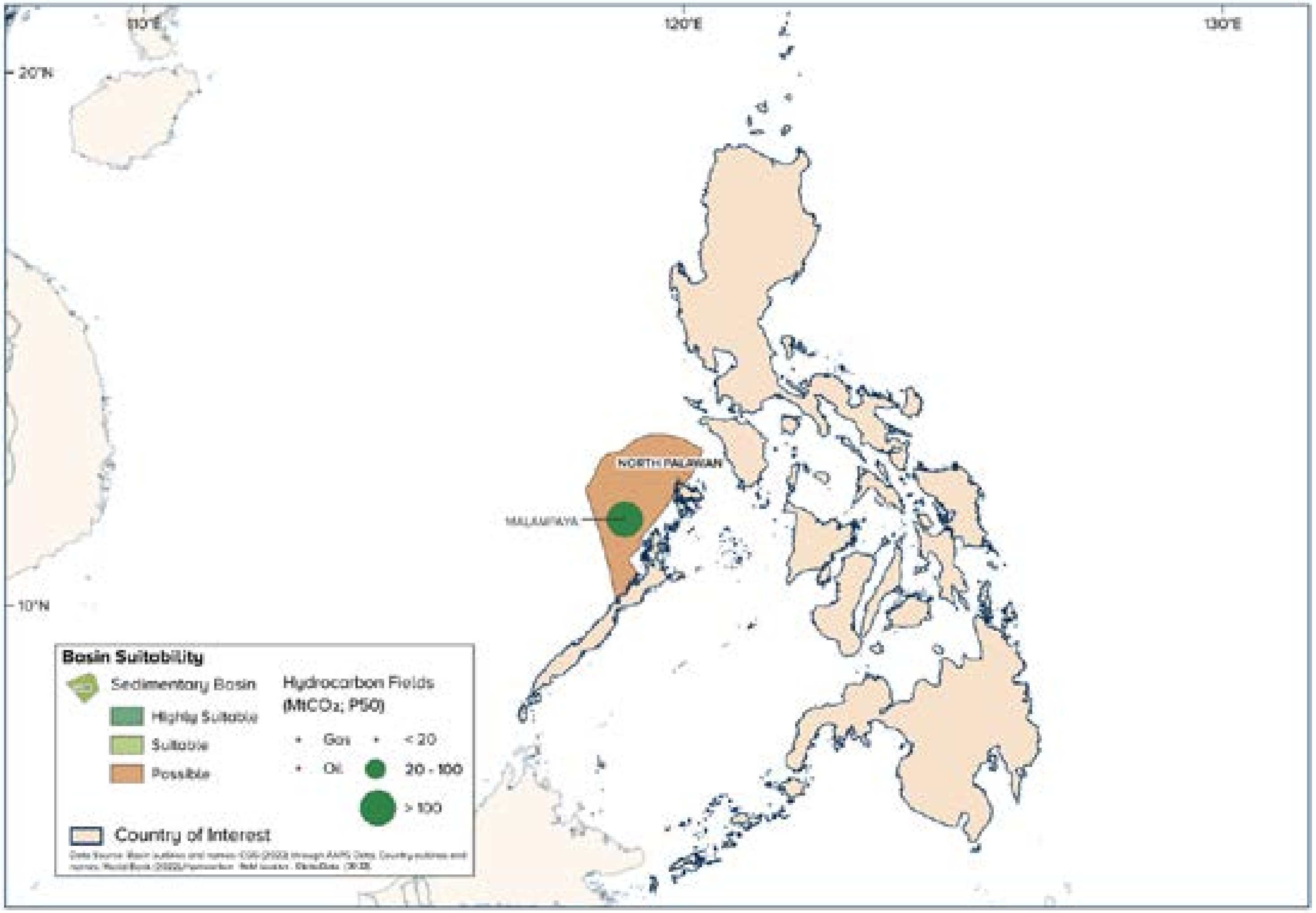
Estimated CO_2 Storage Resources in Selected Saline Formations

No saline formations were assessed due to a lack of reservoir property data.

Estimated CO_2 Storage Resources in Hydrocarbon Fields (See Storage Resource Map for location)

According to this study's methodology, the 5 $MtCO_2$ screening criterion is applied here. Therefore, only the Malampaya Field in the North Palawan Basin was identified. Hydrocarbon fields with smaller volumes would not offer economically viable CCS project opportunities.

5.6.4 STORAGE RESOURCE MAP



Note: Only fields with greater than 20 $MtCO_2$ storage resources are labelled.

5.6.5 PUBLISHED STORAGE RESOURCE ESTIMATES

Storage resource estimates ($GtCO_2$)	Focus of estimates	Source	Confidence in resource estimate
23	• Saline Formations and Depleted Fields • Country wide	Asian Development Bank, 2013	Low confidence • Hydrocarbon fields and saline formations not listed • Hydrocarbon estimates used original hydrocarbon in place values but is outdated • Data used not provided • Volumetric calculation methodology had basin-wide assumptions • Efficiency factors were country-specific, not reservoir specific

5.6.6 COUNTRY SUMMARY

5.6.6.1 Summary of key storage formation and hydrocarbon field

Malampaya Field

The Malampaya gas field is situated at 850 to 1200 m of water depth and was discovered in 1989 (Neuhaus et al., 2004). The field comprises Oligocene to Miocene carbonate build-ups (limestone) of the Nido Formation and sealed by mudstones of the overlying Pagasa Formation (Neuhaus et al., 2004). Porosity ranges from 5% to 30%, and permeabilities range from 0.01 to 1,000 mD (Fournier and Borgomano, 2007). The Malampaya Field is estimated to hold 127 Mt of available CO_2 storage resources and 22 Mt of remaining CO_2 storage resources, for a total CO_2 storage resource base of 149 Mt.

5.6.6.2 Mineralisation

There are several notable mafic and ultramafic formations in the Philippines, each with unique characteristics and rock compositions. Some of these formations include:

- Zambales Ophiolite Complex: Located in Zambales province, it is an extensive mafic and ultramafic rock formation. It comprises various rock units, including gabbros, basalts, and peridotites.

- Angat ophiolites: Located in Luzon. It comprises layered and massive gabbros, diabase sheeted dikes, tonalites, and pillow basalts.

- Camarines Norte Ophiolite Complex: Located in Camarines Norte province, it consists of harzburgites, gabbros, diabasic and basaltic dikes, and pillow lavas.

- Dinagat Ultramafic and Ophiolite Complex: Situated in the Dinagat Islands, this complex comprises ultramafic rocks such as dunites, peridotites, and serpentinites.

- Surigao Ophiolite Complex: located in Surigao del Norte and Surigao del Sur provinces, this belt contains ultramafic rocks, including dunites, peridotites, and serpentinites.

- Leyte Ophiolite Complex: Located in Leyte province, this complex consists of ultramafic rocks such as peridotites and serpentinites.

The presence of ophiolites, dispersed across the Philippines in over 20 significant bodies, suggests a potential for carbon mineralisation in the country, provided they feature open, well-connected, and complex fracture networks. However, it is important to note that the Philippines is in a tectonically active zone. This tectonic activity means that even if fractures are initially sealed, constant movement could re-open them, allowing for fluid flow and injection. However, the country's susceptibility to earthquakes and volcanic eruptions poses challenges for implementing in-situ mineralisation technology. Careful pressure management strategies and well-defined injection rates are necessary to mitigate the risks of induced seismicity. As demonstrated by Iceland's CarbFix operation in a similarly seismically active region, successful practices offer valuable insights.

A detailed evaluation is crucial to fully understand the potential and suitability of each formation for in-situ carbon mineralisation technology. Among the essential steps are precise quantification of their mineralogical composition, thorough characterisation of their fracture networks and fluid flow properties, and comprehensive numerical modellings. With careful consideration of these factors, the Philippines can further explore the promising avenue of in-situ carbon mineralisation.

5.6.6.3 Summary of storage deployment prospects, barriers, and issues

- The Philippines lacks a comprehensive national CO_2 storage resource atlas: the storage potential of onshore and offshore saline formations is unknown. A storage atlas mapping the formations is critical to advancing CO_2.

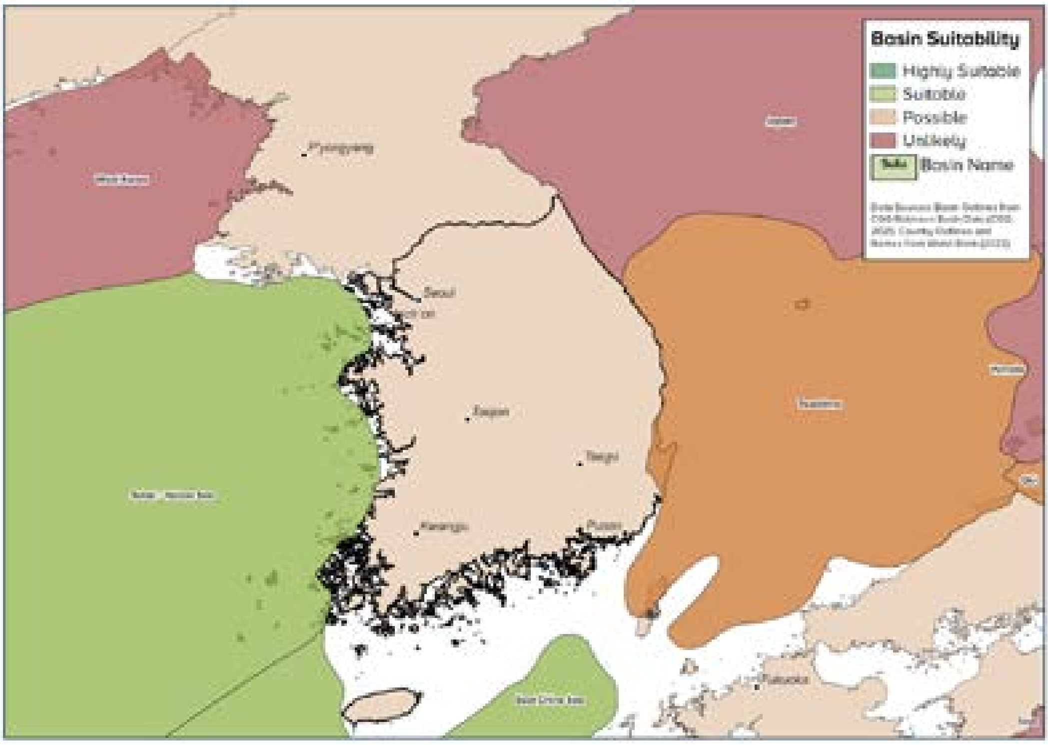
- A detailed evaluation is crucial to fully understand the feasibility and viability of the potential for in-situ carbon mineralisation.

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

- There are no active CCS facilities in the Philippines.

5.7 South Korea

5.7.1 BASIN SUITABILITY



5.7.2 BASIN RANKING

Basin	Geology	Subsurface Knowledge and Data Maturity	Storage Resource Knowledge	Accessibility	Overall
Tsushima	Highly Suitable	Unlikely	Possible	Possible	Possible

Highly Suitable Suitable Possible Unlikely

5.7.3 STORAGE RESOURCES

Estimated CO_2 Storage Resources in Hydrocarbon Fields

Basin	P50- Storage available ($MtCO_2$)	P50- Storage remaining ($MtCO_2$)	P50- Storage net ($MtCO_2$)
Tsushima	11	0	11

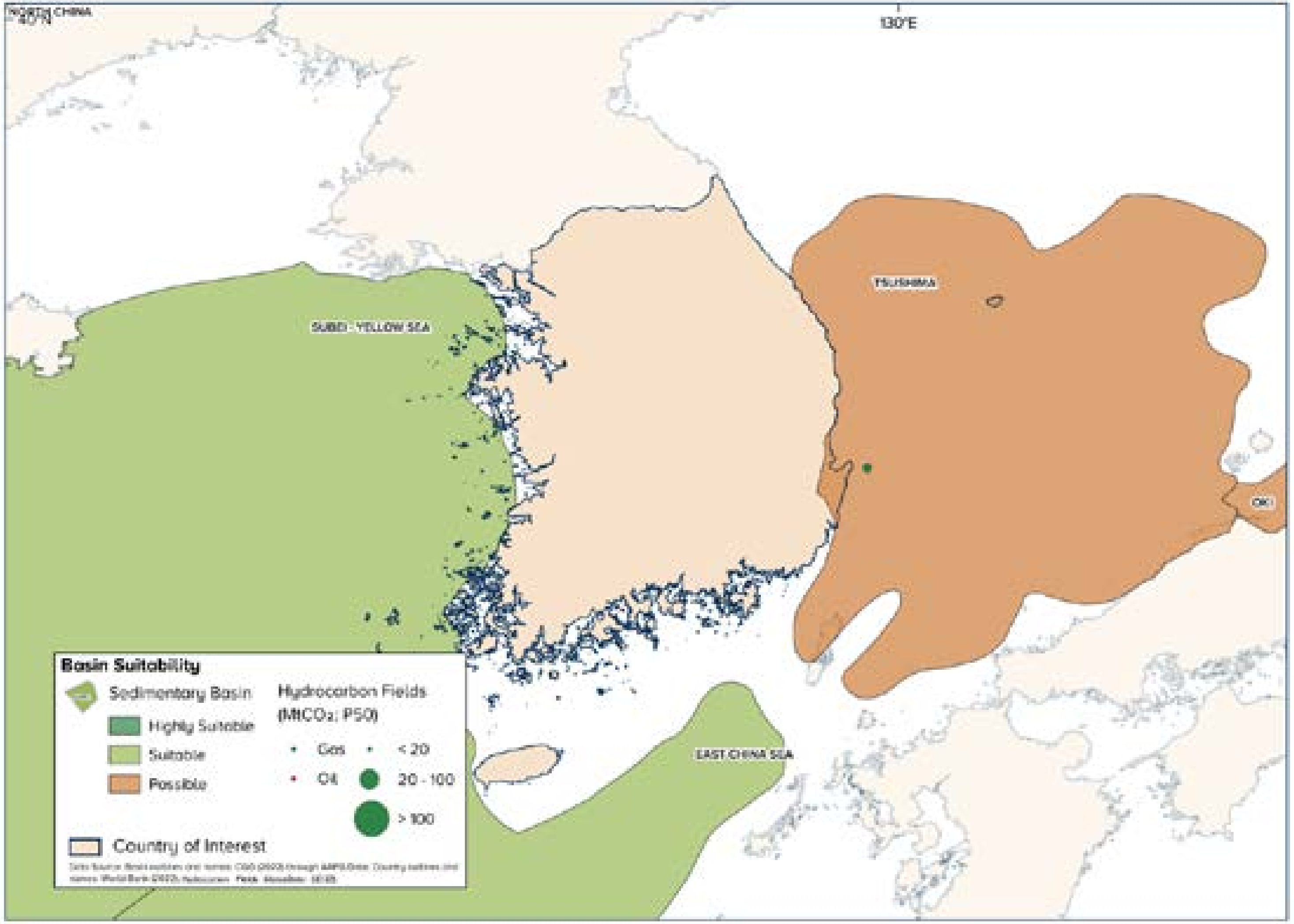
Estimated CO_2 Storage Resources in Selected Saline Formations

Basin	Formation(s)	P90 ($GtCO_2$)	P50 ($GtCO_2$)	P10 ($GtCO_2$)
Tsushima	B2-B5 layers (Donghae-1)		0.02	

Estimated CO_2 Storage Resources in Hydrocarbon Fields

According to this study's methodology, the 5 $MtCO_2$ screening criterion is applied here. Therefore, no fields are shown. Hydrocarbon fields with smaller volumes would not offer economically viable CCS project opportunities.

5.7.4 STORAGE RESOURCE MAP



Note: Only fields with greater than 20 $MtCO_2$ storage resources are labelled.

5.7.5 PUBLISHED STORAGE RESOURCE ESTIMATES

Storage resource estimates ($GtCO_2$)	Focus of estimates	Source	Confidence in resource estimate
0.014	Chungnam, Taeboeksan, Mungyeong basins' sandstones	Hong et al., 2009	Low Confidence • Volumetric resource calculation method not best practice • Method has very large basin-wide assumptions for calculations based on area and percentage of sandstone • Full data provided • Methodology assumptions and data provided
1.011	Sandstones of the Sindong Group, Gyeongsang Basin	Egawa et al., 2009	Moderate Confidence • Volumetric resource calculation method not best practice • Formation-scale evaluation based on area and percentage of sandstone • Full data provided • Methodology assumptions and data provided
0.036 - 0.0243	Estimate for the Donghae-1 Gas Field (Ulleung/ Tsushima Basin)	Park et al., 2018	High confidence • Based on dynamic simulation • Uses subsurface seismic and well data • Data provided

5.7.6 COUNTRY SUMMARY

5.7.6.1 Summary of key storage formation and hydrocarbon field

Donghae-1 Field

The Donghae-1 gas field is situated at 150 m of water depth and was discovered in 1998 (Park et al., 2018; Sung et al., 2001). The field comprises shallow marine sandstones with a porosity of approximately 14% and permeabilities ranging from 23 to 38 mD in the B3 and B4 zones, respectively (Sung et al., 2001). The Donghae-1 Field is an abandoned field estimated to hold 11 Mt of available CO_2 storage resources.

