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Comprehensive CCUS Research Report: Storage, Value Chain, Policy & Regulation and Financing

Prepared by

Global CCS Institute (GCCSI)

With Support of

ERIA (Economic Research Institute for ASEAN and East Asia)

ASIA CCUS NETWORK

ERIA Economic Research Institute for ASEAN and East Asia

GLOBAL CCS INSTITUTE

Comprehensive CCUS Research Report: Storage, Value Chain, Policy & Regulation and Financing

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Preface

In alignment with the Asia CCUS Network's (ACN) vision, which aims to contribute to decarbonisation in the Asian region through the development and deployment of Carbon Capture, Utilisation, and Storage (CCUS), the roadmap emphasises initiating a basin-scale CCS pilot project around 2025 and transitioning CCUS business to a commercial basis after 2030. ACN has taken a comprehensive approach to address key CCUS issues, including:

a. Assessing CO_2 storage potential in the ASEAN region. b. Establishing the policy and legal framework for CCUS business. c. Developing financing mechanisms to secure substantial investments for CCS business. d. Examining the CO_2 value chain, particularly cross-border CO_2 transportation in the Asian region.

In pursuit of these goals, ACN received a research proposal from the Global CCS Institute (GCCSI) to conduct studies on these four crucial points. ACN carefully reviewed the proposal, sought feedback from the ACN Advisory Group members, and forwarded comments to GCCSI. GCCSI revised the proposal based on ACN's feedback, finalising it for implementation.

Following the initiation of the study, lasting approximately one year, GCCSI compiled the results into a comprehensive report, including an executive summary. Upon receiving the report, ACN scrutinised it and provided feedback with several comments to GCCSI. The report was finalised after incorporating ACN's comments.

The key findings of the report include:

a. Identification of substantial CO_2 storage capacity in the ASEAN region, with a notable emphasis on Indonesia. b. Recognition of the indispensability of an appropriate policy and legal framework for successful CCS/CCUS implementation, especially in monitoring CO_2 leakage during specific periods. c. Emphasis on incorporating a financing scheme that includes establishing a suitable carbon price market and carbon credit mechanisms, such as the Joint Credit Mechanism (JCM). d. The necessity of establishing institutions to support CO_2 trade between CO_2 emitting countries and CO_2 storing countries, applying market mechanisms.

In light of these study results, ACN is poised to contribute to the initiation of a CCS pilot project in the ASEAN region.

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Acknowledgements

This report was collaboratively developed by researchers from the Global CCS Institute (GCCSI), each contributing expertise in specific areas:

Dr Christopher Consoli focused on assessing the geological storage potential of CO_2 in Southeast Asia.

Mr Ian Havercroft concentrated on the legal and policy framework for the deployment of CCUS in the Asia region, with a specific focus on ASEAN.

Mr Eric Williams contributed to the study on the financial framework for the deployment of CCUS in the Asia Region, including ASEAN.

Mr Alex Zapantis played a crucial role in establishing the Asia CCS/CCUS value chain as a collective framework in the Asia region.

Additionally, other researchers from GCCSI were actively involved in the preparation of this report. I take this opportunity to express my gratitude to GCCSI for its valuable contributions that significantly contributed to the success of this project.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations/Acronyms

ACCU	Australia Carbon Credit Units
ACE	ASEAN Centre for Energy
ACR	American Carbon Registry
ADB	Asia Development Bank
AEMO	Australian Energy Market Operator
AEOS	Alberta Emission Offset Scheme
AETI	Asia Energy Transition Initiative
ANGEA	Asia Natural Gas and Energy Association
APAC	Asia-Pacific
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of South-East Asian Nations
AUD	Australian Dollar
AZEC	Asia Zero Emission Community
BCG	Boston Consulting Group
BECCS	Bioenergy with Carbon Capture and Storage
BIGST	Bujang, Inas, Guling, Sepat, and Tujoh
BNCCP	Brunei Darussalam National Climate Change Policy
BP	British Petroleum
BPMA	Badan Pengelola Migas Aceh
BRGM	Bureau des Recherches Géologiques et Minières
BSP	Brunei Shell Petroleum
CAPEX	Capital Expenditure
CARB	California Air Resources Board
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation, and Storage
CDM	Clean Development Mechanism

