

Unlocking the Potential of Carbon Capture and Storage (CCS) in Indonesia

Socio-Technical and Governance Readiness Perspectives

Vicky Wijaya



Cover: gettyimages: AerialPerspectives Works

Unlocking the Potential of Carbon Capture Storage (CCS) in Indonesia

Socio-Technical and Governance Readiness
Perspectives

by

Vicky Wijaya

Student ID: 5795427

To obtain the degree of Master of Science in Management of Technology (MSc)
at the Delft University of Technology,

Chair Committee : Dr. Linda M. Kamp (E&I Department)
First Supervisor : Dr. Gideon Ndubuisi (ETI Department)
Second Supervisor : Dr. Ir. Samantha Eleanor Tanzer (E&I Department)

Technology, Policy, and Management Faculty
Delft University of Technology



Growing up in a country with a high gap in education access, pursuing knowledge is a big privilege. My master's study at TU Delft allowed me to explore and extend my learning capabilities, including this thesis, which was culminated through a curiosity: how to leverage Indonesia's resource richness to advance its economy and strengthen its position on the global stage.

This thesis became more than an academic pursuit. It taught me resilience and determination, especially as I walked through moments of deep personal loss of people whom I deeply love, including the passing of my beloved mother. I really thank God for giving me the strength that carried me forward and kept pushing myself while dealing with grief. His blessing reached me through the love and kindness of the people around me

I am deeply grateful to the committee, all supervisors, and the chair, whose guidance sharpened my thinking and expanded my perspective. Thank you for showing me the passion to learn and always believing in my capabilities to finish this thesis with strong determination. These motivate me even stronger to unlock my learning capabilities and make this journey more meaningful.

To my wife, thank you for always being my strength—your prayers, love, and unwavering support are the foundation beneath every step I take. The journey of completing this thesis becomes easier and more beautiful to remember because of your prayers and support.

Finally, I want to thank Indonesia Endowment Fund for Education (LPDP) for believing in my potential and supporting my studies, and to all stakeholders who generously contributed their time to provide meaningful direction for this thesis.

For everyone who walked with me on this journey at TU Delft, thank you. Your presence shaped both the thesis and the person behind it.

*Vicky Wijaya
July, 2025*

Carbon Capture and Storage (CCS) is increasingly recognized as a potential solution for deep decarbonization from hard-to-abate sectors with minimum disruption to carbon-intensive economic development. Indonesia represents this case as carbon intensive dominated developing economy with high carbon emissions. Indonesia has recently emerged as one of the most active CCS developers within the Asia-Pacific region, supported by abundant geological storage potential, growing regional market opportunities, and government ambitions to position Indonesia as a future regional storage hub. Despite this interest, large-scale CCS implementation remains uncertain due to complex technological, governance, and socio-political challenges. Existing studies highly focus on technological feasibility or economic aspects, while limited attention is given to the broader socio-technical and governance conditions that shape CCS implementation in Indonesia. This study, therefore, investigates how CCS can be accelerated in Indonesia as a cross-sectoral national climate mitigation initiative through socio-technical and governance perspectives. The main objective of the research is to identify socio-technical challenges and implementation gaps as well as provide strategic interventions to accelerate CCS implementation beyond the demonstration phase.

To achieve the objective, the research combined Multi-Level Perspective (MLP) analysis, CCS governance readiness assessment, and a diagnostic intervention framework. This study adopted a qualitative approach combining desk study and semi-structured stakeholder interviews. Data were collected through literature review, policy document analysis, institution reports, media coverage, and semi-structured interviews with stakeholders from government, CCS adopters, knowledge actors, and potential CCS adopters.

The findings show that Indonesia's CCS ecosystem is currently dominated by oil and gas actors, with the Ministry of Energy and Mineral Resources (MEMR) as the central coordinating authority. Dedicated CCS institutions such as the Centre of Excellence CCS/CCUS at Institut Teknologi Bandung (CoE-ITB) and the Indonesia CCS Centre (ICCSC) are established to strengthen knowledge development and stakeholder coordination. However, despite the high potential usage of CCS in other high-emitting sectors, cross-sectoral participation remains limited. International organizations also contribute to intergovernmental alignment within Southeast Asian countries and CCS feasibility studies funding support, while public involvement is relatively weak and largely procedural.

From a socio-technical perspective, CCS implementation in Indonesia is currently situated between niche experimentation and early regime formation, where the technology is introduced within the current fossil fuel regime. Global climate pressure, regional carbon market opportunities, and growing decarbonization commitments function as landscape pressure for CCS implementation. However, deployment remains strongly embedded within Indonesia's fossil fuel regime as CCS introduction through the oil and gas sector is perceived as effective to deal with increasing regional market competition. Indonesia's existing CCS implementation reflects a mechanism to maintain economic competitiveness and support the oil and gas sector rather than transformative climate mitigation. Additionally, the domestic motivation for low-carbon project development remains weak. As a result, implementation remains concentrated within incumbent oil and gas sectors and is highly dependent on international market demand. This creates a high barrier for other high emitters to participate and vulnerabilities to geopolitical dynamics.

The governance readiness assessment reveals that Indonesia has established relatively strong CCS-specific regulations and is acknowledged as advanced among developing countries. However, governance readiness remains uneven. Important gaps remain in long-term liability allocation, standardized site closure, monitoring and verification, legal classification of CO₂, cross-border mechanisms, and public participation. Current governance mechanisms primarily focus on attracting investment and accelerating early deployment through specific sectors, while long-term stewardship responsibilities and risk governance arrangements remain insufficiently developed. Although its role in decarbonization is acknowledged, CCS is weakly mentioned within the national development plan and long-term climate efforts, mainly due to fragmented institutional understanding. Given the weak low-carbon investment ecosystem, the existing CCS governance structure further reinforces the oil-and-gas path dependency, limiting broader integration of CCS into national decarbonization strategies through cross-sectoral applications.