5.7.6.2 Mineralisation

According to the Global Lithological Map Database v1.0, certain areas of South Korea contain mafic and ultramafic rocks. Here are some notable examples:

- Uljin Ultramafic Complex: Located in Uljin County, Gangwon Province, this complex consists of peridotite, pyroxenite, and dunite.
- Hongseong Complex: Situated in the Hongseong area of South Korea, this complex comprises a variety of mafic and ultramafic rocks, including gabbro, diabase, peridotite, and serpentinite.
- Samcheok Ophiolite Complex: Found in Samcheok City, Gangwon Province, this complex comprises various rock units, including gabbros, basalts, and ultramafic rocks.
- Daebo Ultramafic Complex: Located in Daebo-ri, Gyeongsangbuk-do Province, this extensive formation comprises peridotites and pyroxenites.

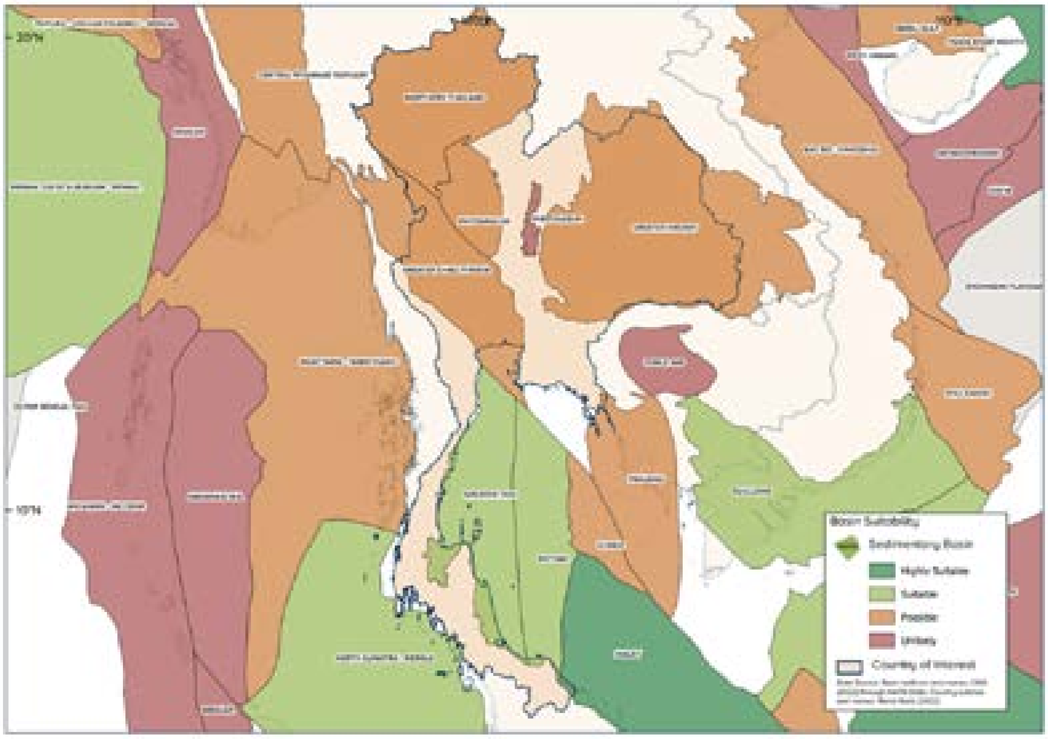
A detailed assessment of each formation is necessary to accurately quantify their mineralogical composition, characterise their fracture networks, and ultimately evaluate their storage potential and suitability for deploying in-situ carbon mineralisation technology.

5.7.6.3 Summary of storage deployment prospects, barriers, and issues

- South Korea has limited suitable sedimentary basins for CO_2 storage.
- CO_2 storage resources in the Ulleung (Tsushima) Basin offshore South Korea's east coast and the Yellow Sea Basin offshore its west coast have not been fully assessed. Due to their large geographic area, these offshore basins likely provide the best opportunities for large-volume CO_2 storage.
- South Korea also lacks a comprehensive suite of sub-surface data that other nations with a mature oil and gas industry host. A CO_2 storage data acquisition programme is therefore required to de-risk storage prospects.
- Although the storage potential of South Korea is largely unknown, given the sheer scale of domestic emissions, the country will likely require the export of CO_2. Several projects, such as Sheperd CCS, have already been announced to export CO_2 from South Korea. In addition, the country has ratified the London Protocol 2009 Amendment to enable the export of CO_2 for sub-seabed geological storage.
- South Korea has limited regulations to enable CO_2 storage. However, the country has also committed to developing legislation supporting CCS within its National Framework Plan.

5.8 Thailand

5.8.1 BASIN SUITABILITY



*The Thai portion (northern) of the Malay Basin is classified as “suitable” compared to the southern Malay Basin, which is categorised as highly suitable. However, this change cannot be reflected in the maps due to the limitations of the mapping program.

5.8.2 BASIN RANKING

Basin	Geology	Subsurface Knowledge and Data Maturity	Storage Resource Knowledge	Accessibility	Overall
Greater Thai	Suitable	Highly Suitable	Possible	Possible	Suitable
Pattani	Possible	Highly Suitable	Suitable	Possible	Suitable
Malay*	Suitable	Highly Suitable	Highly Suitable	Possible	Suitable
Khmer	Suitable	Possible	Possible	Possible	Possible
Northern Thailand	Suitable	Unlikely	Possible	Possible	Possible
Greater Korat	Suitable	Possible	Possible	Possible	Possible
Greater Chao Phraya	Possible	Unlikely	Possible	Possible	Possible
Phitsanulok	Possible	Unlikely	Possible	Possible	Possible
Phetchabun	Suitable	Unlikely	Unlikely	Possible	Unlikely

Highly Suitable   Suitable   Possible   Unlikely

*The Thai portion (northern) of the Malay Basin is classified as "suitable" compared to the southern Malay Basin, which is categorised as highly suitable. However, this change cannot be reflected in the maps due to the limitations of the mapping program.

5.8.3 STORAGE RESOURCES (1/2)

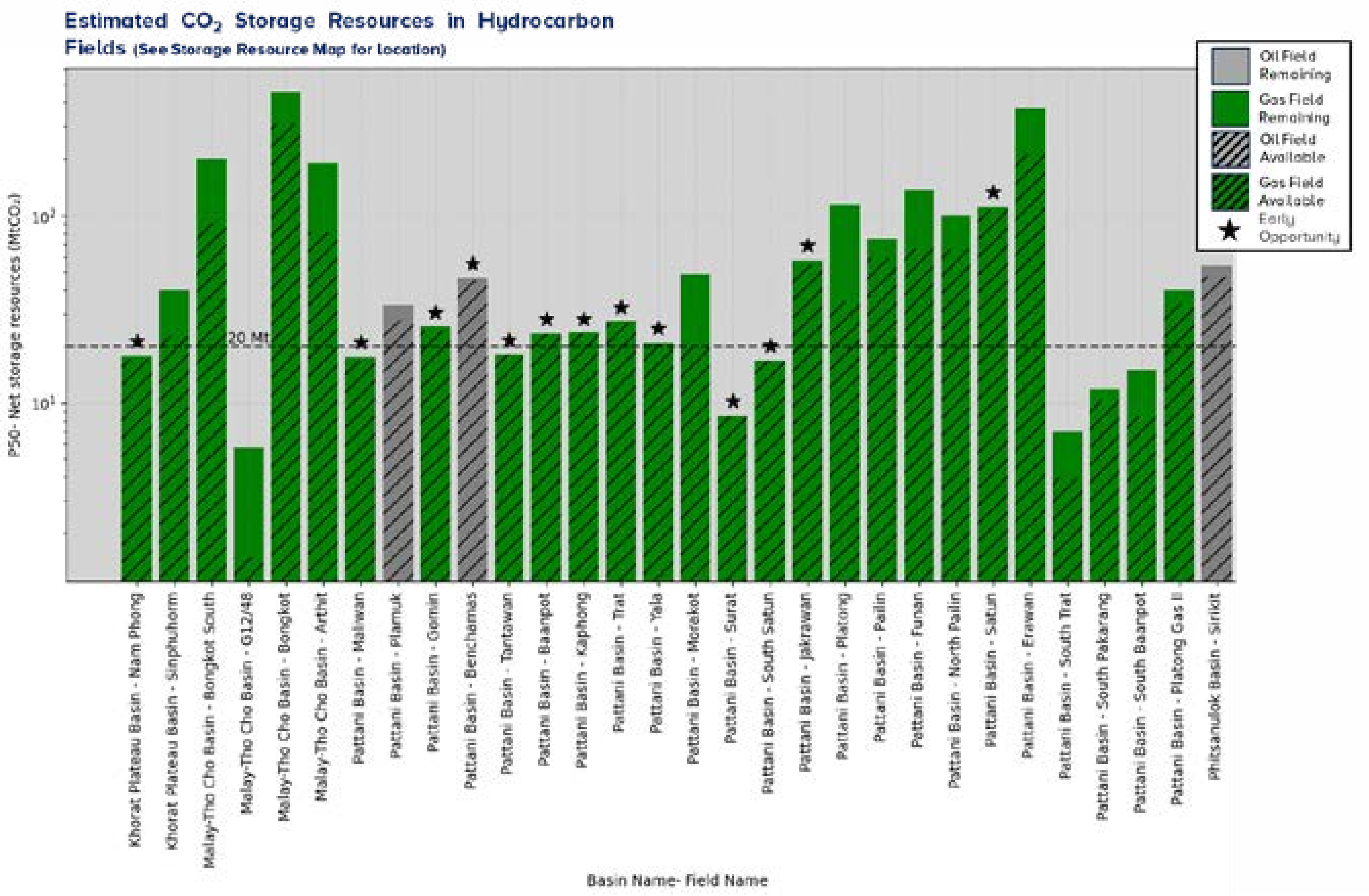
Estimated CO_2 Storage Resources in Hydrocarbon Fields

Basin	P50- Storage available ($MtCO_2$)	P50- Storage remaining ($MtCO_2$)	P50- Storage net ($MtCO_2$)
Khorat Plateau	39	19	58
Malay-Tho Cho	483	370	853
Pattani	924	424	1,348
Phitsanulok	47	7	54
Thailand Total	1,494	819	2,313

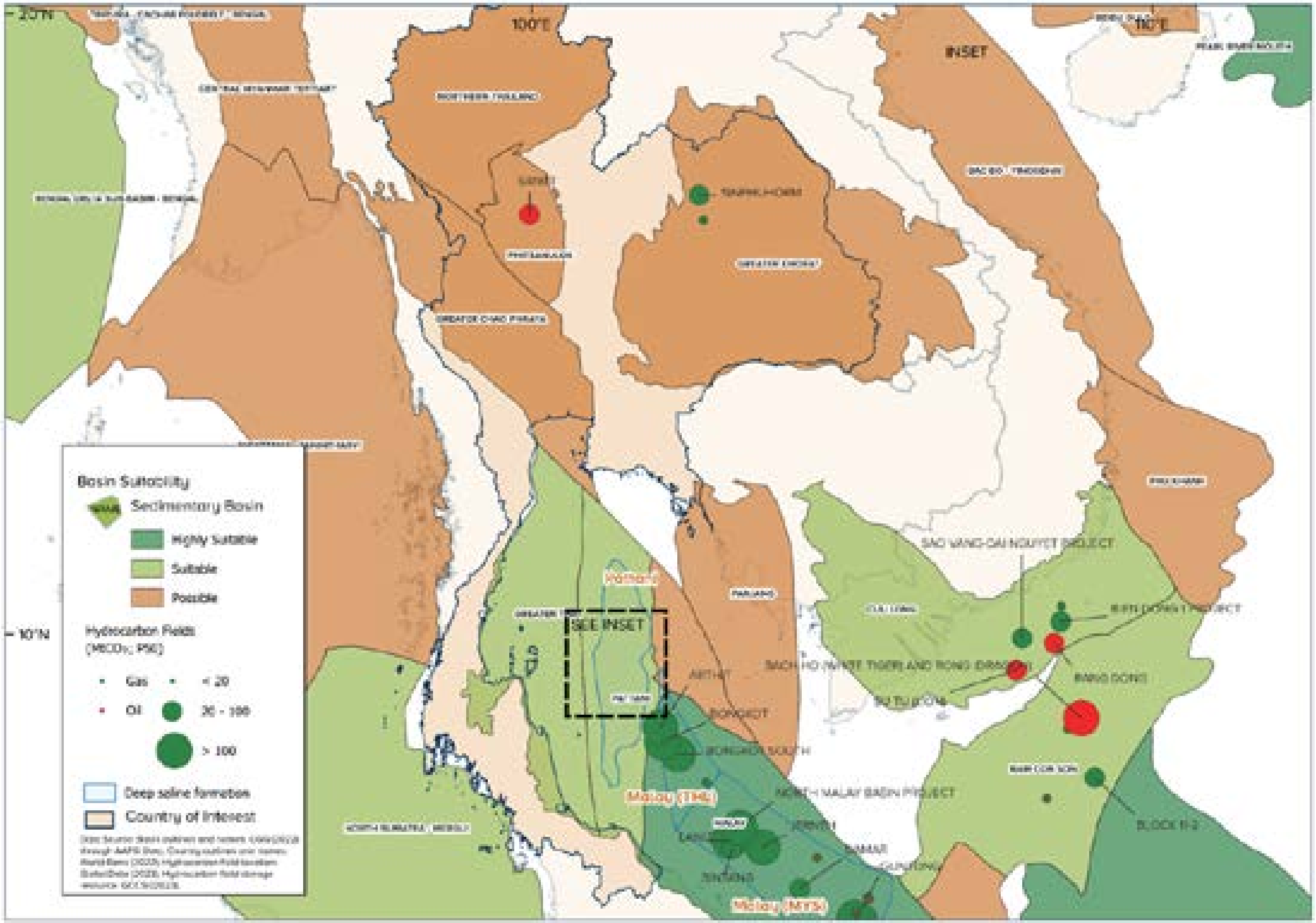
Estimated CO_2 Storage Resources in Selected Saline Formations (See Storage Resource Map for location)

Basin	Formation(s)	P90 ($GtCO_2$)	P50 ($GtCO_2$)	P10 ($GtCO_2$)
Pattani	Bekok, Tapis, Pulai	9	13	18
Malay-Tho Cho (Thailand)	Sandstone below Upper Miocene intraformational seal	1.4	2	4
Thailand Total		10	15	22

5.8.4 STORAGE RESOURCES (2/2)



5.8.5 STORAGE RESOURCE MAP



*The Thai portion (northern) of the Malay Basin is classified as “suitable” compared to the southern Malay Basin, which is categorised as highly suitable. However, this change cannot be reflected in the maps due to the limitations of the mapping program.

Note: Only fields with 20 $MtCO_2$ storage resources are labelled.

5.8.6 PUBLISHED STORAGE RESOURCE ESTIMATES

Storage resource estimates ($GtCO_2$)	Focus of estimates	Source	Confidence in resource estimate
0.0698	Pattani Trough, Gulf of Thailand (simulation for a single storage site)	APEC, 2010	Moderate confidence • Hydrocarbon production values used but outdated • Best practice volumetric calculation methodology used • Data Provided
10.3	Saline Formations and Depleted Fields	Asian Development Bank, 2013	Low confidence • Hydrocarbon fields and saline formations not listed • Hydrocarbon estimates used original hydrocarbon in place values but is outdated • Data used not provided • Volumetric calculation methodology had basin-wide assumptions • Efficiency factors were country-specific, not reservoir specific
2.285	Hydrocarbon production and reserves replacement calculation for onshore and offshore basins.	Choomkong et al., 2017	Moderate confidence • Hydrocarbon production values used but outdated • Best practice volumetric calculation methodology used • Data Provided
0.0135	Songkhla Sub-Basin Lower Oligocene and Lower Miocene only	Choomkong et al., 2020	High confidence • Based on dynamic simulation • Uses subsurface seismic and well data • Data provided

5.8.7 COUNTRY SUMMARY

5.8.7.1 Summary of key storage formation and hydrocarbon field

Bekok, Tapis, and Pulai Formations

The Pattani Basin has CO_2 storage potential in Cenozoic sediments for saline formation storage, including multiple reservoirs and intraformational seals. The Miocene-aged Bekok, Tapis, and Pulai formations were estimated to host storage resources of 13 $GtCO_2$ (P50). This estimate is comparable to the ADB's multi-national assessment that estimated a total theoretical storage potential of around 10 $GtCO_2$ storage resource (ADB, 2013). However, the basin is geologically complex. Accumulations of the oil and gas fields in the basin are known to be volumetrically small as individual reservoirs due to the fluvial depositional nature of the reservoirs and intense faulting.

Bongkot Field

The Bongkot gas field (Malay Basin) is situated in 75 to 80 m of water depth and was discovered in 1973 (Bladier, 1996). The field comprises fluvial-deltaic and shallow marine sandstones with porosities averaging 21% and permeabilities averaging 100 mD (Bladier, 1996). The Bongkot Field is estimated to hold 91 Mt of available CO_2 storage resources and 110 Mt of remaining CO_2 storage resources, for a total CO_2 storage resource base of 201 Mt.

5.8.7.2 Mineralisation

Thailand's geological composition encompasses diverse rock types, such as metamorphic, sedimentary, plutonic, and some volcanic rocks. Notably, basalts have erupted into small bulbs scattered across multiple provinces in Thailand, such as Chiang Rai, Lampang, Phrae, Lopburi, Phetchabun, Surin, Buri Ram, Si Saket, Lampang and Chanthaburi provinces, among others. Some of these basalts, especially those found in active volcanic regions, could be relatively young, dating back several thousand years or even more recently due to ongoing volcanic activity. These younger basalts, dating back to the Quaternary period, may hold promise for deploying in-situ carbon mineralisation technology. However, a comprehensive assessment of each formation is crucial to determine their mineralogical composition precisely, accurately characterise their fracture networks, and ultimately evaluate their storage potential and suitability for deploying in-situ mineralisation technology.