CDR	Carbon Dioxide Removal
CEQ	Council on Environmental Quality
CER	Clean Energy Regulator
CFPP	Coal-Fired Power Plant
CH4	Methane
CIPP	Comprehensive Investment and Policy Plan
CIX	Climate Impact X
CNOOC	China National Offshore Oil Corporation
CO	Carbon Monoxide
CO2	Carbon Dioxide
CO2Stop	Assessment of the CO2 Storage Potential in Europe
COP	Conference of the Parties
CRF	Capital Recovery Factor
CRRU	Carbon Reduction/Removal Unit
CSEM	Controlled Source Electro-Magnetic
CSU	Carbon Storage Unit
DAC	Direct Air Capture
DACCS	Directdirect Air Capture and Storage
DOE	Department of Energy
EC	European Comission
EDX	Energy Data Exchange
EEA	European Economic Area
EIA	Environmental Impact Assessments
ELD	Environmental Liability Directive
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Authority
ERF	Emissions Reduction Fund
ERIA	Economic Research Institute for ASEAN and East Asia
ESG	Environmental, Social and Governance
ESMAP	Energy Sector Management Assistance Program
ETS	Emission Trading System

EU	European Union
EUR	Euro
EV	Electric Vehicle
FEED	Front End Engineering Design
FID	Final Investment Decision
GBP	Great Britain Poundterling
GCCSI	Global CCS Institute
GD2	Guidance Document
GDP	Gross Domestic Product
GENZO	Global Economic Net Zero Optimization
GHG	Greenhouse Gas
GHGRP	Greenhouse Gas Reporting Program
H2	Hydrogen
IBRD	International Bank for Reconstruction and Development
IDA	The International Development Association
IDB	Inter-American Development Bank
IEA	International Energy Agency
IEAGHG	The IEA Greenhouse Gas R&D Programme
IED	Industrial Emissions Directive
IEG	Information Exchange Group
IETA	International Emissions Trading Association
IFC	International Finance Corporation
IIJA	Infrastructure Investment and Jobs Act (
IMF	International Monetary Fund
IMO	International Maritime Organization
IOGP	International Association of Oil and Gas Producers
IPCC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act
IRENA	International Renewable Energy Agency
JBIC	Japan Bank of International Cooperation
JETP	Just Energy Transition Partnership

JOGMEC	Japan Organization for Metals and Energy Security
JSA	Joint Study Agreement
LCER	Low-Carbon Energy Research
LCFS	Low Carbon Fuel Standard
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LPO	Loan Programs Office
MARPOL	International Convention for the Prevention of Pollution from Ships
MCMPR	Ministerial Council on Mineral and Petroleum Resources
MCO_2	Estimated CO_2 Storage Resources
MDB	Multilateral Development Banks
MEMR	Ministry of Energy and Mineral Resources
METI	Ministry of Economy, Trade, and Industry
MFO	Marine Fuel Oil
MGO	Marine Gas Oil
MMP	Minimum Miscibility Pressure
MOU	Memorandum of Understanding
MRV	Measurement, Reporting and Verification
MW	Mega Watt
NCCAP	National Climate Change Action Plan
NCCS	National Climate Change Secretariat
NCOC	North Caspian Operating Company
NDC	Nationally Determined Contributions
NEATS	National Electronic Approvals System
NEMP	National Energy Master Plan
NEP	National Energy Policy
NETL	National Energy Technology Laboratory
NETR	National Energy Transition Roadmap
NG	Natural Gas
NGER	National Greenhouse and Energy

NGO	Non-Governmental Organization
NOC	National Oil Company
NOK	Norwegian Krone
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
OJK	Otoritas Jasa Keuangan
ONGC	Oil and Natural Gas Corporation
OPEX	Operation Expenditure
PDR	People's Democratic Republic
PEP	Philippine Energy Plan
PETRONAS	Petroliam Nasional Berhad
PSC	Production Sharing Contract
PTTEP	PTT Exploration and Production Public Company Limited
PV	Photovoltaics
RCAL	Routine Core Analysis Laboratory
RF	Recovery Factor
ROZ	Residual Oil Zones
SCAL	Special Core Analysis
SEA	South-East Asia
SEACA	South-East Asia CCS Accelerator
SOCAR	State Owned Company of Azerbaijan
SPE	Society of Petroleum Engineer
SRSAI	Significant Risk of a Significant Adverse Impact
TASR	Technically Accessible CO_2 Storage Resource
TBT	Technical Barriers to Trade
TCF	Trillion Cubic Feet
TDS	Total Dissolved Solids
TFEU	Treaty on the Functioning of the European Union

TVD	True Vertical Depth
UIC	Underground Injection Control
UK	United Kingdom
UN	United Nations
UNCLOS	The United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USD	United States Dollar
USDW	Underground Sources of Drinking Water
VCC	Value Chain Centre
VCM	Voluntary Carbon Market
VCS	Verified Carbon Standard
WACC	Weighted Average Cost of Capital
WEF	World Economic Forum
WRI	World Resources Institute
XRD	X-Ray Diffraction

Executive Summary

This report presents four separate studies completed by the Global CCS Institute for the Economic Research Institute for ASEAN and East Asia. Collectively, these studies assess the role of Carbon Capture and Storage (CCS) in southeast Asia to support the achievement of net-zero emissions targets, review the policy and legal frameworks necessary to enable CCS to play that role, examine the need for collaboration between southeast Asian nations including institutional frameworks and discuss options to facilitate the financing of CCS in the region. Each study contains recommendations.