By combining socio-technical and governance readiness analysis, the study identifies socio-technical challenges that are subsequently mapped into CCS vision disruptors, short-term barriers, and long-term barriers. Key vision disruptors include fragmented governance direction, regime lock-in around the oil and gas sector, weak decarbonization motivation, and political discontinuity. Short-term barriers include operational governance uncertainty, a weak economic ecosystem, limited niche learning and infrastructure development, and institutional inertia. Long-term barriers concern governance continuity, economic resilience, and sustained legitimacy.

To address these barriers, the study proposes strategic interventions at both national and corporate levels. At the national level, priority interventions include formalizing CCS coordination through inter-ministerial mechanisms, embedding CCS within national development and climate strategies, strengthening carbon pricing and industrial obligations to reduce emissions, improving governance frameworks, standardizing CCS operation and monitoring, expanding research and development support beyond specific sectors, and developing integrated CCS infrastructure to lower entry barriers for non-oil-and-gas actors. At the corporate level, interventions focus on strengthening low-carbon business development, adopting more adaptive and innovation-oriented organizational cultures, institutionalizing knowledge development, enhancing cross-sector collaboration, and improving stakeholder engagement business practices.

This research contributes analytically by integrating socio-technical theory, governance readiness assessments, and diagnostic intervention design into a comprehensive diagnostic tool for identifying barriers and designing strategic interventions for CCS implementation. The approach demonstrates how governance conditions, institutional dynamics, and socio-technical factors interact to shape technology transitions. Practically, the study provides policy and strategic recommendations for accelerating CCS deployment in Indonesia, moving from niche demonstration to market scaling. More broadly, the study contributes to global discussions on CCS governance in developing countries by highlighting the importance of institutional capacity, policy coherence, long-term stewardship arrangements, and cross-border governance mechanisms in enabling large-scale CCS deployment as a climate mitigation.

Keywords: CCS, socio-technical, governance, implementation barriers, strategic intervention, climate mitigation

Contents

Acknowledgement.....	iv
Executive Summary	v
Table Contents	vii
List of Figures.....	xi
List of Table.....	xii
Nomenclature	xiii
1. Introduction	1
1.1 Background.....	1
1.2 Problem Statement	2
1.3 Research Objectives and Research Questions	4
1.4 Research Scope.....	4
1.5 Research Contribution	5
1.6 Management of Technology (MoT) relevance	5
1.7 Research Outline	5
2. Literature Review.....	6
2.1 Literature Review Approach	6
2.2 Global Experience with CCS Implementation	7
2.2.1 CCS Global Status.....	7
2.2.2 Learning from Commercial CCS Projects	8
2.2.3 Learning from CCS Project Failures	10
2.2.4 CCS Implementation in Developing Countries.....	11
2.3 Socio-Technical Challenges in CCS Implementation	12
2.4 Governance of CCS Implementation.....	12
2.5 Knowledge Gap and Research Positioning	14
3. Methodology and Theoretical Framework	16
3.1 Research Design.....	16
3.2 Theoretical Framework.....	18
3.2.1 Socio-technical Analysis Using the Multi-Level Perspective (MLP)	18
3.2.2 Governance Readiness Framework.....	20
3.2.3 Integrating Governance Readiness into MLP	23
3.2.4 Diagnostic Intervention Framework.....	24
3.3 Data Collection Approach	26

3.3.1	Desk Study Analysis.....	26
3.3.2	Stakeholder Interviews	27
3.4	Data Analysis	28
3.4.1	Interview Analysis: Text-Coding	28
3.4.2	Validity and Reliability.....	28
4	Socio-Technical Conditions of CCS Implementation in Indonesia.....	30
4.1	Actors and Network.....	30
4.2	Landscape-Level Pressures for CCS in Indonesia	33
4.2.1	Global Climate Governance and Decarbonization Pressure	33
4.2.2	Indonesia's National Development Priorities	35
4.2.3	Weak Sustainable Finance and Investment Ecosystem	36
4.2.4	Political-Economic Contestation in Decarbonization Policy	37
4.3	Regime-Level Conditions of CCS Deployment in Indonesia	38
4.3.1	Production-Oriented Energy Regime and CCS Development.....	38
4.3.2	Weak Carbon Pricing and Economic Incentive Structure	39
4.3.3	Fragmented Societal and Institutional Understanding of CCS.....	41
4.3.4	Regulatory Institutionalization for CCS Development.....	42
4.4	Niche-Level Development of CCS in Indonesia	43
4.4.1	Expansion of CO ₂ Storage Exploration Activities	43
4.4.2	Early CCS Project Implementation within the Oil and Gas Sector	44
4.4.3	International Collaboration and Regional Storage Hub Development	45
4.4.4	Increasing Cross-Sectoral Research Interest Beyond the Oil and Gas Sector.....	46
4.4.5	Development of Dedicated Knowledge and Coordination Networks	47
4.5	Socio-Technical Transition of Indonesia's CCS.....	48
5	Governance Readiness of CCS Implementation in Indonesia.....	50
5.1	Legal Foundations for CCS Deployment	50
5.1.1	Existence of CCS-Specific and Supporting Regulations	50
5.1.2	Authorization and Storage Rights Clarity	51
5.1.3	Clarity on CO ₂ Classification and Ownership	52
5.1.4	Inclusiveness of Actor Eligibility	53
5.2	State Capacity and Institutional Alignment.....	54
5.2.1	Inter-Agencies Coordination and Authority Alignment	54
5.2.2	Policy Integration and Strategic Coherence.....	55
5.2.3	Institutional Capacity and Adaptability	57
5.2.4	Alignment with National Decarbonization.....	58