5.8.7.3 Summary of storage deployment prospects, barriers, and issues

- Thailand lacks a modern, comprehensive national storage resource atlas. A particular focus should be on the Khorat, Greater Choo Phraya and Phitsanulok basins onshore.

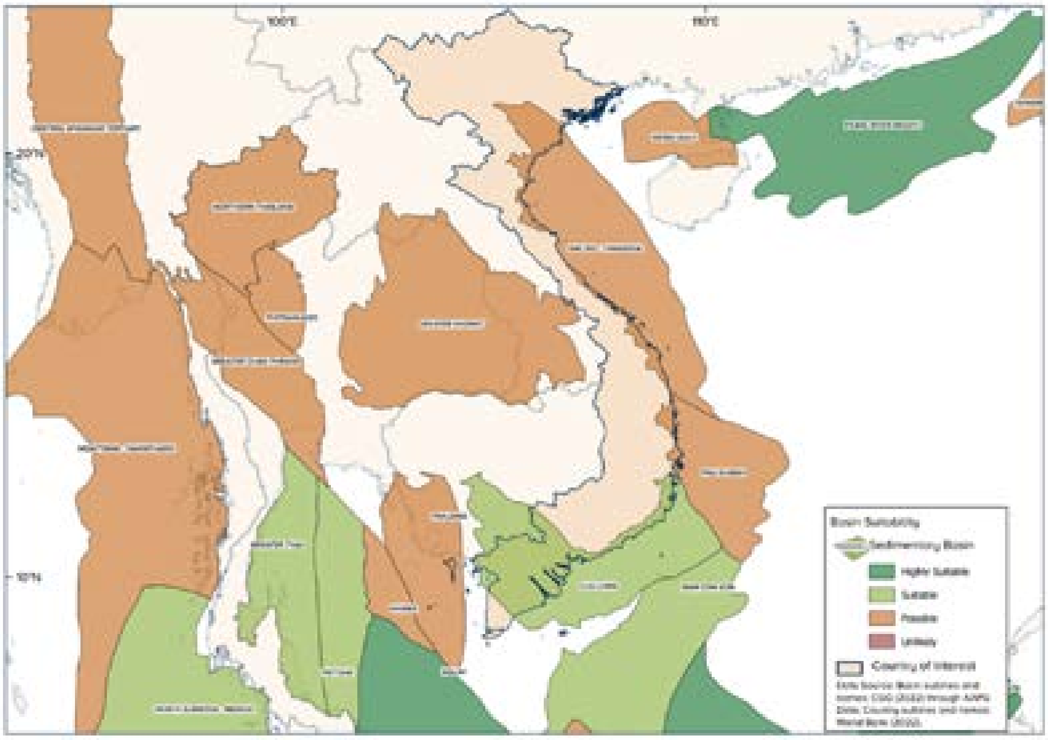
- The Malay and Pattani basins require targeted site-scale characterisation analysis to understand the hydrocarbon fields and associated saline formations. Hence, the basins present a near to long-term (5-10 years+) opportunity for storage.

- Thailand lacks a CCS-specific legal and regulatory framework and CCS-specific domestic policies or incentives. However, the national oil company, PTTEP, are proactive in storage deployment, which may drive changes in the regulatory and policy frameworks.

- PTTEP is developing the Arthit CCS Facility near the boundary of the Malay and Pattani basins. This facility, currently under development, will reduce emissions from gas fields with high CO_2 concentrations. There is no indication of expanding this facility beyond the reservoir CO_2. Also, PTTEP is exploring opportunities to build a CCS Network for industries in Rayong and Chonburi provinces, known as the Eastern Thailand CCS Hub. There is limited information on this announcement.

5.9 Vietnam

5.9.1 BASIN SUITABILITY



5.9.2 BASIN RANKING

Basin	Geology	Subsurface Knowledge and Data Maturity	Storage Resource Knowledge	Accessibility	Overall
Bac Bo	Suitable	Possible	Unlikely	Possible	Possible
Phu Khanh	Possible	Unlikely	Unlikely	Possible	Possible
Cuu Long	Suitable	Possible	Highly Suitable	Possible	Suitable
Nam Con Son	Suitable	Suitable	Suitable	Possible	Suitable

Highly Suitable · Suitable · Possible · Unlikely

5.9.3 STORAGE RESOURCES

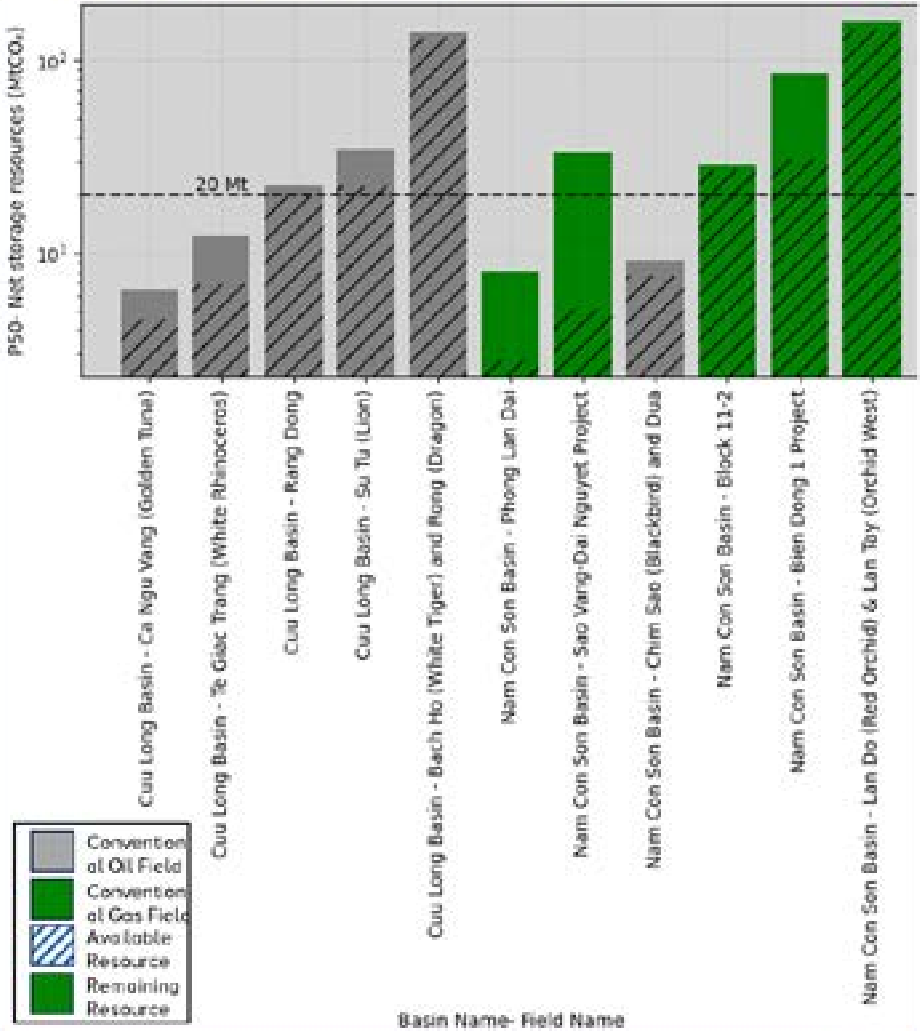
Estimated CO_2 Storage Resources in Hydrocarbon Fields

Basin	P50- Storage available ($MtCO_2$)	P50- Storage remaining ($MtCO_2$)	P50- Storage net ($MtCO_2$)
Cuu Long	185	30	215
Nam Con Son	218	107	325
Vietnam Total	404	137	541

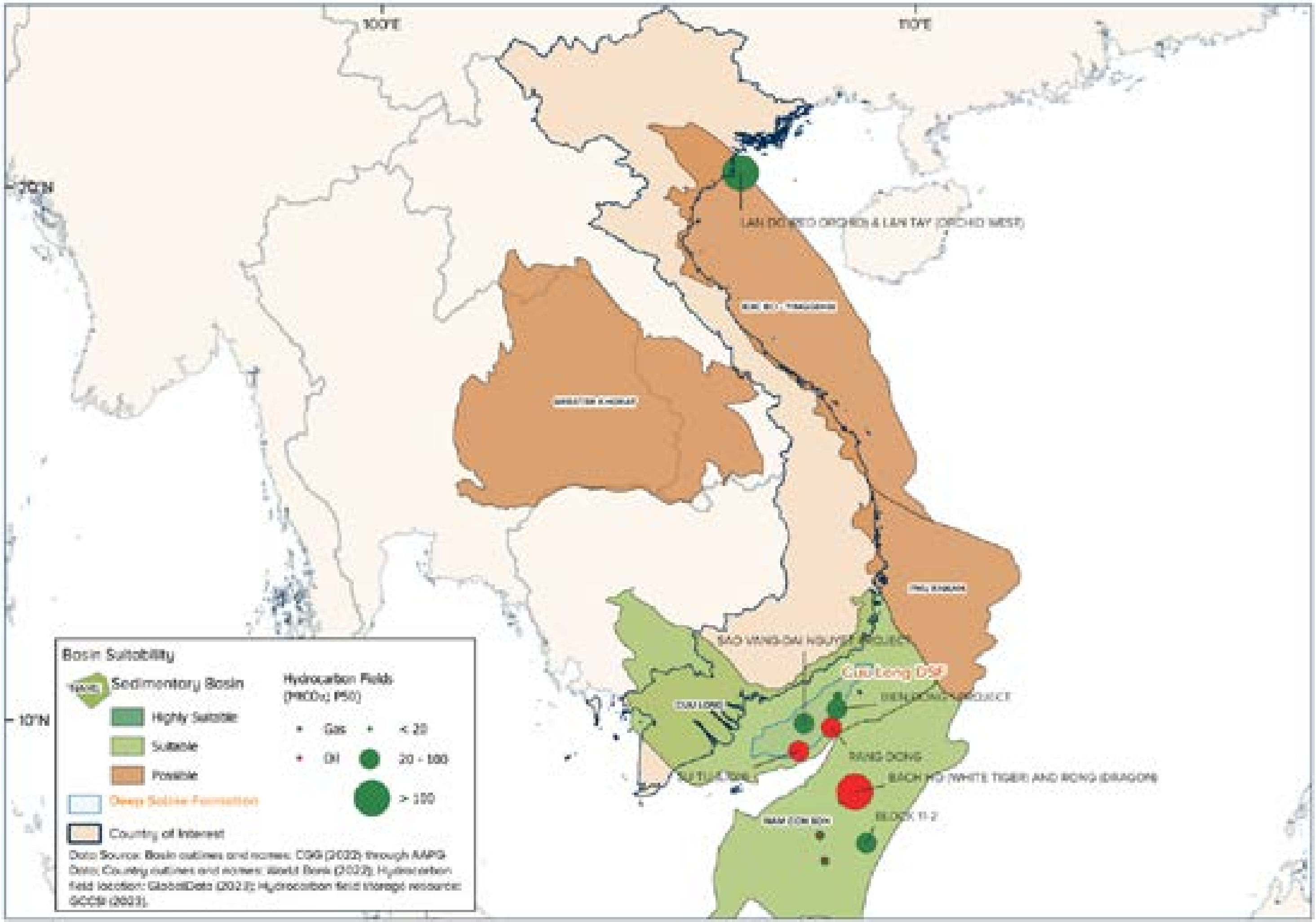
Estimated CO_2 Storage Resources in Selected Saline Formations (See Storage Resource Map for location)

Basin	Formation	P90 ($GtCO_2$)	P50 ($GtCO_2$)	P10 ($GtCO_2$)
Cuu Long	Bach Ho	2.839	5.004	8.683

Estimated CO_2 Storage Resources in Hydrocarbon Fields (See Storage Resource Map for location)



5.9.4 STORAGE RESOURCE MAP



Note: Only fields with 20 $MtCO_2$ storage resources are labelled.

5.9.5 PUBLISHED STORAGE RESOURCE ESTIMATES

Storage Resource Estimate ($GtCO_2$)	Focus of estimates	Source	Confidence in resource estimate
0.1257	Malay Basin only (Groups H, I, J, K, L)	APEC, 2010	Moderate confidence • Hydrocarbon production values used but outdated • Best practice volumetric calculation methodology used • Data Provided
11.7	Saline Formations and Depleted Fields	Asian Development Bank, 2013	Low confidence • Hydrocarbon fields and saline formations not listed • Hydrocarbon estimates used original hydrocarbon in place values but is outdated • Data used not provided • Volumetric calculation methodology had basin-wide assumptions • Efficiency factors were country-specific, not reservoir specific

5.9.6 COUNTRY SUMMARY

5.9.6.1 Summary of key storage formation and hydrocarbon field

Bach Ho Formation

The Bach Ho Formation is estimated to host 5 $GtCO_2$ (P50) storage resources and is the only studied saline formation in this analysis. The Bach Ho Formation comprises Late Oligocene to Early Miocene sandstones and mudstones in the Cuu Long Basin offshore Vietnam. The sediments were deposited in shallow marine-to-fluvial environments, and sandstone thickness ranges from < 10 to 20 m. Bach Ho Formation's porosity ranges from 16% to 25%, and permeability ranges from 1 to 5,000 mD (Giao et al., 2016), making it a suitable target for storage.

Bach Ho (White Tiger) and Rong (Dragon) Fields

The Bach Ho (White Tiger) and Rong (Dragon) offer the highest storage resources among the studied oil fields. The field is estimated to hold 132 Mt of available storage resources and 8 Mt of remaining storage resources, for a total storage resource base of around 140 Mt. The oil fields are approximately 60 m in water depth and were discovered in 1975 (Cuong & Warren, 2009). The fields comprise Mesozoic fractured "basement" rocks (granites and volcanics) as well as overlying Oligocene fluvial-to-lacustrine clastic deposits of the Tra Tran Formation and Oligo/Miocene shallow marine-to-fluvial clastic deposits of the Bach Ho Formation – all of which serve as hydrocarbon reservoirs. Porosities in the Tra Tran Formation range from 9% to 15% and from 12% to 25% in the Bach Ho Formation (Cuong & Warren, 2009; Dien et al., 1997). The fields were the site of a detailed site characterisation study for the World Bank as part of a CO_2-EOR scoping study. The project ultimately did not go ahead.

5.9.6.2 Mineralisation

In Vietnam, igneous rocks have been found dating from the Early Paleozoic to the Quaternary. Here are some examples:

- Luc Yen mafic-ultramafic complex: In Yen Bai Province, this complex comprises mafic and ultramafic rocks such as gabbros, basalts, peridotites, and serpentinites.
- Lai Chau mafic-ultramafic complex: Located in Lai Chau Province, this complex comprises mafic and ultramafic rocks such as gabbros, basalts, peridotites, and serpentinites.
- Nui Chua layered peridotite-gabbro complex: This complex is in northern Vietnam and comprises various mafic and ultramafic rocks, including peridotite, gabbro, and diabase.

The young volcanic rocks in the country suggest the potential for in-situ carbon mineralisation. However, a comprehensive assessment of each formation is crucial to determine their mineralogical composition precisely, accurately characterise their fracture networks, and ultimately evaluate their storage potential and suitability for deploying in-situ mineralisation technology.

5.9.6.3 Summary of storage deployment prospects, barriers, and issues

- Vietnam lacks a modern, comprehensive national CO_2 storage resource atlas.
- The Cuu Long Basin requires a targeted characterisation study, focusing on saline formations and large depleted fields. Subsequently, the basin presents a moderate to long-term (<10 years) opportunity for storage.
- The Song Hong Basin requires an extensive characterisation assessment, given a significant portion of Vietnam's emissions are proximal to this basin.
- Vietnam lacks a CCS-specific legal and regulatory framework and CCS-specific domestic policies or incentives.
- There are no active CCS facilities in Vietnam. However, the country has experience in CO_2 injection and storage, including two pilot CO_2-EOR operations, White Tiger (Bach Ho) and Aurora (Rang Dong). The White Tiger CO_2-EOR operation was the first pilot project in South-East Asia and possibly the only CO_2 injection project to date.

5.10 Singapore

- The geology of Singapore indicates there is no storage potential in the country. However, Singapore has significant emissions, primarily in the petrochemical and refining industries, requiring CCS for decarbonisation. Singapore, therefore, requires transboundary transport of CO_2.
- The saline formations and/or hydrocarbon fields of Indonesia's Central Sumatra and North Sumatra basins are within 300 km of Singapore. However, Indonesia has significant domestic emissions in those regions that could result in competition for CO_2 storage resources. Alternatively, pipeline or shipping routes could export CO_2 to the Malay Basin in Malaysia. Competition for storage resources is less likely in the Malay Basin when compared to onshore Indonesian domestic CO_2 sources.

5.11 Cambodia, Lao, Myanmar

These nations' storage potential is largely unknown, and only minor studies, abstracts, or presentations are available in the public domain. Although they have comparatively minor emissions, CCS will eventually be required in each country.

The primary issue is a lack of CCS awareness and CO_2 storage expertise in these nations. They require the assistance of more advanced countries regionally (Thailand, Malaysia) and internationally.