The studies are:

1. CO_2 Storage Potential in Southeast Asia
2. Establishment of Asia CCS/CCUS Value Chain as a Collective Framework in the Asia Pacific Region
3. Legal and Policy Framework for Deployment of CCUS in Asia Region, focused on ASEAN
4. Study on Financial Framework for Deployment of CCUS in the Asian Region, including ASEAN

Key findings and recommendations from each study are summarised below.

Geological Storage Potential of CO_2 in Southeast Asia

This study investigates the potential of carbon capture and storage (CCS) to decarbonise industrial emissions in Southeast Asia, leveraging the region's numerous suitable storage basins and abundant CO_2 storage resources. The study evaluates emissions and basins across Southeast Asian nations, identifying 13 industrial emission clusters that could form CCS networks matched to storage basins. Networks can lower the cost and commercial risk of CCS deployment through shared infrastructure and knowledge inherent to their part of the CCS technical chain. Key findings and insights from the study include:

Key Findings

The suitability of basins for storage varies across countries as each nation is in a different state of storage resource development:

- Indonesia, Malaysia and Thailand are the most advanced, with suitable and highly suitable offshore and onshore basins, gigatonne storage resources, and active CCS facilities. However, only Indonesia has a national regulatory framework to enable CCS.
- Brunei Darussalam has a suitable offshore basin with gigatonne storage resources. However, storage development and CCS deployment have not commenced, and the nation lacks a dedicated regulatory environment for CO_2 storage exploration.

- Viet Nam and the Philippines host potential storage basins, but there is no storage development in key areas near strategic industrial emission clusters.
- Lao, Myanmar, and Cambodia were not assessed due to a lack of data, and the storage potential of those countries has never been reviewed.
- Singapore does not have a storage basin within its borders.

An estimated 200 gigatons (Gt) of storage resources confirm that the six Southeast Asian countries assessed for storage have sufficient resources to enable CCS in the region. On the estimated storage resource, around 98% is in saline formations. This estimate is remarkable as only nine saline formations in nine basins were reviewed. However, this estimate carries large uncertainty since the storage resources for saline formations are for theoretical storage, whereas the hydrocarbon field storage estimate uses field data.

Table S.1. Estimated Storage Resources in ASEAN Countries

Country	Saline Formation- P50 net storage resources ($MtCO_2$)	Depleted Field- P50 net storage resources ($MtCO_2$) and Number of Fields	CO_2 stored through EOR- P50 ($MtCO_2$) and Number of Fields
Indonesia	49,000	2,275 / 42 fields	153/ 6 fields
Malaysia	127,000	1,773 / 41 fields	105/ 9 fields
Brunei	18,000	579 / 7 fields	200/ 1 field
Thailand	15,000	1,024 / 27 fields	0
Viet Nam	5,000	303 / 9 fields	56/ 3 fields
Philippines	n/a	67 / 1 field	0
Total	**214,000**	**6,021 / 127 fields**	**514/ 19 fields**

Source: GCCSI.

There are limited to moderate opportunities for CO_2 EOR storage in the region, with Brunei, Indonesia, and Malaysia presenting the highest potential in that order.

International import of CO_2 is a very likely option for several basins across Southeast Asia, including Sabah - Baram Delta (Brunei), Sarawak and Malay (Malaysia) and Kutei (Indonesia).

There are significant information gaps related to geological storage resources in the region:

Gap 1: Characterisation of non-hydrocarbon-producing basins is lacking.

Gap 2: Basic basin-scale storage characterisations are lacking for Lao, Cambodia, Myanmar, and the Philippines

Gap 3: Limited characterisation of saline formations in the region.

Gap 4: Basin-wide, site-scale characterisation and appraisal have not been completed in any basin in the region.

Recommendations

- Develop a regional storage atlas led by advanced Southeast Asian nations and international experts using a standardised methodology.
- Create an online database of the atlas to facilitate further storage development and CCS infrastructure planning.
- Conduct detailed site-scale storage analysis, including characterising priority basins (Malay (Malaysia/Thailand), Northwest Java (Indonesia), Cuu Long (Viet Nam), and Pattani (Thailand).

Establishment of Asia CCS/CCUS Value Chain as a Collective Framework in the Asia Pacific Region

Key Findings

The development of CCS hubs and clusters, bringing together a number of different CO_2 emissions sources and/or storage sites in a connected network, offers participants several advantages over vertically integrated CCS projects. Benefits include reduced costs and risk, enabling more cost-effective transport and storage from small volume sources, and maintaining investment and jobs in high-emitting industrial regions.