5.3	Risk and Liability Governance.....	59
5.3.1	Liability Allocation of Long-Term Stewardship	59
5.3.2	Operational Liability and Financial Assurances.....	60
5.3.3	Measurement, Monitoring, and Verification (MMV) Governance	60
5.3.4	Contingency Planning for Carbon Leakage and Failure	61
5.4	Knowledge Development and Public Participation	62
5.4.1	Transparency and Accessibility of CCS Information	62
5.4.2	Stakeholder Engagement Governance.....	62
5.4.3	Knowledge Governance and Institutional Learning.....	63
5.4.4	Public Participation in CCS Development Process.....	63
5.5	Corporate Governance for Supporting CCS as Climate Mitigation	64
5.5.1	Low Carbon Business Development Governance	64
5.5.2	Internal CCS Knowledge Development and Innovation	65
5.6	Governance Readiness Overall Assessment	67
6	CCS in Indonesia: Barriers and Implementation Gaps.....	70
6.1	Socio-Technical Challenges	70
6.2	CCS Vision Disruptors.....	71
6.3	CCS Short-term Barriers.....	73
6.4	CCS Long-term Barriers	74
7	Strategic Interventions in CCS Deployment Acceleration	76
7.1	Strategic Pathways to Enhance CCS Vision.....	76
7.2	Strategic Interventions for Short-Term CCS Acceleration.....	78
7.2.1	National-Level Strategic Interventions	78
7.2.2	Corporate-Level Strategic Interventions.....	81
7.3	Strategic Interventions for Long-Term CCS Implementation	86
8	Discussions	88
8.1	Synthesis of Findings.....	88
8.2	Socio-Technical Dynamics Shaping CCS Trajectories	89
8.3	Strategic Tension Between Decarbonization and Fossil Fuel Expansion	90
8.4	Feasibility and Risk of Proposed Strategic Interventions.....	91
9	Conclusion	92
9.1	Conclusion to sub-research questions	92
9.2	Conclusion to main research question	94
9.3	Research Contribution	95
9.4	Reflection.....	96

9.5	Research Limitation	96
9.6	Future Research Directions	97
	References	98
	Appendix A: Carbon Capture Storage.....	109
	Appendix B: Socio-Technical Analysis.....	114
	Appendix C: Indonesia’s CCS Governance Structure	117
	Appendix D: Barriers.....	123
	Appendix E: Interview Analysis	125
	Appendix F: Interview Protocol.....	130
	Appendix G: Artificial Intelligent (AI) Reflection.....	135

Figure 1. Indonesia's emission as the sixth-largest emitter worldwide (left) and energy landscape (right).....	2
Figure 2. Indonesia's CCS projects and target plans	3
Figure 3. PRISMA approach for literature review	6
Figure 4. Global CCS operation in 2025	7
Figure 5. CCS/CCUS facilities status by number and capture capacity	8
Figure 6. Regulatory considerations for CCS implementation	13
Figure 7. Research workflow diagram	17
Figure 8. Multi-level perspective framework on technology transition	19
Figure 9. Governance readiness framework for CCS implementation	21
Figure 10. Governance readiness framework embedded in MLP framework	24
Figure 11. Strategic Interventions development process	25
Figure 12. Network of actors within CCS systems in Indonesia	31
Figure 13. Market potential for Indonesia as regional storage hub.....	34
Figure 14. CCUS-Enhanced Oil Recovery (EOR) process compared to standalone CCS	38
Figure 15. CCS economic comparison between Indonesia and Norway	40
Figure 16. Indonesia key regulatory frameworks for carbon pricing mechanisms	40
Figure 17. Indonesia regulatory framework for CCS	42
Figure 18. CO ₂ storage distribution of Indonesia sedimentary basin 2024.....	43
Figure 19. The current phase of CCS technology transition in Indonesia	48
Figure 20. Socio-technical conditions mapping of CCS in Indonesia.....	49
Figure 21. Permit types in Indonesia's CCS regulatory framework.....	51
Figure 22. Carbon pricing options for Indonesia's low carbon projects	56
Figure 23. Carbon trading options in IDX Carbon.....	56
Figure 24. Corporate governance summary for low-carbon projects	67
Figure 25. Governance readiness overall comparison	68
Figure 26. Governance readiness of Indonesia within the MLP framework	69
Figure 27. Vision disruptors interconnection and influence on Indonesia's CCS vision	72
Figure 28. Short-term barriers interconnection and influence on Indonesia's CCS adoption.....	74
Figure 29. CCS Value Chain Illustration and key technological options on each chain.....	109
Figure 30. Research design for the study	113
Figure 31. An overview of the diagnostic intervention and its link to the strategic planning process	113

Table 1. Integrated commercial CCS projects in operation	9
Table 2. Key vulnerabilities exploration steps to identify CCS deployment barriers	25
Table 3. Strategic Intervention Development for CCS acceleration	25
Table 4. Literature search process used for socio-technical challenges assessment in this study	26
Table 5. Stakeholders involved in interviews	27
Table 6. Code book used for deductive text-coding as an initial guide	29
Table 7. CCS/CCUS project status in Indonesia in 2026	44
Table 8. Socio-technical challenges of CCS Implementation in Indonesia.....	70
Table 9. Long-term Barriers of CCS Implementation in Indonesia	75
Table 10. Strategic Interventions to address CCS vision disruptors.....	79
Table 11. National-Level strategic interventions to address short-term barriers.....	83
Table 12. Corporate-Level strategic interventions to address short-term barriers.....	84
Table 13. Strategic interventions for long-term barriers	87
Table 14. Health effects of increased CO ₂ concentration	110
Table 15. Recommended quality of CO ₂ stream in CCS pipeline transport	110
Table 16. Governance readiness operationalization	112
Table 17. Actors associated with CCS implementation in Indonesia.....	114
Table 18. Multi-level perspective analysis for CCS implementation in Indonesia	115
Table 19. WIPK offering mechanisms to business entities.....	117
Table 20. Differences between PSC and WIPK scheme in CCS Permit System	119
Table 21. CCS operator obligation and financial incentives schemes.....	120
Table 22. MMV governance in Indonesia's CCS frameworks	121
Table 23. Indonesia's CCS risk mitigation obligations	122
Table 24. Indonesia site Closure guidelines	122
Table 25. Vision Disruptors of CCS Implementation in Indonesia.....	123
Table 26. Short-term Barriers of CCS Implementation in Indonesia	124
Table 27. Final code book for interview analysis with total frequency	125
Table 28. Code grouping for the text-analysis	128
Table 29. Stakeholder grouping for text-analysis	129
Table 30. Text-coding matrix between code groups and stakeholder groups.....	129