- It is recommended that these nations engage with the international storage community to progress CCS in each country. In addition, these nations currently do not have any CO_2 storage analysis, CCS-specific legal and regulatory frameworks or CCS-specific domestic policies or incentives.

5.12 Recommendations

Current Status

- Most knowledge about the storage potential of the region's geology is derived from regional or global studies (ADB, 2013; CO_2CRC, 2010; IEAGHG, 2009). Within those studies, resource estimates have focused on oil and gas fields. However, in most cases, the data behind the estimates was not provided, meaning the calculations could not be reviewed, reducing confidence. Generally, only the basins with oil and gas fields have been reviewed for their storage potential. A limited number of basins have been published with detailed site-specific studies.

Barriers to Deployment

Despite over a decade of storage studies in South-East Asia, a review of the countries above highlights three clear barriers to the development of storage resources:

- The storage resources of saline formations are largely unknown, and formations are uncharacterised. Saline formations in this region will host most storage resources distributed onshore and offshore across the region in almost all basins.
- Published storage resource estimates lack location, methodology, assumptions, limitations, or input data transparency.

- These nations have almost no public access to sub-surface data (such as geological, well-log, seismic reflection surveys, and core data). A lack of public access to data means the data (and therefore knowledge) is only held by oil and gas companies or subscription services. These three barriers prevent the ongoing development of storage resources in South-East Asia and restrict understanding of the applicability of CCS deployment in the region.

Approach

- Each country is at a different stage of maturity in terms of CCS and storage development. A coordinated approach to storage resource development in South-East Asia could accelerate the deployment of CCS in the region.

- A series of public-private partnerships could sponsor the characterisation of storage basins in each nation.

    - International experts and experts in Indonesia, Malaysia, and Thailand could lead these partnerships to assist less advanced countries regarding CCS.

    - Each partnership would focus on its own country to complete an assessment using a standardised approach to data collection, characterisation and resource calculations.

    - The assessment results will be published in a public database of hydrocarbon fields and saline formations, showing the location, area extent, reservoir-seal properties, and resources, amongst other information critical for storage development.

- As a public database, issues such as anti-trust or anti-competitive assertions can be avoided, enabling industry to participate. In addition, new storage operators could rapidly progress initial screening analysis by using the database's outcomes and data.

06

Economic Benefits of CCS in the Asia-Pacific Region

Photo: Adobe Stock

6 Economic Benefits of CCS in the Asia-Pacific Region

6.1 Summary

Please note, full economic analysis may be made available upon request. A condensed version is presented here for brevity.

This exploratory analysis explores pathways for reaching net zero in selected countries of the Association of Southeast Asian Nations (ASEAN) and key trading partners, including Australia, Japan, and South Korea. The analysis is framed around achieving net zero emissions by pledged country targets under three different scenarios and sets of assumptions: Low storage growth, Accelerated storage growth, and Accelerated Emissions Trading (ET).

The **Low Storage Growth** scenario assumes minimal development in CO_2 storage capabilities, with a growth rate of only 5% annually beginning in 2036. This constrained storage development limits the deployment of CCS technologies, leading countries to focus on electrification and hydrogen as primary decarbonisation strategies.

The **Accelerated Storage Growth** scenario, in contrast, assumes an aggressive expansion in CO_2 storage starting at a 60% growth rate from 2036, gradually reducing to 3% growth from 2050 onwards. This scenario enables extensive CCS deployment, facilitating its utilisation by hard to abate sectors while still achieving the net zero target.

The **Accelerated ET** scenario builds upon the storage growth assumptions of the Accelerated scenario but integrates emissions trading between regions. This effectively allows for a shift in carbon removals from APAC countries to locations where these removals are more cost-effective.

With all three scenarios achieving the same net zero target, cost becomes a primary consideration in guiding policymakers toward one potential future pathway versus another. The global energy system costs through 2065 under the Low storage growth scenario are the highest. The Accelerated scenario saves potentially trillions in avoided expenditures. CCS remains capital-intensive and project economics vary materially by capture source, transport distance, storage availability, financing cost and regulatory framework. However, in the GENZO scenarios assessed in this report, faster storage development lowers total modelled energy-system cost relative to constrained storage development because it expands the portfolio of available decarbonisation options and is less costly than other alternatives at a global level. The savings enabled by the Accelerated scenario are driven by the expanded use of CCS technologies that offer lower cost emission reductions than alternative options that rely more heavily on hydrogen production, transport and use infrastructure and other low-carbon fuels, such as biomethane, synfuels and ammonia – most of which are imported by many APAC countries at considerable cost. CCS enables more investment in domestic emission reduction and less imports of low-carbon fuels. Not only is the Accelerated scenario less costly than the Low scenario, but with more domestic investment and less imports, the economic impact of the Accelerated scenario stands to be better than the Low scenario.

The need for CO_2 shipment, which varies depending on region and scenario, plays a crucial role in the total cost of CCS deployment. The Low scenario, with its limited availability of storage capacity, necessitates long-distance CO_2 shipping from APAC countries all the way to the US and Canada. Countries like Singapore, which lack domestic storage options, must export CO_2 regardless of scenario and always face CO_2 shipping costs, though those costs are much higher and are a much greater share of total CCS costs in the Low scenario. The Accelerated scenario reduces shipping costs by developing more extensive storage capacities within the APAC region. Emissions trading in the Accelerated ET scenario further frees available storage capacity and reduces the overall need for shipping because carbon removals are mostly done outside of the region, and those tonnes of CO_2 are no longer competing for nearby storage as they are in the Accelerated and Low scenarios.

The scenarios also lead to a significantly different mix of carbon capture applications (e.g. natural gas combined cycle with CCS vs industrial boilers fuelled by bioenergy with CCS vs direct air capture). They can also lead to different mixes of electricity generation and hydrogen production and to the end-use technologies that consume energy. Limiting CO_2 storage development can have a profound impact throughout the whole energy system, leading to very different systems by 2065.

To understand how CCS investments can provide economic value, an economic impact assessment of CCS infrastructure in the ASEAN region plus Australia, Japan, and South Korea for the Accelerated scenario was undertaken using an integration of the GENZO energy model with Input-Output (I-O) analysis.

CCS projects are projected to sustain significant employment. Initially, employment is driven by the construction industry. Once CCS facilities commence operations, employment shifts to CCS-related activities in industries, power plants, and CO_2 transport. Overall, the economic impact of CCS projects in the accelerated scenario is substantial, contributing to significant GDP growth and job creation in the ASEAN region and beyond, while supporting carbon reduction goals.

6.2 Introduction

This analysis of the economic benefits of CCS in the APAC region uses the Global Economic Net Zero Optimisation (GENZO) model developed by the Global CCS Institute. GENZO is used to explore possible pathways to reach net zero, and this section of the report lays out the methodology and documents the results of this modelling analysis. An economic input-output tool to estimate the potential value added and job creation from CCS investment in the region is also utilised.

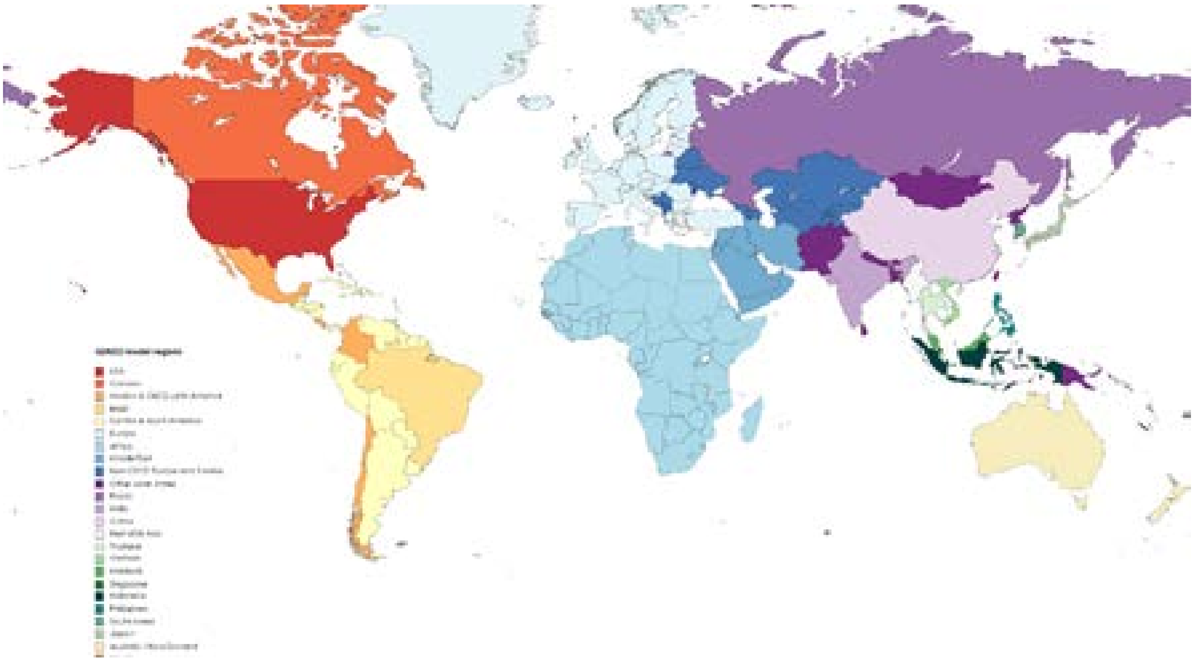
6.3 Methodology

Global Economic Net Zero Optimisation (GENZO) model
The GENZO model is a bottom-up technology-focused model based on the Open Source Energy Modelling System (OSeMOSYS) framework. OSeMOSYS is similar to MARKAL and TIMES and is used widely in academia and in government for policy analysis and energy system planning (Gardumi et al., 2018; Howells et al., 2011; Löffler et al., 2017; Niet et al., 2021; Welsch et al., 2014).

GENZO consists of 24 regions as shown in Figure 5. Although GENZO is run with all 24 regions simultaneously to ensure that results reflect trade in energy and commodities across regions, results are presented in this study for APAC countries based on the following model regions:

ANZ: **Australia/New Zealand**
BRN: **Brunei Darussalam**
IDN: **Indonesia**
JPN: **Japan**
MYS: **Malaysia**
PHL: **Philippines**
RoSEA: **Rest of South-East Asia**
Cambodia, Laos, Myanmar
SKO: **South Korea**
SGP: **Singapore**
THA: **Thailand**
VNM: **Vietnam**

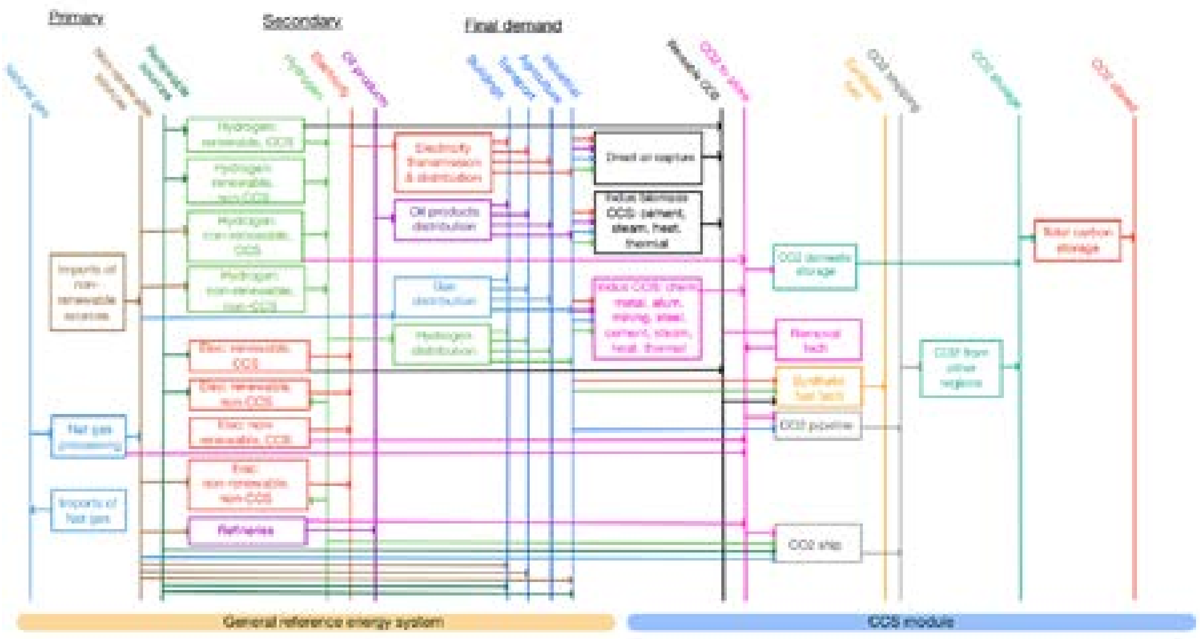
Figure 5. GENZO regions



GENZO solves for the lowest total cost whilst meeting emission trajectories and other constraints. GENZO is technologically rich and has good sectoral representation: 5 heavy industries + other industry, 4 modes of passenger travel, 7 modes of freight transport, buildings, and agriculture. GENZO models trade in oil, LNG, coal, ammonia, bio-LNG, synfuel, steel, aluminium, physical CO_2 for storage, and, optionally, CO_2 emission credits. Appendix 2 contains tables for select technology capital costs in GENZO.

GENZO invests in and operates technologies over the entire energy system from energy resources to energy transformations to end-use technologies to satisfy final demands and to fall within constraints like net-zero pathways (Figure 6). GENZO can choose from all types of decarbonisation technologies to reach the net zero target, including demand-side energy efficiency, more efficient supply-side technologies, renewable energy for electricity generation and hydrogen production, alternative drivetrains in transportation (electric, hydrogen-fuelled and ammonia-fuelled vehicles), low-carbon fuel production and use (biomethane, synfuel, and hydrogen), and CCS technologies in natural gas processing, refineries, electricity generation, hydrogen production, and industry (aluminium, cement, chemicals, steel, other). GENZO has significant advantages over other global energy models, as it models CCS technologies on both energy supply- and demand-sides in detail while representing 24 regions with exceptional disaggregation of South-East Asia. GENZO ensures that all elements of CCS, including capture, transport, and storage, are thoroughly incorporated.

Figure 6. High-level GENZO reference energy system



Representing the full CCS chain is important to make sure that the CCS technologies are modelled in a realistic way. For example, when an industrial natural gas steam boiler is built with carbon capture, GENZO adds the capital and operating cost of capture and accounts for the additional thermal load and associated fuel costs, as well as any additional electricity requirement and costs. Next, it accounts for the capital and operating cost to compress the CO_2 to send it via pipeline, as well as the additional electricity and associated costs. GENZO then accounts for the cost of building pipelines and, if over a certain distance, the cost and electricity required for auxiliary pumping. If a region ships CO_2 to another region, then the cost and energy needed for temporary storage and transfer to the ship is also included. GENZO then takes into account the capital cost of a CO_2 carrying ship and its fuel consumption, cost and emissions, if any, depending on shipping distance, then the offload and temporary storage and energy use and costs, then pipeline and energy use and costs to storage. Finally, GENZO accounts for geologic storage costs. GENZO accounts for similar levels of detail for hydrogen production, transport, and use, as well as electricity generation, transmission, distribution, and use.

In GENZO, future final energy service and commodity demands are exogenous, and everything else is endogenous. For example, we do not set oil prices or have an oil price forecast. GENZO models the supply of oil in each region, and the demand for oil that results from investment in technologies that require oil and the decision to operate those technologies. Oil prices result from the balance of supply and demand, along with trade of oil between regions. The same is true for all energy and commodity prices in GENZO.

The results shown in this report are not forecasts of what is expected to happen in the future. They should be considered "what if" analyses that highlight what, given a particular scenario assumption, is the least-cost structure of the energy system through 2065. This study can be seen as providing a roadmap for what would ideally be achieved. Achieving a particular least-cost path, however, does not happen automatically. It requires carefully crafted and implemented policies in each of the countries highlighted in the study.

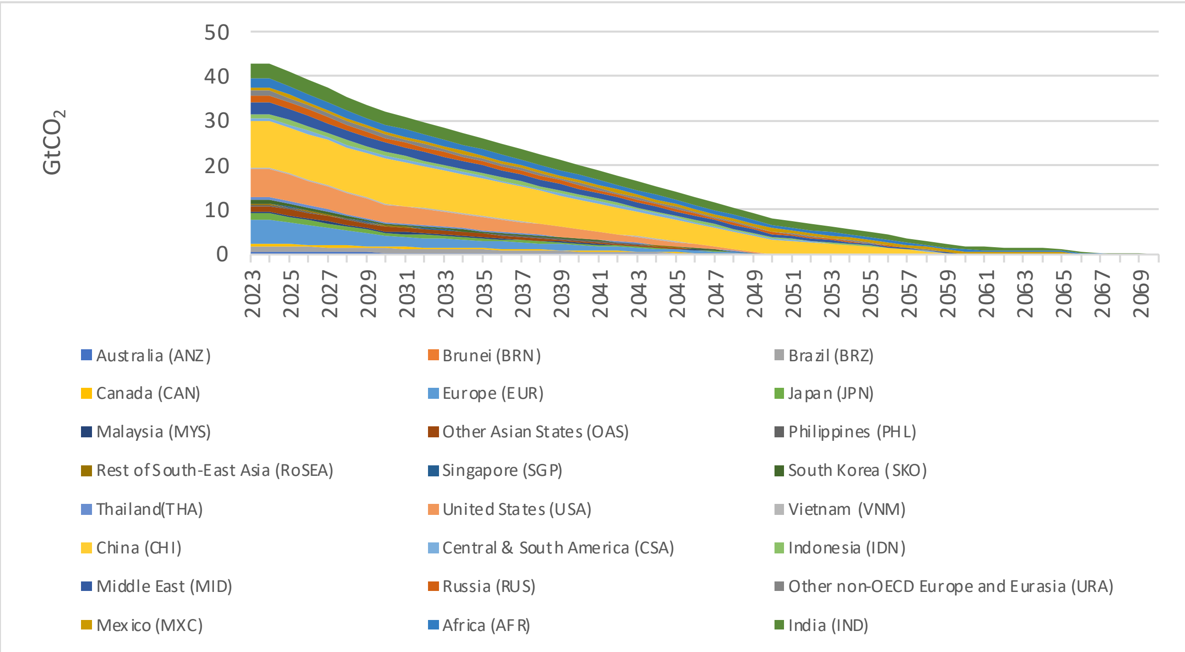
Further information about the GENZO model, its structure and key assumptions can be found in the model documentation (Williams, 2023).