Large-scale deployment of CCS in the region will require a coordinated effort between countries in Southeast Asia, to develop frameworks and platforms for successful and timely project delivery. Integrated upstream policy and robust institutional frameworks will be key to underpin regional project implementation. In addition, coordinated institutional frameworks, including coherent decarbonisation strategies, project approval and procurement strategies, and investment plans, will reduce project risk and enable capital investment.

The establishment of a centralised body, such as a CCS Value Chain Centre (VCC), to coordinate and administer regional efforts, could accelerate CCS deployment in the region.

The VCC, as a coordinating body, could review and make recommendations on how existing national policies, legislation and regulatory frameworks could be adapted to accommodate and enable regional CCS activities, including identification of near- and mid-term activities to support national regulators and policymakers to align national CCS policies to enable collaboration in the region. In collaboration with national policymakers and regulators, the VCC could implement the ASEAN CCS Roadmap currently under development by the ASEAN Center for Energy. As a regional body, the VCC could act as an advisory body, tasked with monitoring national CCS legislation and regulation

development in the region, in line with the ASEAN CCS Roadmap and make recommendations to regulators as appropriate.

In addition, the VCC could coordinate the development of an ASEAN CCS Regulatory Principles guideline, based on the existing 'ASEAN Guidelines on Good Regulatory Practice' to provide guidance on the approach to developing CCS-specific regulation for the region.

The VCC could also play a role in the standardisation of CCS, based on international standards and global best practice and through collaboration with other associations in the climate change space. It could also become the official custodian of an ASEAN geological storage calculation engine and database, accessible to project proponents in the region and coordinate the development of a regional framework for risk assessment and management of CO_2 storage in geological formations.

To support investment in CCS projects in the region and to provide certainty to project sponsors and financiers, the VCC could act as a representative body for ASEAN countries, seeking foreign direct investment and other forms of climate finance. A coordinated multi-national approach will enhance negotiation power and reduce counterparty risk for investors.

Recommendations

Actions that should be considered by project proponents and governments to facilitate the development of CCS hub and cluster networks include:

- Identification of emissions clusters and storage resources that could support the development of CCS networks in each country and regionally. This provides the initial starting point for strategically developing CCS networks.
- Support with resources and funding for the appraisal of CO_2 storage resources in a given country or region. Locally available storage resources will always be more cost-effective than leveraging regional storage resources. Identifying surplus storage resources for the needs of the current emission sources allows for opportunities for low-emissions industry growth and provides storage resources to neighbouring countries with limited or no locally available storage.
- Identify avenues for incorporating new industries (i.e. clean hydrogen or ammonia) with existing emissions clusters early in developing CCS networks.
- Regional CCS networks will in most cases be more complex with the transboundary movement of CO_2. Early identification of these CCS networks will enable project proponents and governments to work through the necessary steps to facilitate their development.
- Identify opportunities to fast-track the development of first-mover CCS networks to expedite knowledge growth and accelerate the development of further CCS networks.

- Well-planned, early engagement with stakeholders and the community in the vicinity of emissions clusters and potential CCS networks.
- Governments should investigate the establishment of CCS Value Chain Centre (VCC) to coordinate and administer regional efforts to accelerate CCS deployment in the region.

Legal and Policy Framework for Deployment of CCUS in Asia Region, focused on ASEAN

Key Findings

The approach to regulating CCS activities is an important preliminary consideration for governments seeking to develop a CCS-specific legal framework. Regulators and policymakers have historically demonstrated a preference for one of two pathways; a stand-alone regulatory framework or enhancing existing oil and gas legislation to regulate CCS activities.

Regulators and policymakers may decide to expand the focus of regulatory frameworks to include the broad suite of applications that constitute CCS technologies across the industrial and power sectors. The inclusion of various applications will depend on the objectives underpinning the legislative framework for the technology, which may relate to the nation's climate change mitigation, energy transition and economic development priorities.

Permitting approaches may differ for various applications and separate permitting pathways may be established for specific applications. In some countries, certain enhanced hydrocarbon recovery applications, such as Enhanced Oil Recovery (CO_2-EOR), have been excluded entirely from the scope of CCS-specific frameworks.

Learning from the experiences of early-mover nations and engaging with international stakeholders provides valuable insights and expertise in the development of regulatory frameworks for CCS. Policymakers and regulators can benefit from established international forums and engagement in formal and informal dialogues to inform their decision-making processes regarding CCS-specific legislation.

Within the region, the experiences of the governments of Indonesia and Thailand offer tangible examples of the processes involved in developing regulatory frameworks for CCS. Both countries have undertaken collaborative, iterative processes, that have engaged a diverse group of stakeholders across various levels of government.