Abbreviation	Description
ADB	Asian Development Bank
AMDAL	Environmental Impact Assessment <i>Analisis Mengenai Dampak Lingkungan Hidup</i>
ASEAN	The Association of Southeast Asian Nations
BAU	Business as Usual
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilization, and Storage
CMEA	Coordinating Ministry of Economic Affairs
CMFA	Coordinating Ministry of Food Affairs
CoE-ITB	Centre of Excellence for CCS/CCUS
DAC	Direct Air Capture
EGR	Enhanced Gas Recovery
EOR	Enhanced Oil Recovery
ETS	Emissions Trading Systems
FEED	Front-End Engineering Design
GCF	Green Climate Funding
GHG	Greenhouse Gas
GoI	Government of Indonesia
ICCSC	Indonesia Carbon Capture and Storage Centre
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JOGMEC	The Japan Organization for Metals and Energy Security
JSA	Job Safety Analysis
LNG	Liquefied Natural Gas
LoI	Letter of Intent
LTS-LCCR	Long-Term Strategy for Low Carbon and Climate Resilience
MEF	Ministry of Environment and Forestry
MEMR	Ministry of Mineral and Energy Resources
MF	Ministry of Finance
MHEST	Ministry of Higher Education, Science, and Technology
MIDI	Ministry of Investment and Downstream Industry
MLP	Multi-Level Perspective
MMAF	Ministry of Maritime Affairs and Fisheries
MMV	Measurement, Monitoring, and Verification
MNDP	Ministry of National Development Planning
MoI	Ministry of Industry
MOT	Ministry of Transportation
MRV	Measurement, Reporting, and Verification
MSOE	Ministry of State-Owned Enterprises
Mtpa	Million tonnes per annum

Abbreviation	Description
NDC	Nationally Determined Contribution
NDPA	National Development Planning Agency
NGO	Non-Governmental Organization
OJK	<i>Otoritas Jasa Keuangan</i> – Financial Services Authority
OPEX	Operational Expenditure
POD	Plan of Development
RPJMN	<i>Rencana Pembangunan Jangka Menengah Nasional</i> Medium-term National Development Planning
RPJPN	<i>Rencana Pembangunan Jangka Panjang Nasional</i> Long-term National Development Planning
SATGAS TEH	Energy Transition and Green Economy Task Force <i>Satuan Tugas Transisi Energi dan Ekonomi Hijau</i>
SOEs	State-Owned Enterprises
SRN-PPI	National Climate Change Control Registry System <i>Sistem Registri Nasional Pengendalian Perubahan Iklim</i>
SRUK	National Registry for Carbon Unit <i>Sistem Registri Unit Karbon</i>
WIPK	Carbon Storage Permit Areas <i>Wilayah Izin Penyimpanan Karbon</i>
ZTI	Injection Target Zone <i>Zona Target Injeksi</i>

Introduction

1.1 Background

Growing climate pressure requires limiting global warming below 2°C by 2100, where CO₂ concentrations should be below 450 ppm. Yet CO₂ concentration had already reached 94% of this threshold by 2024, highlighting the urgency of accelerating global decarbonization (IEA, 2025b; IPCC, 2023). Among the portfolio of mitigation technologies, Carbon Capture and Storage (CCS) has been widely recognized as a critical solution for large-scale emission reduction, especially from carbon-intensive sectors such as fossil fuel energy production, cement, steel, and petrochemical industries, where low-carbon options remain limited or economically challenging. This technology captures CO₂ directly from resources, transports it to the geological storage sites, and the carbon is then stored permanently in subsurface pores (IEA, 2020; Kuckshinrichs & Hake, 2015; Ma et al., 2022; Sara et al., 2015)¹. According to Peters et al (2017), achieving the target of below 2°C would require approximately 4000 Mtpa-CO₂ to be stored through CCS by 2050, highlighting the strategic role of CCS in global climate mitigation.

Despite international recognition and more than three decades of technology development, the global deployment of CCS remains substantially below the level expected to meet the climate target. According to the Global Institute (2025), global operational CCS capacity reached only 64 Mtpa in 2025, which accounts for approximately only 1.6% of the required capacity by 2050. Additionally, existing CCS operations are concentrated within developed economies such as Canada, Europe, the USA, and Australia and remain dominated by enhanced oil recovery (EOR) for hydrocarbon enhancement rather than permanent emissions mitigation (Global CCS Institute, 2025; Peters et al., 2017). This significant gap between the recognized importance of CCS and its actual adoption shows that the challenges are complex and extend beyond technological maturity.

These challenges are particularly evident in developing countries, where CCS is increasingly viewed as a promising pathway to progress climate mitigation without major disruption to carbon-intensive economies. Emerging economies such as Indonesia, China, South Africa, India, and Brazil exhibit high geological storage potential while continuing to rely heavily on hard-to-abate industrial sectors (Ibe & Nwosi-Anele, 2024; Ko et al., 2021; H. Liu, 2011; Ramadhan et al., 2024; Shirmohammadi et al., 2020). These combinations position CCS as a way to balance both climate

¹ See Appendix A (section A.1) presents a value chain perspective on CCS

efforts and existing economic development. Despite this potential, CCS is predominantly still limited to demonstration projects in these countries.