6.4 Scenarios

This study focuses on a selection of countries in the Asia-Pacific region. The primary focus is on the ASEAN countries of Brunei[5], Indonesia, Malaysia, Singapore, Thailand, and Vietnam. The study also considers results for Australia, Japan and South Korea because of the important trade relationships between ASEAN countries and these countries, as well as the potential for transporting CO_2 for storage between ASEAN countries and Australia, Japan and South Korea.[6]

The purpose of this study is to understand the potential investment and operation of CCS infrastructure in the APAC region. Because CCS technologies are used almost exclusively to reduce CO_2 emissions, we explore the potential for CCS in the context of climate change commitments. Specifically, the results shown and discussed in this report are all based on the net zero assumptions shown in Figure 7, which are linear reductions to a 2030 target if a particular country has one and to a net zero target by the year consistent with the net zero pledges by the countries in those regions. While we are only showing results pertaining to the regions of interest in the study, all the results from those regions are, in part, dependent on all the other regions because of trade in energy, commodities and even transport of CO_2 that are possible between all regions in the model.

Figure 7. Net zero pathways for all regions in GENZO



What distinguishes the scenarios discussed and evaluated in this report is the assumption around the growth in the development of CO_2 storage capacity. The development of storage capacity and the transport infrastructure to deliver CO_2 to storage must be in place for carbon to be captured from emission sources, and this development can have a long lead time. How quickly this storage can be developed and how aggressively this storage continues to be developed over time effectively serves as an upper limit to how

5 Because the Brunei region is so small relative to the other regions in the model and detailed energy data is lacking, the Brunei region has been simplified compared to the others. Brunei is available as a CO_2 storage location. Because of the limitations of this model region, we only show some key high-level results and some detail on CCS within Brunei.

6 For the sake of simplicity and brevity, when we refer to the entire group of countries that are the focus of this study, we use the term “APAC countries”. In these instances, we are not referring to all APAC countries, but only to the countries mentioned as the focus of the study.

much CO_2 can be captured, apart from any CO_2 for utilisation. By assuming different growth rates in CO_2 storage development, we implicitly limit how much CCS can be deployed. If CCS is limited, hydrogen and electrification become the primary decarbonisation pathways. An integrated energy system model like GENZO not only can find these pathways but can illuminate the costs of each. With all pathways resulting in the same emission reduction outcome, cost becomes a primary consideration.

We distinguish between the growth in the development of storage capacity from the total evaluated storage resource available. Just like any resource, it must be developed to be used, and development of storage takes time. We create storage development scenarios that apply to all regions in GENZO. To construct these scenarios, we start with what we know about planned development in each region through the mid-2030s. We are not aware of all developments, and many storage developments that will happen have not yet been planned.

To account for this uncertainty, we make a minimum development assumption for a Low scenario and Accelerated scenario for each region.[7] We compare the known planned development with the assumed minimum development and pick the greater of the two for a region's annual storage capacity in 2035, which becomes the starting point for applying scenario-based growth rates. We assume that the low storage growth scenario grows at 5% per year beginning in 2036 and continues through 2065. We assume that the accelerated storage growth scenario begins at 60% growth in 2036 and declines to a 3% growth rate from 2050 onwards. Figure 4.4 shows assumptions for storage development for the APAC countries in this study for the low and accelerated storage growth scenarios.

We have a third scenario that we evaluate in this study, and this scenario, Accelerated ET, uses the same CO_2 storage development assumption as the Accelerated scenario, but we allow the model to engage in the trade of CO_2 emissions credits between regions. Please note that the trade of CO_2 emissions credits is not the same as shipping physical CO_2 to be stored in a different region from where it was captured.

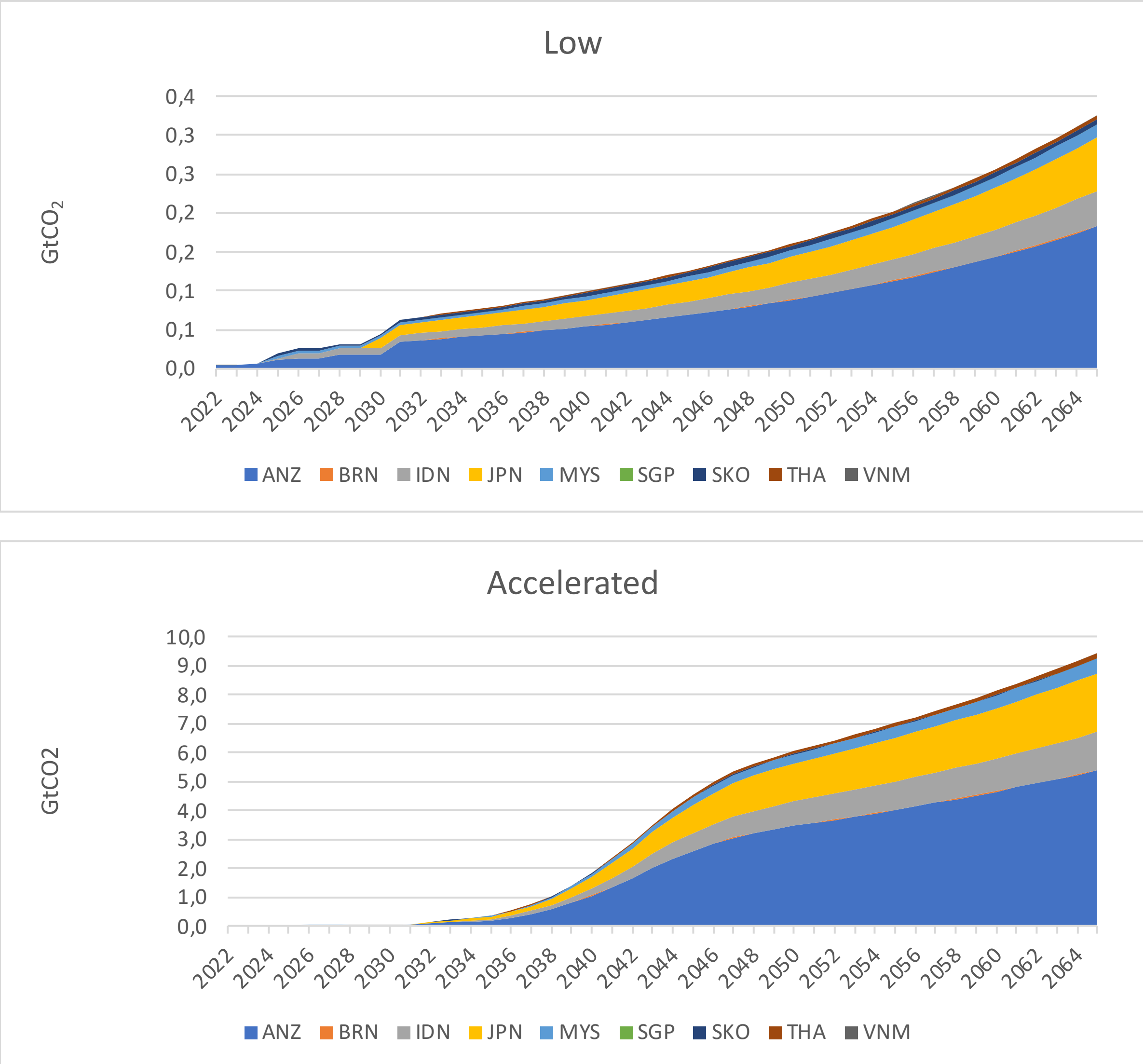
For each scenario, the same storage development assumptions are also applied to the other GENZO regions that are not the focus of this study. Thus, in the Low storage growth scenario, CCS is limited globally. Similarly, storage is accelerated globally in the accelerated and Accelerated ET storage growth scenarios.

The low storage growth and accelerated storage growth scenarios do not require that GENZO store any amount of CO_2 but place a limit on how much can be stored by when; GENZO can opt to store less if it is economic to do so. We also place a cumulative storage capacity limit based on the assessed geologic storage capacity in each region – no region can store more than it has the total capacity to store.[8]

7 The assumption is that all regions develop storage infrastructure to accommodate an annual injection of at least 0.002% of their estimated total storage capacity by 2035 in the Low scenario and at least 0.0035% in the Accelerated scenario.

8 GENZO can transport physical CO_2 by ship or by pipeline from one region to another, so if an opportunity to store in a neighbouring or even more distant region is available in any scenario, and doing so lowers the total system cost, then GENZO will opt to transport CO_2 to other regions. Singapore, which has no storage capacity of its own, and South Korea, which has very little storage capacity, can both still take advantage of carbon capture opportunities by transporting their captured CO_2 elsewhere.

Figure 8. CO_2 storage development assumptions for scenarios: APAC countries



6.5 High-level results

Figure 9 shows at a high level how the APAC countries achieve net zero in each scenario. The black dotted line in each figure shows direct emissions. Net zero is achieved through carbon removals and, if available, emission credit purchases. Combined, these removals and credits offset direct emissions to net zero. These figures also show the number of $GtCO_2$ captured and stored by deploying fossil-based CCS technologies.

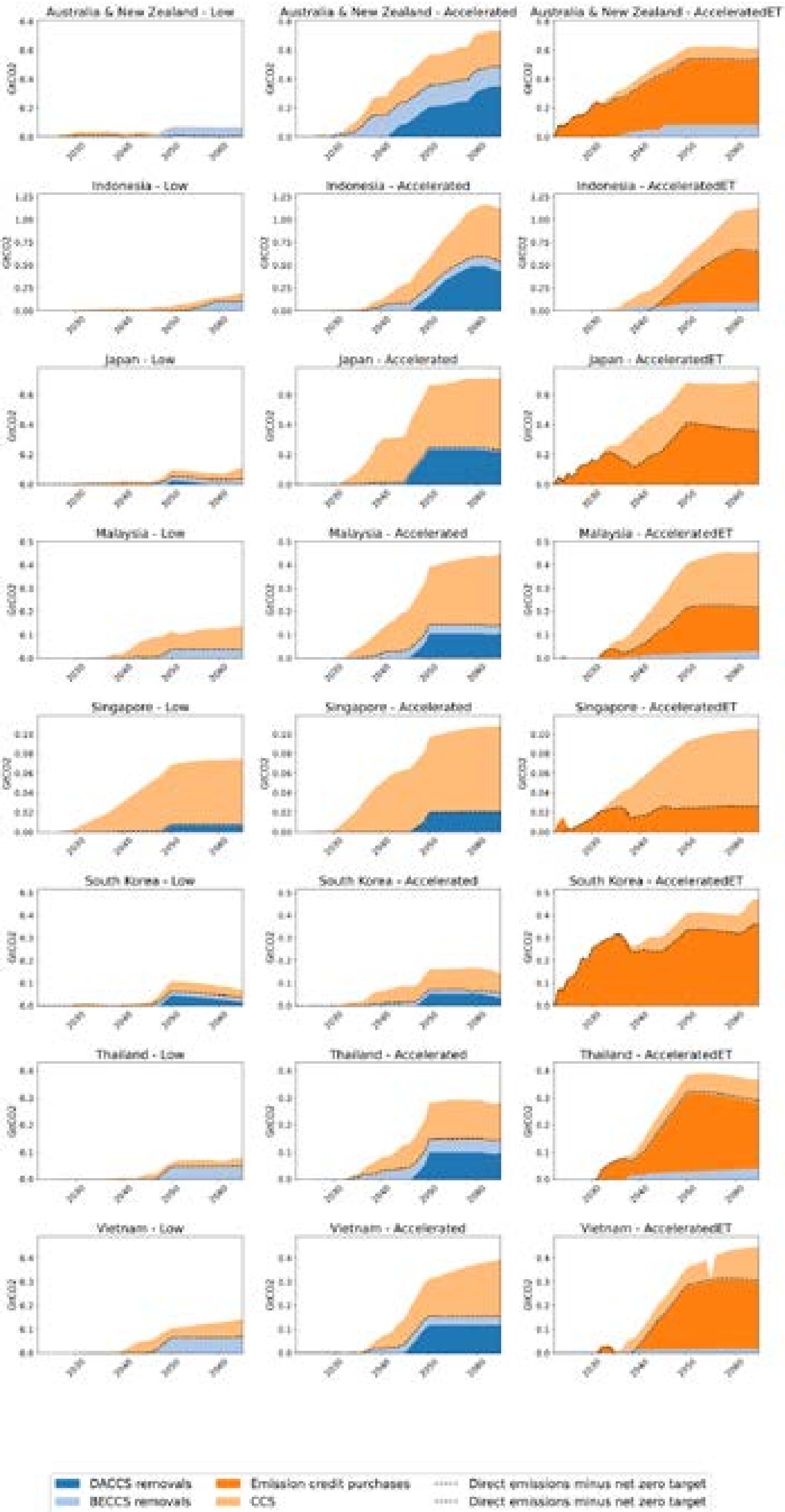
The low storage growth scenario limits the development of CO_2 storage capacity. Most regions decarbonise primarily through a mix of electrification and hydrogen or hydrogen-based fuels in the Low scenario.

Limited availability of CO_2 storage space means that BECCS becomes a relative priority for most of the regions. BECCS serves two roles, providing useful carbon-neutral energy while removing CO_2 from the atmosphere. With BECCS and in some cases DACCS (Singapore and South Korea) prioritised given limited storage space, fossil CCS is much more limited in the Low scenario in most regions compared to the other scenarios. Singapore is an interesting example because it has no domestic CO_2 storage to begin with and must import most energy. Singapore also has very limited domestic biomass resources, and importing raw biomass is not economically feasible, so it must instead rely primarily on DACCS for removals. Whatever CO_2 it captures to store must be shipped elsewhere at relatively high cost. Singapore faces similar trade-offs in all scenarios and makes similar decisions across the scenarios, including a similar proportion of fossil CCS in the Low scenario compared to the other scenarios, unlike the other regions.

By developing significantly greater CO_2 storage capacity, the Accelerated storage growth scenario allows for an increase in direct emissions because the storage capacity is in place to offset those emissions with carbon removals. At a certain point, lower-cost abatement options are exhausted, and it becomes cheaper to remove an additional tonne of CO_2 through DACCS or BECCS than to avoid emitting. That greater CO_2 storage capacity in the Accelerated scenario also allows for much more CCS that is not related to removals. Implicitly, this means that the Accelerated scenario can take advantage of relatively inexpensive fossil fuels while still meeting the net zero target, while being less dependent on more expensive hydrogen and electrification pathways. Notably, compared to the Low scenario, ASEAN countries rely much less on expensive imported low-carbon fuels in the Accelerated scenario, while Australia produces dramatically less hydrogen in the Accelerated scenario.

When emissions trading is introduced, the amount of fossil CCS across the regions is slightly lower than without emissions trading. What emissions trading primarily does is to eliminate the need for DACCS and to significantly reduce BECCS in the APAC countries compared to the identical scenario without emissions trading. Other countries, such as the US and Canada, have much more available CO_2 storage capacity and have lower energy costs compared to the APAC countries, so emissions trading allows for APAC countries to, in effect, pay the US and Canada to build DACCS on their behalf. One tonne of CO_2 removed anywhere in the world is as effective at reducing climate impacts as one tonne of CO_2 removed anywhere else in the world. If other regions can do removals at lower cost, gains from trade are available that can lower the global cost of achieving net zero. However, as with any trade, there are winners and losers, which we will discuss later.