CCS-specific frameworks may build upon existing licensing regimes and in some instances rely upon established pathways to regulate discrete aspects of the CCS process. The resulting regulatory frameworks will therefore require the involvement of numerous regulatory authorities and/or agencies, as permits and licenses are sought for capture, transport, and storage activities.

Many of the government departments and authorities likely to assume roles and responsibilities in the regulation of the technology, throughout the project lifecycle, will be unfamiliar with the technology. There is a risk of delay or a disconnect within the regulatory process, where these stakeholders take time to familiarise themselves with the technology and new regimes.

Activities involving the transport of CO_2 across international maritime zones and marine areas have implications under a broad range of international agreements, including those relating to the pollution of the marine environment, the safety of maritime transport, the transport of dangerous goods and the carriage of compressed gases.

The London Protocol removed barriers to the technology's deployment and provided a basis under the Protocol's mechanisms for the regulation of CO_2 sequestration in sub-seabed geological formations. Recent amendments to this agreement offer an important pathway for facilitating the transboundary transportation of CO_2 for geological storage.

A substantial body of domestic legislation will ultimately apply to the entirety of a CCS project. For many nations within the ASEAN region, existing oil and gas operations will provide a good analogue for the various regimes that may also apply to CCS activities.

Compliance with CCS-specific legal and regulatory regimes is an important feature of many carbon crediting schemes that offer support for CCS activities.

The detailed reporting and accounting of stored CO_2, as part of geological storage operations, is an important aspect of ensuring compliance with CCS-specific legislation and for ensuring the wider integrity of CCS operations.

The 2006 IPCC Guidelines offer an important indication as to how national accounting schemes may manage the reporting of transboundary CCS operations.

Legal and regulatory issues will arise in the context of transboundary project models, which will trigger obligations under international, regional, and national regimes. The absence of clear legal and regulatory frameworks for these operations, within international and national law, suggests this issue is addressed in the pre-injection phase and prior to operation.

Examples from current regulatory frameworks demonstrate that countries have chosen to adapt or enhance a variety of existing regulatory regimes to regulate these activities. Legislation governing oil and gas and resources operations, environmental protection, property, planning, health and safety, and pollution control, may all have an impact upon CCS operations.

Existing regulatory frameworks, predominantly those facilitating other industrial activities, may serve as the basis for CCS regulation in the ASEAN region. Further amendment of these frameworks will be necessary to fully address the regulatory issues posed by CCS activities.

The responsible and safe closure of a CO_2 storage site are the focus of regulatory requirements during the closure phase. Legislation will require project operators to seek

authorisation to close a CO_2 storage site upon the fulfilment of prescribed criteria and may include well decommissioning and plugging requirements.

Regulatory obligations during the post-closure phase will include long-term monitoring and responsible site care, to ensure the safety and security of CO_2 storage sites. Regulatory frameworks may oblige project operators to provide post-closure monitoring plans to address potential risks, including leakage and site integrity concerns.

Liability for stored CO_2 is a key issue that regulators and policymakers have attempted to address within early CCS-specific legal and regulatory frameworks.

Regulatory provisions enabling the transfer of liability for a storage site or stored CO_2, from an operator to a state's competent authority, following the closure of the storage site is a key mechanism adopted across various regulatory frameworks.

Regulatory frameworks also mandate financial security provisions to address the long-term liabilities associated with the closed CO_2 storage site, by requiring financial guarantees to cover closure, post-closure, and potential CO_2 leakage liabilities, to reduce the burden on public funds.

Recommendations

- Evaluate national policy priorities relating to climate change mitigation, energy security and economic development to evaluate the objectives that will underpin CCS-specific legislation and the preferred pathway for regulating the technology.
- Engage the wider public to better understand public sentiment towards CCS, and to gauge the public's level of knowledge and awareness of the technology's role in reducing greenhouse gas emissions.
- Review existing legal and regulatory frameworks relating to resources, energy, environment, property and planning, the adequacy of these regimes in regulating the novel aspects of CCS and the possibility of amending or adapting these frameworks to regulate CCS activities throughout the project lifecycle.
- Identify the specific applications to be covered by the scope of domestic regulatory frameworks.
- Review the extent to which existing regulatory frameworks, relating to resources, environment, property, and planning, may support dedicated geological storage and enhanced hydrocarbon recovery projects.
- Ensure CCS-specific regulatory frameworks remain future focused and are adaptable to reflect the technological advances associated with various applications and emerging technologies.
- Establish dedicated processes, that engage all relevant stakeholders within government, to examine and consider the relevant policy, legal and regulatory issues.

Activities may include the conducting studies to obtain an understanding of the nuances required in regulating CCS technologies.