Evidence from global commercial CCS projects highlights that successful deployment depends not only on technological advancement but also on sustained funding, robust regulatory frameworks, and effective governance structures (Ma et al., 2022; Markusson et al., 2012; Saxena et al., 2024; Shirmohammadi et al., 2020). This emphasizes that technology readiness alone is insufficient to increase technology adoption. Instead, commercial scaling requires coordinated socio-technical aspects and strong institutional arrangements. While many CCS studies emphasize the importance of socio-technical factors in CCS deployment (Markusson et al., 2012; Osazuwa-Peters & Hurlbert, 2020; Pihkola et al., 2017; Van Alphen et al., 2010; Wilson et al., 2009), governance arrangement aspects remain underexplored. The governance challenges become even more pronounced in the developing-country context where CCS implementation is constrained by the absence of established markets, evolving regulatory frameworks, and strong dependence on state support. (Abdullah et al., 2021; Ko et al., 2021; Mascarenhas et al., 2019). Existing studies in the developing-country context, including Indonesia, predominantly focus on isolated dimensions, such as technical readiness, cost estimation, public perception, or regulatory gaps (Adisaputro & Saputra, 2017; Araújo, 2021; Ha-Duong & Nguyen-Trinh, 2017; Ibe & Nwosi-Anele, 2024; A. A. Putra et al., 2018; A. D. Setiawan & Cuppen, 2013; L. Yang et al., 2016). While these studies are valuable, they lack an understanding of how broader institutional and governance dynamics shape the transition from demonstration stage to commercial scaling.

1.2 Problem Statement

Under increasing pressure from climate change, developing countries struggle to balance economic growth and emission mitigation, particularly where carbon-intensive economies are central to national development. Although CCS is increasingly recognized as a large-scale emission reduction while keeping carbon-intensive economies growing, its large-scale deployment in developing countries remains limited and uncertain (IEA, 2020).

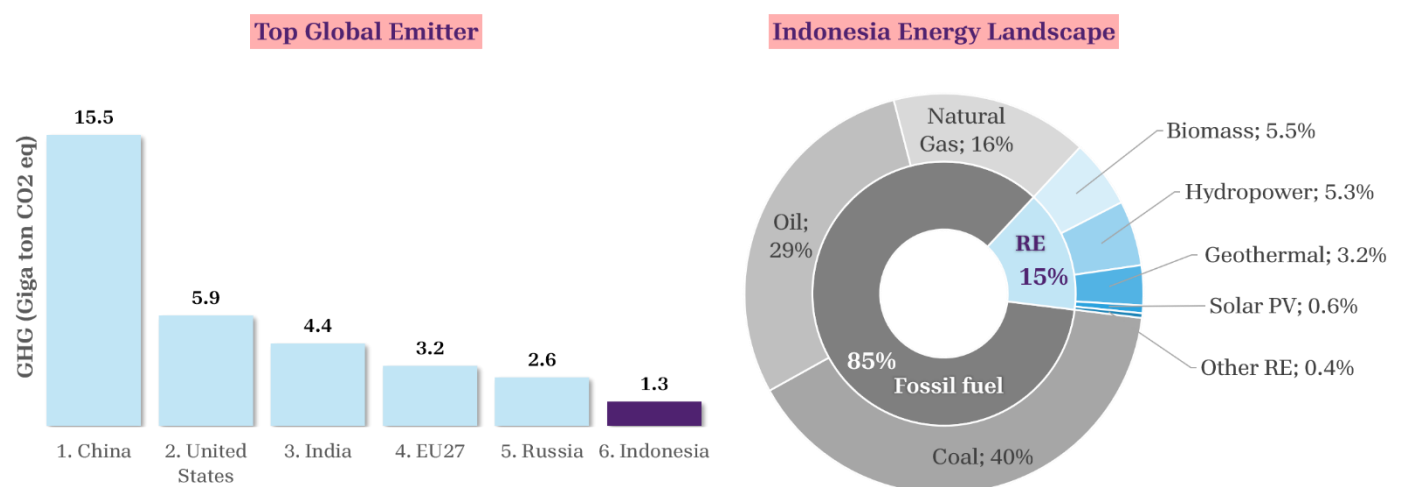


Figure 1. Indonesia's emission as the sixth-largest emitter worldwide (left) and energy landscape (right)

Source: adapted from (IESR, 2025; JRC, 2025; MEMR, 2025a)

Indonesia represents a particularly relevant case, as it is among the world's sixth-largest CO₂ emitters, reaching 1.3 Gt-CO₂eq in 2024 (see Figure 1) while remaining dependent on carbon-intensive sectors (IESR, 2025; Shah et al., 2024). Indonesia's energy production largely relies on fossil fuels; approximately 85% of national energy demand is supplied by oil, gas, and coal-based technologies (see Figure 1), limiting the pace at which deep decarbonization can be achieved through renewable energy alone. Recognizing this, Indonesia has identified CCS as a promising strategy to reach committed emission reduction targets, given the country's high potential in geological storage reaching 573 Gt-CO₂, combining both saline aquifers and depleted oil and gas reservoirs (MEMR, 2024a; Ramadhan et al., 2024).