Figure 9. Carbon removals, CCS and direct emissions minus net zero target



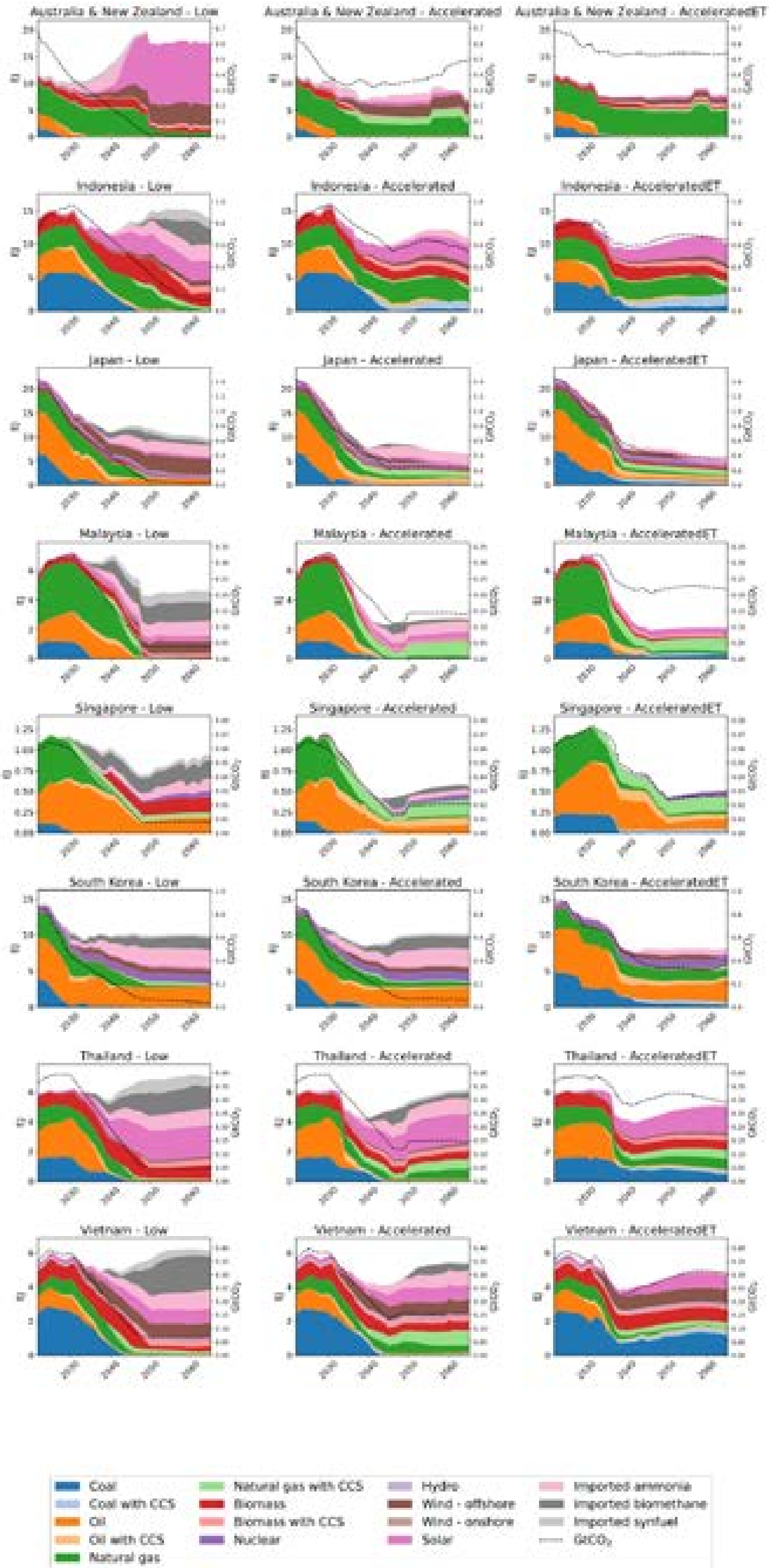
What is not apparent in the previous figure but can be seen in Figure 4.6 is that many of the ASEAN countries opt to import low-carbon fuels as an alternative to CCS in the Low scenario because other countries with better renewable resources can produce hydrogen at lower cost than they can produce it domestically (and with limited CO_2 storage, hydrogen from fossil fuels is also limited). Their cost of producing electricity is also relatively high. These countries decarbonise as much as possible through imported low-carbon fuels, including ammonia, synfuels and biomethane (imported as bio-LNG). By the 2050s, the ASEAN countries import expensive low-carbon fuels that account for around half and in some cases, such as Malaysia, over half of their primary energy use. Australia has low-carbon fuel imports early on, but its ample solar energy resources enable it to produce its own hydrogen needs by the mid-2040s, pushing solar to represent 2/3 of Australia's primary energy use by 2050. Like the ASEAN countries, South Korea also imports about half of its primary energy in the form of low-carbon fuels by 2050. Japan also imports a significant but lower proportion – about 1/3 – of its primary energy use as low-carbon fuels in the Low scenario.

Coal, oil and natural gas use without CCS in the Low scenario drops to close to zero in all regions except South Korea and Singapore, where oil use declines but is still significant. Direct emissions in the Low scenario, consequently, decline largely in step with the net-zero commitments and are much nearer net zero in the later years than the other scenarios.

In the Accelerated scenario, the import of low-carbon fuels is much lower compared to the Low scenario. At the same time, natural gas and oil use is higher, but most of that use is in conjunction with CCS by at least the mid-2040s. Coal use still drops close to zero. Australia then no longer produces a staggering amount of hydrogen from solar, so the amount of solar energy in Australia's primary energy use decreases sharply compared to the Low scenario. Despite the increase in fossil fuel use compared to the Low scenario, domestic renewable resource use remains high in countries with strong renewable resources like Australia, Indonesia, Vietnam and Thailand. In fact, poor renewable resources in the other countries result in limited domestic renewable use even in the Low scenario, which is why they import so much low-carbon fuel in that scenario. Direct emissions are noticeably higher in the Accelerated scenario compared to the Low scenario, but those emissions, as discussed earlier, are offset by BECCS and DACCS to reach the same net zero trajectory.

The Accelerated ET scenario results in more fossil fuel use and very little low-carbon fuel imports. Even the use of coal, including coal without CCS, continues in all the regions except Australia. Thailand and Vietnam have relatively high proportions of coal use without CCS. The result is that the direct emissions in the Accelerated ET scenario are the highest among the scenarios. While direct emissions go down in all regions compared to the early years, the overall reduction in direct emissions through 2065 is modest, though this scenario does meet the same net-zero trajectory as the others. The emission reductions are taking place in other regions of the model that are selling these emission credits to the countries in this study. Whether or not such high levels of emissions trading would be allowed under applicable international rules is beyond the scope of this study. We are merely trying to reveal what the implications might be for CCS and the energy systems in the APAC region if trading at these levels were to occur.

Figure 10. Primary energy and direct CO_2 emissions



The low scenario has the highest total cost in all regions both before and after accounting for trade (Figure 10). Limiting the development of CO_2 storage and, by extension the overall deployment of CCS, leads to substantially higher costs for meeting energy needs and reaching net zero.

Costs for the APAC region for the Low and Accelerated scenarios are consistent with the global costs. Achieving the same climate targets at substantial costs savings that can be used to meet other societal needs is an important result, especially for developing economies in ASEAN that may not have the luxury to choose a more costly path toward net zero.

Within the context of these globally optimal results, there is the potential for all regions to be made better off. When we account for the value of trade, we apply the marginal cost of a given type of traded fuel or commodity or CO_2 emission credit and multiply it by the quantity traded. The countries, for example, that produce emission credits to sell have costs of generating those credits that are lower than all but the last CO_2 credit generated, which as the marginal cost of CO_2 reductions defines the price of CO_2 credits. The credits generated at the low end of the credit supply curve receive the same price as the price-setting marginal credit, creating producer surplus. What this means is that in principle, if the countries that stand to lose with emissions trading refuse to agree to emissions trading, the suppliers of credits could give up some producer surplus to the purchasing countries through a negotiated outcome in which both sides are made better off than an outcome without emissions trading.

6.6 References

Afriyan Rachmad, & DFDL. (2024, March 28). Indonesia: New Presidential Regulation on Promoting Carbon Capture and Storage for Economic Growth and Acceleration of Net Zero Emission by 2060. Legal and Tax Updates. https://www.dfdl.com/insights/legal-and-tax-updates/indonesia-new-presidential-regulation-on-promoting-carbon-capture-and-storage-for-economic-growth-and-acceleration-of-net-zero-emission-by-2060/

Aker Carbon Capture. (2024, February 20). Aker Carbon Capture. Website. https://www.akersolutions.com/who-we-are/power-the-change/carbon-capture/

Alberta, P. (n.d.). Mines and Minerals Act. www.qp.alberta.ca

Andrew Frans, Alma Chesya Jasmine, & ATAMA. (2024, February 12). Unravelling the Legal Framework of Indonesia's Carbon Capture and Storage under Presidential Regulation No. 14 of 2024. Publication.

Ashurst. (2024). Indonesia issues further regulations for CCS and CCUS deployment – A quick guide to Presidential regulation 14/2024 and SKK Migas regulation PTK-070. https://www.ashurst.com/en/insights/indonesia-issues-further-regulations-for-ccs-and-ccus-deployment/

Australian Government. (2021, October 1). Explanatory Statement - Carbon Credits (Carbon Farming Initiative) Act 2011. Explanatory Statement - Carbon Credits (Carbon Farming Initiative) Act 2011. https://www.legislation.gov.au/Details/F2021L01378/Explanatory%20Statement/Text

Australian Government. (2024). Future Gas Strategy.

Australian Government, & Clean Energy Regulator. (updated 2024, November 9). About the Emissions Reduction Fund: How does it work. https://cer.gov.au/schemes/australian-carbon-credit-unit-scheme/accu-scheme-methods/domestic-commercial-and-industrial-wastewater-method/guide-to-domestic-commercial-and-industrial-wastewater-method/about-emissions-reduction-fund

Australian Government, & Clean Energy Regulator. (2019, September 27). Statement of opportunities in the ACCU market. Statement of Opportunities in the ACCU Market.

Australian Government, & Clean Energy Regulator. (2021a, August 2). Eligibility to participate in the Emissions Reduction Fund. Eligibility to Participate in the Emissions Reduction Fund. http://www.cleanenergyregulator.gov.au/ERF/About-the-Emissions-Reduction-Fund/eligibility-to-participate-in-the-emissions-reduction-fund

Australian Government, & Clean Energy Regulator. (2021b, September 9). About the Emissions Reduction Fund. About the Emissions Reduction Fund. http://www.cleanenergyregulator.gov.au/ERF/About-the-Emissions-Reduction-Fund

Australian Government, & Clean Energy Regulator. (2022a, May 17). Australian Carbon Exchange. Australian Carbon Exchange.

Australian Government, & Clean Energy Regulator. (2022b, May 27). Understanding carbon abatement contracts. Understanding Carbon Abatement Contracts. https://cer.gov.au/schemes/australian-carbon-credit-unit-scheme/how-to-participate-accu-scheme/carbon-abatement-contracts

Australian Government, & Clean Energy Regulator. (2023, April 19). Safeguard Mechanism - Calculated baseline. Guidance. https://www.dcceew.gov.au/climate-change/emissions-reporting/national-greenhouse-energy-reporting-scheme/safeguard-mechanism

Australian Government, & Department of industry Science Energy and Resources. (2021, July 26). Carbon capture and storage method: proposed new method under the Emissions Reduction Fund. Carbon Capture and Storage Method: Proposed New Method under the Emissions Reduction Fund. https://consult.industry.gov.au/carbon-capture-and-storage-method

Australian Government, & Department of Climate Change, E. the E. and W. (2023). Safeguard Mechanism Reforms. https://storage.googleapis.com/files-au-climate/climate-au/p/prj23cd662ff4387d8c254ae/public_assets/Safeguard%20Mechanism%20Reforms%20Position%20Paper.pdf

Australian Government Department of Foreign Affairs and Trade. (n.d.). Singapore-Australia Green Economy Agreement. Retrieved May 4, 2023, from https://www.dfat.gov.au/geo/singapore/singapore-australia-green-economy-agreement

Australian Government, & Department of Industry Science Energy and Resources. (2021, October 2). Safeguard Mechanism. Safeguard Mechanism. https://www.industry.gov.au/regulations-and-standards/national-greenhouse-and-energy-reporting-scheme/safeguard-mechanism

Azmi and Associates, Dhanya Laxmi Sivanantham, & Alfred Tan Hsiong Vei. (2022, January 31). Legal Aspects Of Carbon Capture Storage (CCS) Facility In Malaysia. Legal Aspects Of Carbon Capture Storage (CCS) Facility In Malaysia. https://www.mondaq.com/renewables/1155888/legal-aspects-of-carbon-capture-storage-ccs-facility-in-malaysia

Bursa Malaysia Berhad. (2023). Bursa Carbon Exchange (BCX). Webpage. https://www.bursamalaysia.com/trade/market/voluntary-carbon-market-exchange/overview

Carbon Credits (Carbon Farming Initiative) Amendment (Carbon Capture and Storage Projects) Rule 2021, Pub. L. No. F2021L01378, Carbon Credits (Carbon Farming Initiative) Amendment (Carbon Capture and Storage Projects) Rule 2021 (2021). https://www.legislation.gov.au/Details/F2021L01378

Carbon Markets Express. (2022). Recent Developments of The https://www.jcm.go.jp/jc/wp-content/uploads/sites/3/202311_JCM_goj_eng.pdf

Clayton Utz. (2023, April 1). Last minute Safeguard Mechanism Reforms introduce new obligations. Summary. https://www.claytonutz.com/knowledge/2023/april/last-minute-safeguard-mechanism-reforms-introduce-new-obligations

Corrs Chambers Westgarth. (2023, January 19). Explainer: recently announced reforms to the Safeguard Mechanism and implications for industry. Insight. https://www.corrs.com.au/insights/explainer-recently-announced-reforms-to-the-safeguard-mechanism-and-implications-for-industry

East CO_2AST Cluster. (2022). East CO_2AST Cluster. East CO_2AST Cluster. https://eastcoastcluster.co.uk/#nep

Elec Times. (2024). Government begins enacting CCUS law enforcement ordinance... Industry: "Licensing simplification, incentives must be included." https://www.electimes.com/news/articleView.html?idxno=332820

Energy Market Authority of Singapore. (2024). Carbon Capture & Storage Programme Office. https://www.ema.gov.sg/content/dam/corporate/resources/corporate-publications/annual-reports/pdf-files/EMA-Annual-Sustainability-Report-2023-2024.pdf.coredownload.pdf

ExxonMobil. (2023, July 13). ExxonMobil announces acquisition of Denbury. Press Release. https://corporate.exxonmobil.com/news/news-releases/2023/0713_exxonmobil-announces-acquisition-of-denbury

Framework Act on Low Carbon and Green Growth, Pub. L. No. 9931, Statute (2010). https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=49999&type=part&key=39

Gardumi, F., Shivakumar, A., Morrison, R., Taliotis, C., Broad, O., Beltramo, A., Sridharan, V., Howells, M., Hörsch, J., Niet, T., Almulla, Y., Ramos, E., Burandt, T., Balderrama, G. P., Pinto de Moura, G. N., Zepeda, E., & Alfstad, T. (2018). From the development of an open-source energy modelling tool to its application and the creation of communities of practice: The example of OSeMOSYS. Energy Strategy Reviews, 20, 209–228. https://doi.org/10.1016/j.esr.2018.03.005

Gilbert + Tobin. (2023, April 6). Parliament approves the Safeguard Mechanism (Crediting) Amendment Bill 2023. Knowledge. https://www.gtlaw.com.au/knowledge/parliament-approves-safeguard-mechanism-crediting-amendment-bill-2023

Global CCS Institute. (2023a). Global Status of CCS 2023.

Global CCS Institute. (2023b). Global Status of CCS 2023. https://www.globalccsinstitute.com/resources/publications-reports-research/global-status-of-ccs-2023-executive-summary/

Global CCS Institute, Staib, C., Zhang, T., Burrows, J., Gillespie, A., Havercroft, I., Rassool, D., Consoli, C., Liu, H., Erikson, J., Loria, P., Nambo, H., Wu, Y., Judge, C., & Gebremedhin, R. (2021). Global Status of CCS 2021. https://www.globalccsinstitute.com/wp-content/uploads/2021/10/2021-Global-Status-of-CCS-Report_Global_CCS_Institute.pdf

Global Environment Centre Foundation (GEC). (2023, April 6). Call for Proposals: Financing Programme for JCM Model Projects in FY2023. Website. http://gec.jp/jcm/kobo/mp230406/

Gluyas J. G., & Bagudu U. (2020). The Endurance CO_2 storage site, Blocks 42/25 and 43/21, UK North Sea. Geological Society Memoirs, 52, 163–171. https://www.lyellcollection.org/doi/abs/10.1144/m52-2019-47

Government of Alberta. (2010, November 1). Amendments guide use of carbon capture and storage technology. Statement. https://www.alberta.ca/release.cfm?xID=294320918CA1C-D461-CFF6-EABAFA536F30F0DC

Government of Alberta. (2022). Carbon capture, utilization, and storage – Overview. Carbon Capture, Utilization, and Storage – Overview. https://www.alberta.ca/carbon-capture-and-storage

Government of Brunei Darussalam. (2020). Brunei Darussalam Nationally Determined Contribution (Issue 2015, pp. 1–14).

Government of Canada. (2022). Shell Canada Energy Quest Project. Natural Resources Canada - Current Investments. https://natural-resources.canada.ca/funding-partnerships/shell-canada-energy-quest-project

Government of Indonesia. (2022). Enhanced Nationally Determined Contribution: Republic of Indonesia.

Government of Malaysia. (2018). Malaysia Third National Communication and Second Biennial Update Report To The UNFCCC.

Government of Malaysia. (2021a). 12th Malaysian Plan: 2021 - 2025.

Government of Malaysia. (2021b). Malaysia's Update of Its First Nationally Determined Contribution (Vol. 2, Issue November 2015).

Government of Malaysia. (2022). National Energy Policy 2022 - 2040.