- Engage a diverse range of expert stakeholders from across industry, academia, research institutions and civil society, to gather expert perspectives on the regulation of the technology.
- Leverage international expertise through dialogue with international stakeholders experienced in addressing CCS regulatory challenges. Engage in formal discussions or collaborations through established platforms to benefit from international insights and experiences.
- Government should identify and formally designate a lead government department or regulatory authority, to promote the development and implementation of a CCS-specific regulatory regime.
- The lead authority or department may then act as a coordinator to ensure that all relevant policy and regulatory entities are engaged and familiar with their roles and responsibilities, as part of the regulatory process.
- Governments may wish to consider developing an education and capacity development programme, aimed at familiarising the relevant policy and regulatory stakeholders with the technology and their roles and responsibilities within the regulatory process.
- Government, through the lead regulatory authority, may undertake a formal process of public consultation to ensure interested parties are afforded the opportunity to provide their feedback and that this information is formally captured.
- A formal information programme, delivered by government and/or third-party expert organisations, may be delivered in-tandem with the public consultation effort. A programme of this nature could seek to clarify the role of CCS in addressing domestic climate change commitments or address any misconceptions surrounding the technology.
- Undertake a detailed review of national commitments under wider international law, to determine their impact upon CCS operations.
- Investigate the implications of exporting/importing CO_2 from those countries which are Parties or non-Parties to the London Protocol.
- Develop secondary guidance to support project developers when advancing projects that feature the transboundary movement of CO_2.
- Undertake a detailed review of national legislation to determine key legal instruments applicable to CCS operations.
- As part of this review, policymakers and regulators should identify the wider approvals pathways for CCS projects, to reflect all necessary national and sub-

national legislation. The review should also seek to clarify obligations for project proponents and determine responsibilities between various national and sub-national regulatory authorities.

- Identify overlapping permitting responsibilities between national and sub-national regulatory authorities and identify any potential challenges.
- The development of secondary guidance may assist project proponents in navigating the requirements of wider legal and regulatory regimes.
- Timely engagement with project proponents to understand project proposals in development.
- Ensure that the development of any subsequent CCS-specific legislation adequately manages these new and emerging project models.
- Undertake a formal review of the inclusion of CCS activities within any existing or proposed domestic carbon crediting scheme or mechanism.
- Examine the legal and regulatory implications of formally recognising the geological storage of CO_2 within any existing or proposed scheme or mechanism.
- Review current emissions reporting and accounting frameworks to determine the extent to which CCS operations may be addressed.
- Ensure clarity within domestic emissions accounting frameworks of the treatment of CO_2 subject to transboundary movement.
- Review existing national protocols and guidance that may support the development and interpretation of future CCS-specific legislation.
- Where legislation is being proposed or implemented, policymakers and regulators may consider the development secondary guidance to support project developers in complying with the new legislative requirements.
- Determine how captured CO_2 is to be treated within domestic legal frameworks. Consider the necessity of excluding it from the scope of current waste management legislation.
- Establish guidelines or standards regarding the purity and composition of CO_2 streams.
- Clarify and define ownership rights over subsurface geological formations and the pore space, potentially through legislation or regulatory amendments.
- 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.

- Engage with regulators and policymakers in the region to support the development of a consistent approach to the transboundary movement of CO_2.
- Ensure that these activities and requirements are adequately captured within a domestic permitting framework.
- Develop a regulatory regime aimed at facilitating the operational phase of a CCS project, including technical requirements that ensure the safe operation of capture, transport and storage activities.
- Review existing regulatory frameworks and the extent to which they accommodate the regulatory issues associated with the technology and ensure that CCS activities are sufficiently integrated within wider legal frameworks that may also be applicable.
- 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.
- Clarify project operators' responsibilities during operation and ensure clarity as to the allocation of liabilities during this phase in instances of non-compliance with regulatory obligations or in the event of any accident or leakage.
- Establish adequate monitoring and reporting procedures to ensure robust accounting verification of the stored CO_2.
- Ensure there are adequate, formal opportunities for regulators to monitor activities and ensure compliance with the regulatory framework.
- Develop a procedure within the regulatory framework to formally authorise site closure.
- Review existing legislation relating to oil and gas exploration and production for the purpose of enhancing or adapting provisions relating to well abandonment and site closure.
- Develop regulatory provisions addressing long-term monitoring after site closure and require approval of these plans to ensure adherence to safety and reporting provisions.
- Consider how long-term liabilities are to be managed within a domestic regime and, in particular, whether a transfer mechanism would be an option.
- Introduce provisions requiring operators to provide financial security to cover potential long-term liabilities arising from CCS activities.