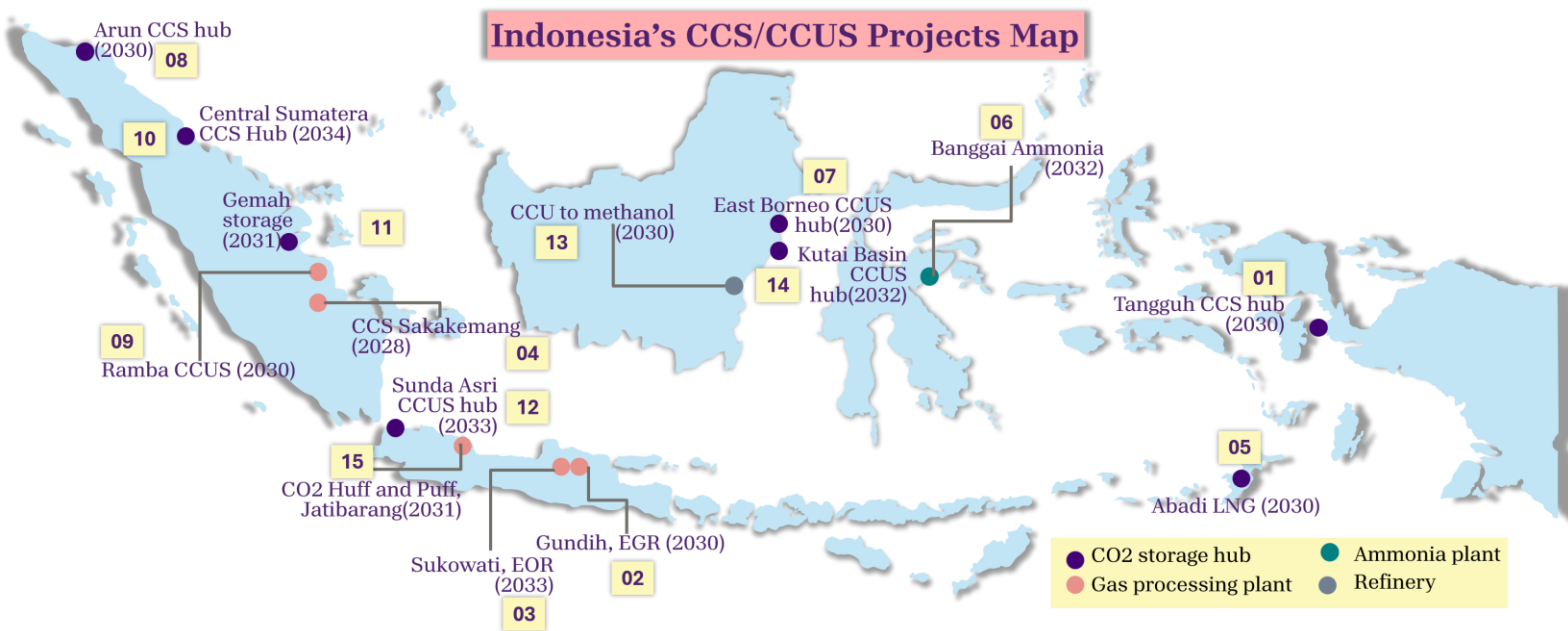


Figure 2. Indonesia's CCS projects and target plans

Source: synthesized from (Bloomberg, 2026; CoE-ITB, 2024; Pertamina, 2026; Ramadhan et al., 2024)

Indonesia has signalled strong policy ambition to develop CCS projects as its climate strategy. The Ministry of Energy and Mineral Resources (MEMR) has announced 15 projects associated with CCS and Carbon Capture, Utilization, and Storage (CCUS) targeted for implementation before 2035 (see Figure 2), many of which are developed through domestic-international partnerships involving states and private industry actors (IEA, 2023; Ramadhan et al., 2024). However, the country's readiness to support deployment of CCS as a large-scale and high-risk technology remains unclear. Currently, the implementation of CCS in Indonesia is largely situated in the demonstration phase, with limited market signals highlighting the urgency to develop strategic interventions to advance CCS beyond the niche experimentation stage. Existing studies (Adisaputro & Saputra, 2017; Amelinda & Soekarno, 2023; A. A. Putra et al., 2018; Ramadhan et al., 2024) demonstrate Indonesia's technical feasibility and geological storage potential for CCS but provide limited insights into socio-technical and governance dimensions in shaping CCS trajectories in Indonesia. There remains limited understanding of how socio-technical factors and governance readiness shape the transition of the CCS system from early development to commercial-scale development in emerging economies such as Indonesia. This gap is particularly important because CCS in developing countries remains formative and depends heavily on governance arrangements to coordinate actors, ensure regulatory frameworks, mobilize investment, and facilitate technological learning. Addressing this gap can help to identify key barriers and enablers of CCS development and provide strategic interventions for technology deployment acceleration.

1.3 Research Objectives and Research Questions

The main objective of this study is to investigate socio-technical and governance conditions influencing the development of CCS in Indonesia and to identify key barriers and implementation challenges affecting the CCS transition from demonstration to large-scale deployment. Building on these challenges, the study aims to propose strategic interventions that can accelerate cross-sectoral CCS implementation in Indonesia as a national emission reduction strategy. Additionally, this research aims to contribute to the broader understanding of CCS implementation in emerging economies.

To achieve the objective, the following research questions are formulated.

Main research question:

How can the deployment of Carbon Capture and Storage (CCS) be accelerated as a cross-sectoral national climate strategy in Indonesia?

To answer the question, several sub-questions are synthesized as follows:

Sub-research questions:

1. What actors are involved in Indonesia's CCS development, and what roles and relationships characterize the current actor network of CCS implementation?
2. What socio-technical conditions shape the existing development phase of CCS in Indonesia?
3. What governance conditions enable or constrain the development of CCS in Indonesia from demonstration level to large-scale implementation?
4. What strategic interventions could accelerate the deployment of CCS in Indonesia at national-level and corporate-level?

1.4 Research Scope

This research examines the implementation of CCS in Indonesia to understand technology dynamics in a developing-country context. This study focuses specifically on standalone CCS as climate mitigation. However, the distinction between standalone CCS and CCUS, particularly application for enhanced-oil recovery (EOR) and enhanced-gas recovery (EGR), is not always explicit in policy documents and industrial practice. In Indonesia, regulatory frameworks, national strategies, government discourses, and project development frequently address CCS and CCUS jointly. Therefore, while the analytical focus is on standalone CCS for climate mitigation, relevant CCUS policies, documents, and initiatives are included to understand broader technology dynamics in shaping CCS implementation. The study adopts socio-technical and governance perspectives to investigate factors influencing the scaling of CCS development. This study does not assess the technical feasibility or economic viability through engineering or economic modelling. Instead, it focuses on understanding how socio-technical factors and governance structures shape the development and scaling of CCS. Empirically, the study is limited to Indonesia's context, where the economy remains highly reliant on carbon-intensive sectors. The study investigates socio-technical challenges and key barriers affecting CCS implementation as well as provides strategic interventions at both national and corporate levels to accelerate broader CCS deployment.

1.5 Research Contribution

Theoretically, this study advances CCS transition research by highlighting governance conditions as a critical enabling condition within socio-technical transition pathways. Notably, it shows how institutional arrangements, policy coordination, and actor alignment influence the acceleration of CCS technology as a national decarbonization strategy. The study also proposed and used an integrated diagnostic tool to identify socio-technical challenges for large-scale and high-risk technology, CCS. Building on this, the study identifies systemic vulnerabilities within the CCS system, including technology vision disruptors, short-term barriers, and long-term barriers that could slow the adoption of CCS technology.