Howells, M., Rogner, H., Strachan, N., Heaps, C., Huntington, H., Kypreos, S., Hughes, A., Silveira, S., DeCarolis, J., Bazillian, M., & Roehrl, A. (2011). OSeMOSYS: The Open Source Energy Modeling System. Energy Policy, 39(10), 5850–5870. https://doi.org/10.1016/j.enpol.2011.06.033

Hydrocarbons Technology. (2015). Quest Carbon Capture and Storage Project, Alberta. News Article. https://www.hydrocarbons-technology.com/projects/quest-carbon-capture-and-storage-project-alberta/

HyNet North West. (2022a). HyNet North West. HyNet North West. https://hynet.co.uk/

HyNet North West. (2022b). HyNet North West Partners and Supporters. HyNet North West. https://hynet.co.uk/partners-funding/

HyNet North West. (2022c, August 12). HyNet projects receive go-ahead. HyNet North West. https://hynet.co.uk/wp-content/uploads/2022/08/12082022-HyNet-projects-receive-go-ahead.pdf

IEA. (2021). Carbon capture, utilisation and storage: the opportunity in Southeast Asia. 60.

International Carbon Action Partnership (ICAP). (2023a). Japan - Tokyo Cap-and-Trade Program. Webpage. https://icapcarbonaction.com/en/ets/japan-tokyo-cap-and-trade-program

International Carbon Action Partnership (ICAP). (2023b). Malaysia Factsheet. Report and Website. https://icapcarbonaction.com/en/ets/malaysia

International Carbon Action Partnership (ICAP). (2023c). Thailand Factsheet. ETS News. https://icapcarbonaction.com/en/ets/thailand

International Carbon Action Partnership (ICAP). (2023d, February 27). Indonesia launches emissions trading system for power generation sector. ETS News. https://icapcarbonaction.com/en/news/indonesia-launches-emissions-trading-system-power-generation-sector

International Carbon Action Partnership (ICAP). (2023e, June 22). *Indonesia Factsheet*. ETS News. https://icapcarbonaction.com/en/ets/indonesia

International Carbon Action Partnership (ICAP). (2023f, July). Korea Factsheet. Webpage. https://icapcarbonaction.com/en/ets/korea-emissions-trading-scheme

International Emissions Trading Association (IETA. (updated in 2025). Korea Carbon Market Business Brief. https://www.ieta.org/business-briefs-korea

International Energy Agency. (2022). An Energy Sector Roadmap to Net Zero Emissions in Indonesia. https://doi.org/10.1787/4a9e9439-en

Japan CCS Co. Ltd. (2022a). Company Profile. JCCS. https://www.japanccs.com/en/

Japan CCS Co. Ltd. (2022b). JCCS Shareholders. JCCS. https://www.japanccs.com/en/corporate/holder.php

Japan Organization for Metals and Energy Security (JOGMEC). (2022, November 14). JOGMEC's strengthening of functions, name change and organizational restructuring due to legal amendments. Website. https://www.jogmec.go.jp/news/release/news_10_00065.html

Jong Ik Yoo, & Korea Research Institute on Climate Change. (2018, February 7). Introduction to the Korea Emission Trading Scheme: Korean Offsetting Program. Presentation. https://www.icao.int/sites/default/files/environmental-protection/CORSIA/2018%20CORSIA%20webinar/Seminar%20on%20Carbon%20Markets/04_Session2_Yoo_KETS.pdf

Kensuke Shiomi, & Ministry of Economy, T. and I. (2023). Overview of CCS activities on the Joint Crediting Mechanism (JCM). https://www.jogmec.go.jp/content/300382142.pdf

Kingdom of Thailand, & UNFCCC. (2022a, November). Thailand's 2nd Updated Nationally Determined Contribution. Report. https://unfccc.int/sites/default/files/NDC/2022-11/Thailand%202nd%20Updated%20NDC.pdf

Kingdom of Thailand, & UNFCCC. (2022b, November). Thailand's Long-term low emissions greenhouse gas emission development strategy. Report. https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf

Lee & Ko. (2024). Enactment of the Carbon Dioxide Capture, Utilization and Storage Act (CCUS Act).

Löffler, K., Hainsch, K., Burandt, T., Oei, P.-Y., Kemfert, C., & Von Hirschhausen, C. (2017). Designing a Model for the Global Energy System—GENeSYS-MOD: An Application of the Open-Source Energy Modeling System (OSeMOSYS). Energies, 10(10), 1468. https://doi.org/10.3390/en10101468

Lot, H., Yeow, A., Mahmood, A. B., Ismail, B. H., Abidin, M. A. Z., & Abdul Wahab, W. A. W. (2023). Business Model of Carbon Capture and Storage (CCS) Projects for High-CO_2 Fields. Society of Petroleum Engineers - SPE EuropEC - Europe Energy Conference Featured at the 84th EAGE Annual Conference and Exhibition, EURO 2023. https://doi.org/10.2118/214359-MS

Malaysia Ministry of Foreign Affairs. (2023, December 16). ELEVATION OF BILATERAL RELATIONS BETWEEN MALAYSIA AND JAPAN TO COMPREHENSIVE STRATEGIC PARTNERSHIP.

Massachusetts Institute of Technology. (2016, September 30). Quest Fact Sheet: Carbon Dioxide Capture and Storage Project. Website. https://sequestration.mit.edu/tools/projects/quest.html

Mines and Minerals Act, Pub. L. No. 9780779827831, Mines and Minerals Act (2021). https://www.qp.alberta.ca/1266.cfm?page=M17.cfm&leg_type=Acts&isbncln=9780779827831&display=html

Ministry of Economy Trade and Industry Japan. (2024, February). Cabinet Approvals on the "Bill for the Act on Promotion of Supply and Utilization of Low-Carbon Hydrogen and its Derivatives for Smooth Transition to a Decarbonized, Growth-Oriented Economic Structure" and the "Bill for the Act on Carbon Dioxide Storage Businesses." https://www.meti.go.jp/english/press/2024/0213_003.html

Ministry of Economy Trade and Industry (METI). (2023). CCS Long-Term Roadmap.

Ministry of Energy and Mineral Resources, & Republic of Indonesia. (2022, November 4). Teknologi CCS-CCUS Jadi Tren Baru Hadapi Transisi Energi. Press Release. https://www.esdm.go.id/en/media-center/news-archives/teknologi-ccs-ccus-jadi-tren-baru-hadapi-transisi-energi-

Ministry of Environment and Water, & Government of Malaysia. (2021). National Guidance on Voluntary Carbon Market Mechanisms. https://repoemc.ukm.my/items/18c17a00-82b0-4307-b587-74e0e0419399

Ministry of the Environment, & Government of Japan. (2012). Introducing a tax to combat global warming. Website. https://www.env.go.jp/policy/tax/about.html

Ministry of Trade and Industry Singapore. (2024). Singapore and Indonesia sign Letter of Intent to collaborate on carbon capture and storage (CCS). https://www.mti.gov.sg/newsroom/singapore-and-indonesia-sign-letter-of-intent-to-collaborate-on-carbon-capture-and-storage--ccs-/

Misato Fukushima, & Hiroyasu Konno. (2024a). Japan's CCS Bill in Brief.

Misato Fukushima, & Hiroyasu Konno. (2024b). Japan's CCS Bill in Brief.

National Assembly of South Korea. (2024). Act on Carbon Dioxide Capture, Transport, Storage and Utilization. https://www.law.go.kr/LSW/lsInfoP.do?lsiSeq=259701&viewCls=lsRvsDocInfoR#

National Climate Change Secretariat Singapore. (n.d.). Singapore's Long-Term Low-Emissions Development Strategy. Retrieved May 4, 2023, from https://www.nccs.gov.sg/media/publications/singapores-long-term-low-emissions-development-strategy/

National Climate Change Secretariat Singapore. (2024). Carbon Tax. https://www.nccs.gov.sg/singapores-climate-action/mitigation-efforts/carbontax/

National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015, Pub. L. No. F2020C00399, Compilation (2020). https://www.legislation.gov.au/Details/F2020C00399

NDC Partnership. (2013). Web-based GHG Management System of the Republic of Korea. Report. https://api.knack.com/v1/applications/5b23f04fd240aa37e01fa362/download/asset/5c9397f79d3cc709a989cd4e/2013onwardsghgmanagementsystem_korea.pdf

Nicholas Mapa, & ING. (2022, August 1). Indonesia's carbon tax on hold, but investment in electric cars could pay off. Article. https://think.ing.com/articles/indonesia-carbon-tax-on-hold-but-investment-in-electric-cars-could-pay-off

Niet, T., Shivakumar, A., Gardumi, F., Usher, W., Williams, E., & Howells, M. (2021). Developing a community of practice around an open source energy modelling tool. Energy Strategy Reviews, 35, 100650. https://doi.org/10.1016/j.esr.2021.100650

Office of Natural Resources and Environmental Policy and Planning. (2020). Thailand's Updated NDC.

Office of Natural Resources and Environmental Policy and Planning, & Ministry of Natural Resources and Environment. (2022). Long-Term Low Greenhouse Gas Emission Development Strategy (Revised Version). www.onep.go.th

Office of Natural Resources and Environmental Policy Thailand. (2015). Thailand Climate Change Master Plan 2015 - 2050.

Paul Greening, Jooyoung Song, & Akin Gump. (2023, April 13). Indonesia's New CCS/CCUS Regulations: Promoting Energy Transition in Southeast Asia. Insight. https://www.akingump.com/en/insights/blogs/speaking-energy/indonesias-new-ccsccus-regulations-promoting-energy-transition-in-southeast-asia

Presidential Committee on Carbon Neutrality and Green Growth 2050 Korea. (n.d.). Basic Plan for Carbon Neutrality and Green Growth.

Presidential Regulation No. 18 of 2020 Concerning the National Medium-Term Development Plan for 2020-2024, Presidential Regulation (2020). https://perpustakaan.bappenas.go.id/e-library/file_upload/koleksi/migrasi-data-publikasi/file/RP_RKP/Narasi-RPJMN-2020-2024-versi-Bahasa-Inggris.pdf

Presidential Regulation No. 61 of 2011 on the National Action Plan on Greenhouse Gas Emission Reduction, Nomor 61 Tahun 2011 (2011). https://policy.thinkbluedata.com/node/3979

Presidential Regulation (PERPRES) Number 14 of 2024: Implementation of Carbon Capture and Storage Activities (2024). https://peraturan.bpk.go.id/Details/276843/perpres-no-14-tahun-2024

Preston, C. K. (2018). IEAGHG Summary Report of the Shell Quest Carbon Capture and Storage Project. https://www.researchgate.net/publication/337063987_The_Shell_Quest_Carbon_Capture_and_Storage_Project

Prime Minister of Vietnam. (2022). Decision No. 888/QD-TTg on approval for Scheme Setting Out Tasks and Solutions for Implementation of Outcomes of the 26th Conference of the Parties to the Untied Nations Framework Convention on Climate Change.

Regulation of the President of The Republic of Indonesia Number 98 of 2021, Presidential Regulation (2021). https://cdn.climatepolicyradar.org/navigator/IDN/2021/presidential-regulation-no-98-of-2021-on-the-implementation-of-carbon-pricing-to-achieve-the-nationally-determined-contribution-target-and-control-over-greenhouse-gas-emissions-in-the-national-development_ee96e6383b7350773bfdb7578312b935.pdf

Renewable Energy Hub. (2022, May 30). Carbon Market Prices. Carbon Market Prices. https://www.renewableenergyhub.com.au/market-prices/

Richters, O., Kriegler, E., Al Khourdajie, A., Bertram, C., Bresch, D. N., Ciullo, A., Cornforth, E., Cui, R., Edmonds, J., Fuchs, S., Hackstock, P., Holland, D., Hurst, I., Kikstra, J., Klein, D., Kotz, M., Kropf, C. M., Lewis, J., Liadze, I., … Zwerling, M. (2024). NGFS Climate Scenarios Data Set. Zenodo. https://doi.org/10.5281/zenodo.10807824

Shell. (2022). Quest Carbon Capture and Storage. Projects and Sites. https://www.shell.ca/en_ca/about-us/projects-and-sites/quest-carbon-capture-and-storage-project.html#vanity-aHR0cHM6Ly93d3cuc2hlbGwuY2EvZW4vYWJvdXRzaGVsbC9vdXItYnVzaW5lc3MtdHBrZy91cHN0cmVhbS9vaWwtc2FuZHMvcXVlc3QuaHRtbA

Shell. (2023). Scotford. Website. https://www.shell.ca/en_ca/about-us/projects-and-sites/scotford.html

Shell Canada Limited. (2022). Quest Carbon Capture and Storage Project. In 2021 Annual Status Report. https://url.de.m.mimecastprotect.com/s/o8EDCVv4lmhkEOkxfGfrWhEZg2U?domain=open.alberta.ca

Shell Singapore. (n.d.). Shell to explore carbon transport and storage in Brunei and Singapore | Shell Singapore. Retrieved May 4, 2023, from https://www.shell.com.sg/media/2022-media-releases/shell-to-explore-carbon-transport-and-storage-in-brunei-and-singapore.html

Shell Singapore. (2022). Shell to explore carbon transport and storage in Brunei and Singapore. https://www.shell.com.sg/media/2022-media-releases/shell-to-explore-carbon-transport-and-storage-in-brunei-and-singapore.html

Socialist Republic of Vietnam. (2022). Nationally Determined Contribution (NDC) of Vietnam. October, 43. https://unfccc.int/documents/622541

S&P Global. (2023). South Korea revises 2030 target for greenhouse gas emissions. S&P Global Commodity Insights. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/041123-south-korea-revises-2030-target-for-greenhouse-gas-emissions

The Government of Singapore. (n.d.). Singapore Green Plan 2030. Retrieved May 4, 2023, from https://www.greenplan.gov.sg/

The Hon Chris Bowen MP, & Australian Government. (2023, March 27). Safeguard Mechanism one step closer to Parliamentary passage. Press Release. https://minister.dcceew.gov.au/bowen/media-releases/safeguard-mechanism-one-step-closer-parliamentary-passage

The Northern Endurance Partnership. (2022). The Northern Endurance Partnership. The Northern Endurance Partnership. https://northernendurancepartnership.co.uk/

The World Bank. (2022). Carbon Pricing Dashboard. Carbon Pricing Dashboard. https://carbonpricingdashboard.worldbank.org/

Tim Power, Fiona Curl, & White & Case. (2023, April 4). A baseline-and-credit greenhouse gas emissions system for Australia: Reforms to the Safeguard Mechanism. Thinking. https://www.whitecase.com/insight-alert/baseline-and-credit-greenhouse-gas-emissions-system-australia-reforms-safeguard

Victoria State Government, & Department of Jobs Precincts and Regions. (2022). The CarbonNet Project - About the project. Earth Resources. https://earthresources.vic.gov.au/projects/carbonnet-project/about-the-project

Welsch, M., Deane, P., Howells, M., Ó Gallachóir, B., Rogan, F., Bazilian, M., & Rogner, H.-H. (2014). Incorporating flexibility requirements into long-term energy system models – A case study on high levels of renewable electricity penetration in Ireland. Applied Energy, 135, 600–615. https://doi.org/10.1016/j.apenergy.2014.08.072

Western Australian Government. (2023). Carbon capture study reveals major opportunity for WA. https://www.wa.gov.au/government/media-statements/Cook-Labor-Government/Carbon-capture-study-reveals-major-opportunity-for-WA-20231117

Williams, E. (2023). Global Economic Net Zero Optimization (GENZO) model documentation. https://status23.globalccsinstitute.com/pdf/genzo1123.pdf

World Bank. (2023). State and Trends of Carbon Pricing 2023. Report. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099805106052321586

7 Appendix 1: Methodology for storage

- In the graphical display of **Estimated** CO_2 **Storage Resources in Hydrocarbon Fields**, a 20 Mt line is shown. However, no official standards exist for categorising a storage site by its resource estimate. Generally, a storage site should host 20-40 years of a commercial CCS facility's CO_2 emissions. Therefore, at a minimum, a small site would have a total storage capacity of less than 20 $MtCO_2$.
- The aggregated resource table in the CO_2 **Storage Resources Management System Classification (OGCI, 2022)** represents the summed storage resource across all maturity classes. Therefore, this value should not be viewed as representative of the country's potential.
- Early storage opportunities are identified as fields with available resources equal to or exceeding 95% of net storage resources. A star icon in the figures denotes them.

7.1 Methodology – Depleted Fields

Known Recovery Replacement (USGS, Brennan et al., 2010)
This analysis considered depleting and depleted fields. In a depleted hydrocarbon field, the majority of the economically recoverable oil or gas has already been extracted, leaving behind a relatively small amount of hydrocarbons that are uneconomical to produce using conventional drilling and extraction methods. Depleted fields may still contain some residual hydrocarbons, but the cost of extracting them may outweigh the potential profits. Depleting fields means the field is in production and still has economically recoverable oil or gas. This study did not have any metrics to distinguish between depleted and depleting fields, as the ultimate aim was to estimate available, remaining, and net CO_2 storage resources.