Study on Financial Framework for Deployment of CCUS in the Asian Region, including ASEAN

Key Findings

CCS and other climate mitigating technologies deliver a public good; a stable climate. The value they create for society is far greater than the value that can be captured by a private sector investor in an individual project. Thus, any consideration of the financing of CCS, or any climate mitigation technology, necessarily requires a consideration of public policy to ensure that investment is sufficient to meet the needs of society. Public policy must create additional incentives for private sector investment beyond those that naturally exist in the market to secure the investment necessary to meet broader societal objectives (stable climate) that would otherwise not be made. These policies will generally require the allocation of public and private resources by governments on behalf of the communities they represent.

All ASEAN Member States have made commitments to achieve net zero emissions by 2050 or 2060. Having set the achievement of net-zero emissions as one of many priorities or commitments, governments need to find the lowest cost solution. This can only be defined through the use of an appropriate model, such as the Global CCS Institute's Global Economic Net Zero Optimization (GENZO) model.

Assuming the central scenario modelled in this report (Accelerated Storage Scenario), 2Gtpa CO_2 must be captured in southeast Asia by 2060 to support net zero commitments. This will require almost US$880 billion to invested in CCS between now and 2065 across southeast Asia, peaking at over USD40 billion per year, on average, in the 2040s. However, this investment will reduce the overall cost to the region of meeting net zero commitments by more than US$20 trillion over the same period.

Mobilising this quantum of capital for CCS will require both public and private finance. The private sector has enormous financial resources, human capital and capabilities necessary for the development and operation of CCS projects. However, the private sector can only invest where there is an appropriate risk weighted return on that investment. Current experience from around the world demonstrates that significant public finance is necessary to leverage the private finance required to accelerate CCS investment.

Policies are required that align private investment incentives with public good investment incentives. This can be done through any combination of:

- Increasing the cost of emitting CO_2 (e.g. carbon taxes or emissions trading)
- Command and control mechanisms (e.g or prohibition or mandates through regulation)
- Reducing the cost to private sector investors of CCS (e.g. through capital grants or concessional finance)

- Increasing the revenue created through CCS (e.g. through payments per tonne of CO_2 stored or operational subsidies)

Of the 376 commercial CCS facilities in development, construction or operation in the Global CCS Institute's database, 254 are in the USA, Europe, the United Kingdom or Japan. A common factor across these leading jurisdictions is that public finance, whether through capital grants or operational subsidies or tax credits, is a critical enabler of the rapid growth in the CCS project pipeline. Even in Europe where carbon prices have approached and even exceeded Euro100 per tonne, CCS has required significant policy support including public financing to attract private sector investment.

In summary, the role of public finance in this phase of CCS deployment, where there is a requirement to accelerate investment well beyond what the market would deliver without intervention, is to de-risk private investment in CCS.

However, ASEAN countries' economic and political structure differs significantly from the US and the EU. ASEAN Member States, perhaps with the exception of Singapore, have far fewer resources available to allocate to climate change mitigation. Potential sources of external finance for CCS include multilateral development banks (World Bank Group, Asian Development Bank), international climate related funds and foreign direct investment from the governments of developed countries with climate related aid or investments in the region.

ASEAN members benefit from the considerable resources, experience and expertise of national and international oil companies that are active in the region. This industry has some of the lowest cost opportunities for very significant emissions reductions in their production value chain. For example, reservoir CO_2 which is currently vented to atmosphere, may instead be compressed ready for transport and geological storage after minimal clean up (e.g. dehydration).

The oil and gas industry also holds subsurface data from oil or gas exploration and production necessary to identify, appraise and develop pore space for the geological storage of CO_2 and has the technical expertise and knowledge necessary to establish and operate CO_2 transport and injection infrastructure. In some cases, existing infrastructure such as pipelines or offshore platforms may be utilised or re-tasked to support CCS operations, very significantly reducing the necessary capital investment.

These first projects, being developed in the 2020s, are likely to be the lowest cost opportunities for CCS projects and may also be the anchor projects for the establishment of CCS networks that will serve the broader needs of industry in the region seeking a carbon management solution. In the absence of a material carbon price, these first CCS projects in the region will likely require capital investment support to reach FID.

Investment in CCS in the 2030s must ramp up significantly to stay on track to achieve net-zero emissions targets, reaching an average of USD15.6 billion per year (Accelerated Storage Scenario) during this decade in southeast Asia. By this time, the global CCS industry will have accrued another decade of operational and commercial experience.

Business models, risk mitigation strategies, and commercial confidence will have matured. More providers of CCS technologies and services will have entered the market and the policy and regulatory environments in developed economies will probably have strengthened the business case for CCS. The European Carbon Border Adjustment Mechanism will be in force, effectively exposing exports to Europe to the ETS carbon price. Private sector finance will likely be more accessible and attract a much lower risk premium (if any) as the finance sector becomes familiar with CCS. The first CCS projects in southeast Asia will have commenced operations.