Empirically, Indonesia serves as a critical case for examining CCS implementation in a developing country context. The country presents a unique combination of high geological storage potential, strong ambition for CCS deployment, and high reliance on carbon-intensive energy systems. However, the implementation of CCS is largely situated at an early stage and depends on regulatory developments, institutional capacity building, and government coordination. These characteristics make Indonesia an analytically valuable case for understanding how governance and socio-technical factors shape CCS implementation in the context where market signals and infrastructure development are still evolving. While the findings are grounded in Indonesia's context, the analytical framework developed in this study can inform future comparative CCS governance studies in other developing-country contexts. Practically, the findings of this study reveal structured system vulnerabilities and the development of strategic interventions required at the national policy-level and corporate-level to accelerate CCS deployment, offering policy and business insights for CCS stakeholders.

1.6 Management of Technology (MoT) relevance

This research aligns closely with the objectives of Management of Technology (MoT) because it examines CCS development as a socio-technical challenge beyond technological performance, involving interaction of technology, institutions, market, and multiple stakeholders. By analysing socio-technical conditions and governance readiness, the study identifies system vulnerabilities and develops strategic interventions to accelerate CCS technology implementation beyond niche experimentation. The study reflects MoT program focus on understanding technology dynamics and managing complex innovation systems with multi-actor interaction. The study advances understanding of technology management within complex innovation systems and low-carbon technology transition. Also, it provides relevant insights for policymakers and business players in accelerating CCS technology as a decarbonization pathway.

1.7 Research Outline

The remainder of this study is structured as follows. **Chapter 2** discusses background knowledge on CCS implementation, building on insights from global CCS experiences, socio-technical and governance studies. **Chapter 3** includes research methodology and theoretical frameworks used to guide the study. **Chapter 4** reveals actors and networks within the CCS system and existing socio-technical conditions of Indonesia's CCS. **Chapter 5** discusses governance readiness assessment. Building on Chapter 4 and 5, **Chapter 6** identifies CCS vision disruptors and barriers, while **Chapter 7** provides strategic interventions to address these barriers. Finally, **Chapter 8** is discussions of broader implications of the study findings, and **Chapter 9** presents the conclusion.

Literature Review

2.1 Literature Review Approach

This study adopts the PRISMA framework to identify relevant studies for CCS implementation and to understand the literature gaps. Figure 3 outlines the sequential steps used to select studies for the literature review. The review focuses on four key areas: (1) Carbon Capture and Storage (CCS) implementation and challenges, (2) the socio-technical dimensions of CCS adoption, (3) governance of CCS technology, and (4) CCS implementation in developing countries. The selected studies provide insights about CCS global implementation for both successful and operationally constrained projects. The studies also highlight the socio-technical challenges associated with CCS implementation. In addition, the review examines CCS as a climate mitigation strategy.