CO_2 storage resource estimates for depleting and depleted conventional oil and gas fields were calculated using the approach published by the United States Geological Survey (Brennan et al., 2010). This method assumes that some portion of the reservoir pore volume originally occupied by hydrocarbons produced from that reservoir can be replaced with injected CO_2. As such, the estimated CO_2 storage resources ($MtCO_2$) of the hydrocarbon fields can be calculated using Equations 1-3:

Equation 1

$$M_{CO\,2available} = (N_{o-produced} \cdot B_o + N_{g-produced} \cdot B_g) \cdot E \cdot \rho_{CO\,2}$$

Equation 2

$$M_{CO\,2remaining} = (N_{o-remaining} \cdot B_o + N_{g-remaining} \cdot B_g) \cdot E \cdot \rho_{CO\,2}$$

Equation 3

$$M_{CO\,2Net} = M_{CO\,2available} + M_{CO\,2remaining}$$

Where:

- E refers to storage efficiency, which is ''site-specific'' and can be determined via reservoir simulations. The values used for E in oil and gas fields in this study are shown in the table on this page.
- B_O and B_g stand for the formation volume factors of the oil and gas, respectively, dependent on oil and gas properties and current reservoir conditions.
- ρ_{CO2} represents the CO_2 density at reservoir conditions, a function of reservoir pressure and temperature.
- $N_{(o-produced)}$ and $N_{(g-produced)}$ refers to the produced volume of the oil and gas in a field.
- $N_{(o-remaining)}$ and $N_{(g-remaining)}$ refers to the remaining volume of oil and gas in a field.
- $M_{CO2available}$ refers to the storage resources currently available due to hydrocarbons that have been produced.
- $M_{CO2remaining}$ refers to remaining storage resources in a field that can become available upon production of the hydrocarbons (the field becomes depleted).
- M_{CO2Net} refers to the net CO_2 storage resources of a field.

Assumptions

- Recovered resource volumes for hydrocarbon fields were obtained from the hydrocarbon reserves database compiled by Global Data. In many instances, essential field data, such as average depth, temperature, and pressure, were unavailable. The depth was estimated to address the missing data issue using a well's True Vertical Depth (TVD) within the field where TVD data is available. Otherwise, an arbitrary depth of 1200 m was assumed. The acquired depth data were then employed to calculate the average field pressures, utilising a hydrostatic pressure gradient of 1.45 psi/m.

- The depth data was also used to determine the average field temperatures using a Gaussian probability distribution (Monte Carlo) and the geothermal gradient's minimum, maximum, and standard deviation values, as presented in the table below.

Parameter	Average	Min	Max	Standard Deviation
Geothermal gradient (°C/km)	33	23	40	6
B_o	1.5	1.1	2	0.2
E_oil fields	0.3	0.2	0.4	0.04
E_gas fields	0.7	0.4	1	0.15

- Utilising the calculated pressure and temperature data, densities of CO_2 and CH_4 were calculated for each field. Assuming that natural gas within each field, if present, is completely made of CH_4 and utilising the CH_4 specific gravity of 0.554, the gas formation volume factor (Bg) for each field was computed.

- Regarding the oil formation volume factor (Bo), the minimum, maximum, and standard deviation values reported in the table below were defined due to data limitations. These values were used to calculate the oil formation volume factor for each field using a Gaussian probability distribution. The table below also presents the values used in calculating storage efficiency for each field using the Gaussian probability distribution. A Monte Carlo simulation was employed to estimate resources, conducting one thousand simulations with a sample size of five for each parameter in every simulation.

- As mentioned earlier, this study only examined producing and abandoned conventional oil and gas fields. Currently discovered or planned-to-be-produced fields were not assessed due to data limitations. More importantly, these fields would not be ready for CO_2 storage until they become depleted, or in the case of oil fields, until their primary production recovery rate becomes so low that it justifies CO_2 EOR storage. Furthermore, the fields were screened based on their depth and P50-net CO_2 storage resources, and only fields with a depth equal to or higher than 800 m and net storage resources greater than 5 $MtCO_2$ are included in the calculations and reported Tables and figures. The depth criterion is crucial because CO_2 would not be in a supercritical phase in shallow fields. The 5 $MtCO_2$ screening criterion is applied because fields with smaller volumes would not offer economically viable CCS project opportunities.

- It should be noted that the calculated average pore pressure, temperature, gas formation volume factor, and estimated oil formation volume factor values for each field obtained through the above methodology may not precisely represent the actual values in each field. However, the utilised method is the most reliable approach to understanding the storage resources of the fields. A detailed analysis of each field is essential to acquire accurate information regarding its storage resources.

- Additionally, water and gas production during primary production, as well as water flooding or any other secondary injection techniques that may have been applied to some fields, are beyond the scope of this study. The equations used account only for the physical trapping of CO_2 and do not consider solubility trapping.

- Understanding the local geological conditions is out of the scope of this analysis. Studied hydrocarbon fields are assumed to have a viable reservoir(s) and overlying seal(s). Furthermore, the calculation does not consider pore-space connectivity and assumes all pore spaces are available to CO_2. Compartmentalisation can negatively impact CO_2 storage resources and injectivity.

7.2 Methodology – Saline Formations

NETL CO_2-SCREEN (Sanguinito et al., 2022)
Saline formations are deep (>800 m) geological bodies saturated with brine with a high total dissolved solids (TDS) concentration. According to underground sources of drinking water (USDW) in the US, those formations with TDS exceeding 10,000 mg/L can be targeted for CO_2 storage (US EPA, 40 CFR § 144.3, 2010). Since total dissolved solids data for formations were unavailable for this report, it is assumed the formations assessed herein could be potential targets for CO_2 storage.

The United States Department of Energy, National Energy Technology Laboratory (US DOE NETL) has developed a CO_2 storage resource calculator called CO_2-SCREEN, intended to be used as a high-level screening tool to predict the storable mass of CO_2 in saline formations (Sanguinito et al., 2022). The Pythonbased tool utilises Monte Carlo simulations to perform probabilistic resource estimates for saline formations, shale zones, and residual oil zones (ROZ). It is available for download from the US DOE NETL Energy Data Exchange website (EDX) here: https://edx.netl.doe.gov/dataset/CO_2-screen (Sanguinito et al., 2022).

Version 4.1 of CO_2-SCREEN was used to estimate the CO_2 storage resource in the major saline formations in each highly suitable basin. The following data and assumptions were used when determining the physical parameters for the saline formations:

- Area – estimated from the distribution of well penetrations using the Global Data database
- Gross Thickness – averaged from well data in the Global Data database
- Porosity – averaged from well data in the Global Data database
- Pressure – estimated from the reservoir depth (using a hydrostatic gradient of 1.45 psi/m when pressure data in wells was unavailable)
- Temperature – estimated from the reservoir depth (using a geothermal gradient of 33 °C/km when temperature data was unavailable)

Storage efficiency factors developed by the International Energy Agency Greenhouse Gas R&D Programme (IEA GHG, 2009) were used for resource estimation. Default IEA efficiency factors were selected for the relevant formation lithology and depositional environment (IEA GHG, 2009). Default net-to-total area, net-to-gross thickness, and effective-to-total porosity were also used.

Assumptions

Understanding the local geological conditions is out of the scope of this analysis. It is assumed there is a viable reservoir(s) and overlying seal(s) for saline formations. The analysis doesn't consider reservoir properties, such as porosity, permeability, pressure or temperature variations, or faulting. In addition, in the resource assessment, the calculation assumes that the pore space will be available for CO_2. The calculation does not consider pore-space connectivity. Saline formations could be heterogeneous or compartmentalised due to faulting, impacting storage resource estimates.

This approach accounts only for the physical trapping of CO_2 and does not consider solubility trapping. Finally, the approach assumes that the saline formation has open boundaries, which may not be true for all formations. Therefore, the results may be overly optimistic.

7.3 Methodology – Basin Suitability Assessment

The Institute's storage basin assessment tool was used to assess every basin in the APAC region.

The suitability of basins uses publicly available data and the expert opinion of the Institute. Over 70 basins were reviewed using the Institute's storage basin assessment tool. The assessment tool is a quantitative and qualitative criteria-based approach to define a basin's potential to store CO_2. The criteria incorporate best practice guidelines on storage site selection by IEAGHG (IEA Greenhouse Gas R&D Programme, 2000), NETL Best Practice manual (NETL, 2017) and DNV (DNV GL, 2012).

Each basin is assessed using 23 criteria. Broadly, these criteria include:

- Geology – tectonics, basin size, depth, water depth, reservoir-seal potential, depositional environment and geothermal history
- Hydrocarbon maturity and prospectivity – multiple factors, including the hydrocarbon potential, exploration and production history, presence of giant fields (3 TCF), and CO_2-EOR potential

- Storage assessment maturity – scale (region, national basin, formation, site) and the comprehensiveness of the basin's storage assessment published in English-speaking publications

- Storage resource maturity – confidence and comprehensiveness of published English-speaking resource estimates guided by categorisation according to the Storage Resource Management Scheme (Society of Petroleum Engineers (SPE), 2018)

- Storage operation maturity – the scale of injection and storage, ranging from test injection to pilot, through to multiple commercial operations

- Sub-surface data and transport infrastructure – the density of hydrocarbon wells, platforms, and pipelines

- Accessibility – based on environmental, social and cultural constraints, regulatory frameworks, potential sources conflicts (e.g. potable water), and density of CO_2 sources near the basin.

Based on the criteria and their total score, each basin is categorised as follows:

Highly-suitable (dark green in maps)
These basins have the most if not all, the following factors:

- Completed multiple detailed assessments of its storage characterisation and resource estimates by various parties with consensus on results

- In most instances, the injectivity and storage have been tested, undertaken (pilot/EOR) or modelled

- The basin hosts a commercial-scale storage operation or advanced planning

- The basin is (or has been) a mature and major oil and gas producer

- The basin is accessible for storage operations

Suitable (light green)
These basins meet many properties of a highly suitable basin, but generally:

- Storage assessments have been more localised on particular parts of the basin

- Do not host active or completed storage operations (commercial or pilot)

- CO_2 storage operations may have accessibility issues

Possible (orange)
These basins have the following:

- Prominent indicators of viable storage geology, such as oil and gas operations suggesting viable reservoirs and seals for CO_2

- Storage analysis is limited to only broad, regional assessments, generally focusing on the oil and gas fields

- Can have significant accessibility issues for storage operations

Unlikely (red)
These basins generally have either:

- Obstructing accessibility issues for storage operations

- The geology is currently defined as Unlikely for storage, for example, a shallow (<800 m) basin.

The suitability colour scheme above in this methodology is presented for each basin in each country.

The suitability for each basin is also presented as a table to detail the results of the overall basin suitability. The 23 criteria used in the assessment have been summarised into five categories:

I. Geology: tectonics, basin size and depth, water depth, reservoir-seal potential, depositional environment.

II. Sub-surface Knowledge and Data Maturity: hydrocarbon potential, exploration and production history, field density and size, and density of hydrocarbon wells, platforms, and pipelines.

III. Storage Resource Knowledge: level of detail in storage assessments, confidence and comprehensiveness of resource estimates.

IV. Accessibility: accessibility to data, environmental, social and cultural constraints, regulatory frameworks, potential sources conflicts (e.g. potable water),

V. The suitability is based on the basin suitability assessment score using the 23 criteria.

The categories are then presented as a traffic light system in a series of tables titled “basin ranking” for each country.

- Highly suitable (dark green in tables)
- Suitable (light green)
- Possible (orange)
- Unlikely (red)

8 Appendix 2: Capital cost assumptions for select technologies in GENZO

The following tables are capital costs for the US region, which is the base cost region in GENZO. Costs in other regions, including the APAC countries in this study, are adjusted based on location cost adjustment factors. The costs do not change across the different scenarios in this study, so we are including only one scenario for illustration. GENZO also has fixed and variable operating cost assumptions for these technologies, as well as capital, fixed and variable cost assumptions for end-use technologies in industry, transportation, and buildings.

Electricity capital costs USA (USD per kw)

Scenario	Categories	2025	2030	2035	2040	2045	2050	2055	2060	2065	% Reduction
Accelerated											
Accelerated	Biomass with CCS	6571.3	6030.9	5475.4	5002.7	4565.0	4126.6	4126.6	4126.6	4126.6	37.2
Accelerated	Biomass	4057.3	3749.6	3429.8	3159.1	2908.1	2653.9	2653.9	2653.9	2653.9	34.59
Accelerated	Supercritical coal with CCS	5918.8	5432.8	4933.1	4507.8	4114.0	3719.6	3719.6	3719.6	3719.6	37.16
Accelerated	CCS retrofit for existing coal	1223.5	1123.0	1019.7	931.8	850.4	768.9	768.9	768.9	768.9	37.16
Accelerated	Supercritical coal	3654.4	3377.7	3090.1	2846.6	2620.8	2392.2	2392.2	2392.2	2392.2	34.54
Accelerated	Concentrating solar power	7126.9	6660.7	6083.3	5600.3	5155.1	4705.5	4621.9	4621.9	4621.9	35.15
Accelerated	Hydroelectric	1503.2	1412.9	1315.6	1234.7	1159.2	1263.1	1263.1	1263.1	1263.1	15.97
Accelerated	Hydrogen combustion turbine	718.8	655.5	604.1	560.9	520.7	481.2	481.2	481.2	481.2	33.06
Accelerated	Hydrogen fuel cell	6061.7	5344.1	4637.6	4023.1	3458.6	2915.7	2375.0	1845.3	1315.6	78.3
Accelerated	Natural gas combined cycle with CCS	2518.1	2297.9	2086.9	1907.3	1741.0	1576.1	1576.1	1576.1	1576.1	37.41
Accelerated	CCS retrofit for existing natural gas combined cycle	1573.7	1423.1	1276.3	1150.5	1034.2	920.1	920.1	920.1	920.1	41.53
Accelerated	Natural gas combined cycle	944.4	874.8	810.5	756.8	706.7	656.0	656.0	656.0	656.0	30.54
Accelerated	CCS retrofit for new natural gas combined cycle	1731.1	1565.5	1404.0	1265.5	1137.7	1012.1	1012.1	1012.1	1012.1	41.53
Accelerated	Natural gas combustion turbine	718.8	655.5	604.1	560.9	520.7	481.2	481.2	481.2	481.2	33.06
Accelerated	Nuclear	6162.1	5693.4	5206.5	4794.2	4411.9	4025.1	3653.3	3285.8	2918.2	52.64
Accelerated	Oil steam turbine	1827.8	1718.0	1599.7	1501.3	1409.5	1313.3	1313.3	1313.3	1313.3	28.15
Accelerated	PV	719.4	637.4	575.7	524.9	477.8	430.8	430.8	430.8	430.8	40.12
Accelerated	PV with battery system	7606.1	7245.5	6973.7	6750.0	6542.9	6336.1	6336.1	6336.1	6336.1	16.7
Accelerated	Municipal solid waste	1579.0	1484.1	1381.9	1296.8	1217.5	1134.5	1134.5	1134.5	1134.5	28.15
Accelerated	Wind - offshore - far	6652.9	5329.8	4209.1	3677.1	3331.7	3055.7	3055.7	3055.7	3055.7	54.07
Accelerated	Wind - offshore - inermediate	5363.3	4296.7	3393.2	2964.3	2685.9	2463.4	2463.4	2463.4	2463.4	54.07
Accelerated	Wind - offshore - near	4750.8	3806.0	3005.7	2625.8	2379.1	2182.1	2182.1	2182.1	2182.1	54.07
Accelerated	Wind - onshore - near	1278.1	1201.3	1118.6	1049.8	985.6	918.4	918.4	918.4	918.4	28.14
Accelerated	Wind - onshore - intermediate	1917.2	1802.0	1677.9	1574.6	1478.3	1377.5	1377.5	1377.5	1377.5	28.15
Accelerated	Wind - onshore - far	2236.7	2102.3	1957.5	1837.1	1724.7	1607.1	1607.1	1607.1	1607.1	28.15
Accelerated	Wind onshore with battery system	6588.9	6367.6	6129.2	5930.9	5746.0	5552.3	5552.3	5552.3	5552.3	15.73

Ammonia capital costs USA (USD for the capacity to convert 1 GJ)

Scenario	Categories	2025	2030	2035	2040	2045	2050	2055	2060	2065	% Reduction
Accelerated											
Accelerated	Hydrogen to ammonia conversion	7.35	5.87	5.31	4.76	4.76	4.76	4.76	4.76	4.76	35.24
Accelerated	Ammonia to hydrogen conversion	16.48	16.48	16.48	16.48	16.48	16.48	16.48	16.48	16.48	0.0

Hydrogen capital costs USA (USD for the capacity to produce 1 GJ)

Scenario	Categories	2025	2030	2035	2040	2045	2050	2055	2060	2065	% Reduction
Accelerated											
Accelerated	Biogasification with CCS	86.03	80.87	73.99	67.1	67.1	67.1	67.1	67.1	67.1	22.0
Accelerated	Coal gasification with CCS	86.03	80.87	73.99	67.1	67.1	67.1	67.1	67.1	67.1	22.0
Accelerated	Electrolysis - from grid	27.54	23.37	19.19	15.02	15.02	15.02	15.02	15.02	15.02	45.46
Accelerated	Electrolysis - dedicated solar	363.4	302.9	260.4	217.9	217.9	217.9	217.9	217.9	217.9	40.04
Accelerated	Electrolysis - dedicated wind	521.6	466.2	421.1	376.1	376.1	376.1	376.1	376.1	376.1	27.89
Accelerated	Natural gas SMR	27.62	26.07	24.53	22.99	21.45	19.91	19.91	19.91	19.91	27.91
Accelerated	Natural gas partial oxidation with SMR	27.62	26.07	24.53	22.99	21.45	19.91	19.91	19.91	19.91	27.91
Accelerated	Oil partial oxidation with SMR	27.62	26.07	24.53	22.99	21.45	19.91	19.91	19.91	19.91	27.91

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