The top three sectors which must host capture projects in the 2030s include, in decreasing order of investment, bioenergy with CCS in industry, electricity generation, and refining. These capture projects will require access to CO_2 transport and storage infrastructure which will likely be provided, in the majority of cases through networks. The importance of investment in networks this decade is clear from the GENZO model (Accelerated Storage Scenario). From GENZO, of the USD155 billion required to be invested in CCS in the region in the 2030s, over USD73 billion is required for CO_2 transport and storage including shipping, pipelines and geological storage development. This infrastructure is essential to enable the region to reach its net zero targets.

In the 2040s, as operational experience accumulates and networks are established in the region, government can shift from a capital subsidy policy model toward supplemental loan guarantees to lower the cost of private finance as the private sector takes a more active role. Government can gradually remove loan guarantees as the private sector gains confidence in lending for CCS projects and as the CO_2 price signal goes higher, making CCS projects more and more cost-effective.

Recommendations

A phased approach to driving investment in CCS is recommended.

<u>Phase 1 – First Projects; 2020s</u>

- The oil and gas industry is studying several CCS projects in the ASEAN region that share a common strategy; establish CCS infrastructure to enable the reinjection of their own reservoir CO_2, and explore opportunities to receive third party CO_2 for storage for a fee. Establishing the first CCS projects and their infrastructure to kickstart CCS deployment in the region this decade and lay the foundations for broader CCS deployment should be a priority for government climate policy in the region.
- Where the developer of a CCS project is a National Oil Company, government should consider supporting the financing of the CCS project off the company's balance sheet. This will necessarily require government to accept a reduced return from the NOC for a period. This represents, in effect, government investment in the establishment of CCS infrastructure that will deliver a return in the future.

- Government should put in place a proactive strategy to identify and obtain sources of external finance that could support these first CCS projects. This could be provided in the form of grants or concessional loans or loan guarantees. Sources to consider include the World Bank Group, the Asian Development Bank, the Green Climate Fund and developed countries with climate aid programmes or climate - related investments in the ASEAN region such as Japan, Australia, and the USA. Multilateral initiatives focused on CCS such as the Carbon Management Challenge which has an explicit objective of supporting carbon management efforts in the Global South (Clean Air Taskforce, 2023) should also be actively engaged.
- Government should consider the provision of targeted low-cost loans, capital grants or operational subsidies to CCS projects to bridge any remaining finance gap and allow developers to reach FID. Public finance could be awarded on a competitive basis to ensure funds are allocated and utilised efficiently.
- Governments should commence the development and implementation of carbon pricing schemes, starting at low prices for the least developed ASEAN economies, but with announced plans to increase the price in the future. Even at low prices of a few dollars per tonne of CO_2, carbon pricing, if applied broadly across the economy, could generate hundreds of millions of dollars of revenue for each government which could then be used to support climate mitigation initiatives, including CCS. These schemes will also set a clear expectation in the market of more stringent future climate policies and higher carbon prices that will incentivise increased analysis of CCS opportunities, entrepreneurial activity and CCS project development.

Phase 2 – CCS Network Establishment and Deployment Ramp-up; 2030s

- In the 2030s, Governments should aim to facilitate investment in the next wave of CCS projects especially where they leverage the infrastructure developed by the first wave of CCS projects.
- Governments should prioritise investment in additional CO_2 transport and storage infrastructure, including shipping necessary to establish CCS networks that will reduce the overall cost of CCS, and emissions mitigation, in the region. This will require continued development of carbon pricing programs (carbon price should continue to rise), continued engagement with multilateral development banks and other potential sources of external finance, and continued provision of targeted capital support.
- Governments should increase international collaboration and regional cooperation and proactively seek to facilitate investment in geological storage resource development and CCS networks.
- In addition to leveraging CO_2 transport and storage infrastructure that has been constructed in the 2020s to service the first CCS projects, Governments should

deliberately target specific opportunities to create CO_2 collection hubs to service regions with significant emissions intense industry, to support the next wave of investment in CO_2 capture projects.

Phase 3 – CCS Industry Maturity; 2040s and beyond

- During this decade, governments should achieve material carbon prices that are sufficient to drive investment in CCS, and all other climate mitigating technologies, with little or in some cases no public finance or policy support. The capital investment required for CCS in the region peaks in the 2040s at an average on over USD40 billion per year. Investment at this scale will only be possible with full private sector engagement.
- In the 2040s Governments should look for opportunities to facilitate private sector investment in CCS investments that are commercially viable without significant public finance. One potential opportunity will likely be the production of low carbon hydrogen and its derivatives.