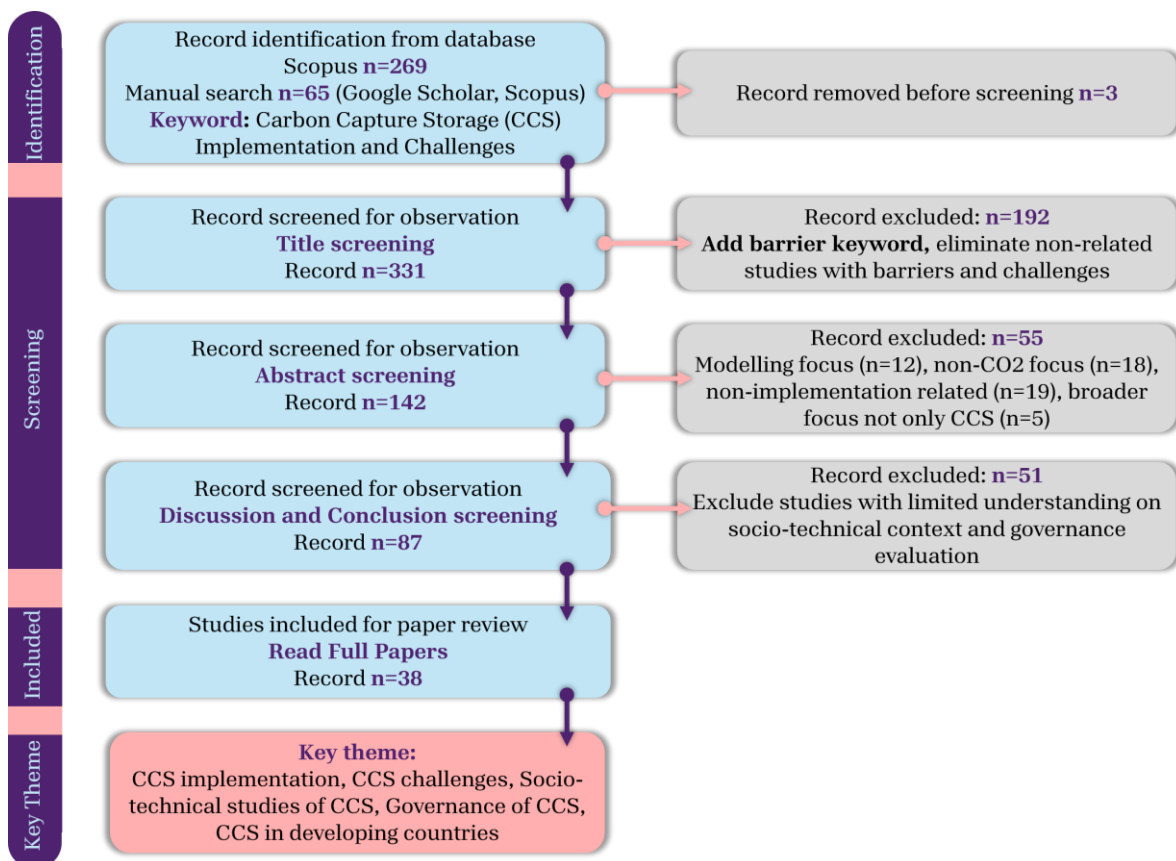


Figure 3. PRISMA approach for literature review

2.2 Global Experience with CCS Implementation

2.2.1 CCS Global Status

According to the Global CCS Institute (2025), 77 CCS/CCUS facilities were operating globally in 2025, with a combined capacity of 64 million tonnes of CO₂-eq per year (Mtpa), representing a 54% rise compared to 2024. Despite this rapid growth, it remains only 1.6% of the expected storage by 2050 to achieve the Paris climate target (Peters et al., 2017), illustrating the substantial gap between projected and actual deployment. Additionally, the CCS project pipeline reached 513 Mtpa in 2025 (see Figure 5), with 64 Mtpa in operation, 44 Mtpa under construction, and the remaining projects largely still at the development study stage. While this shows growing CCS interests, it is approximately only 1% of total global emissions (Global CCS Institute, 2025; JRC, 2025; Rasool & Moiz Hashmi, 2025). The existing project compositions also suggest that commercial CCS remains largely linked to EOR for hydrocarbon production (see Figure 4). Approximately 43% of operating facilities use EOR, where only 22% of projects employ deep saline formations as widely recognized storage for long-term carbon sequestration, aligned with climate mitigation efforts. This indicates that projects designed purely for climate mitigation remain relatively limited. Additionally, 27% of projects have unspecified storage types, suggesting that the actual share of emission reduction-driven CCS can be even smaller. The existing CCS global landscape shows that its implementation is largely shaped by fossil-fuel-linked interests rather than dedicated emission reductions.

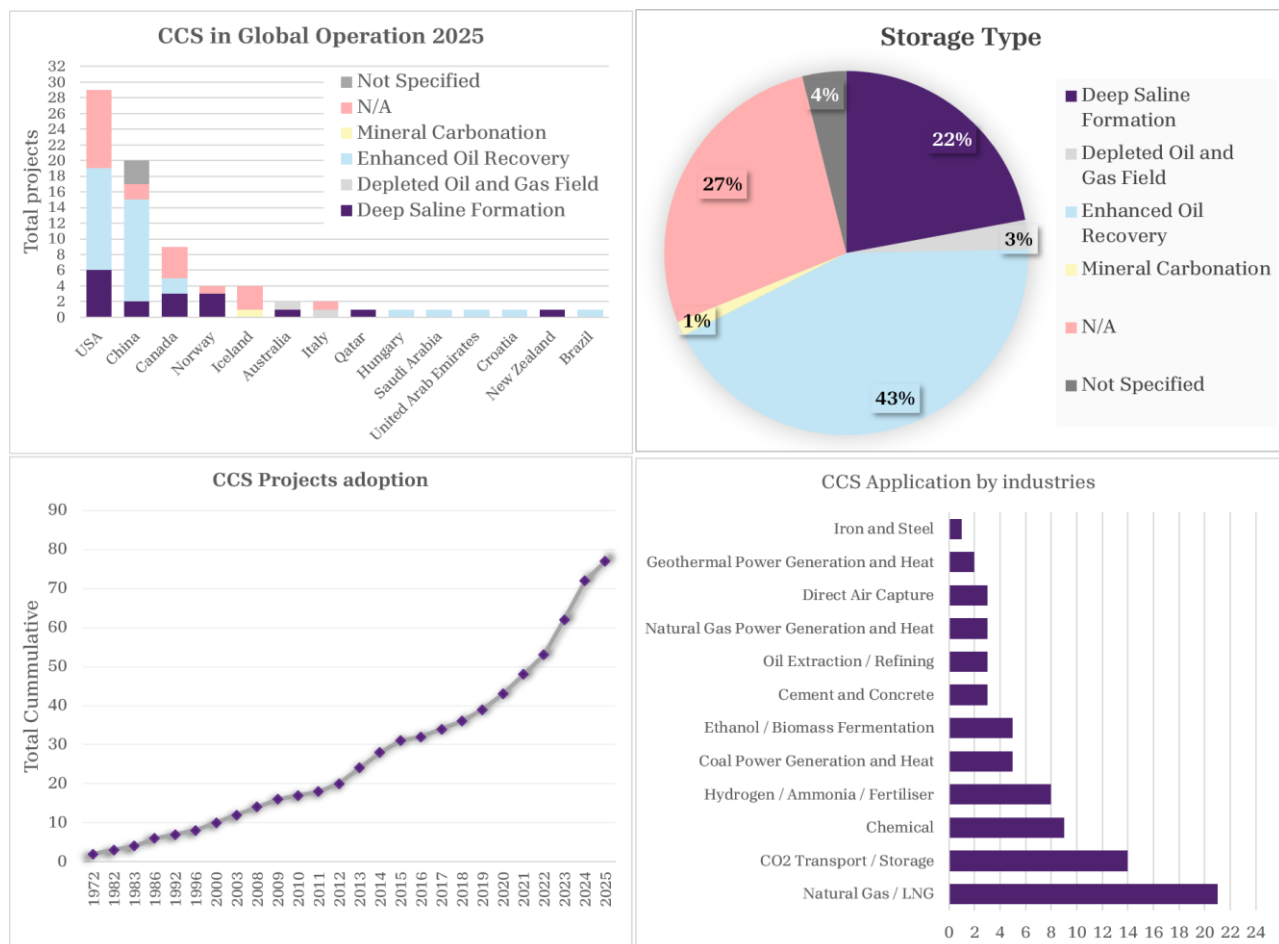


Figure 4. Global CCS operation in 2025

Source: synthesized from (Global CCS Institute, 2025)

(a - right above) CCS/CCUS plants based on countries (b - left above), storage type of current operating CCS (c - right below), CCS global adoption rates based on facilities construction number (d - left below), CCS application based on industries.

This imbalance is also reflected geographically, as shown in [Figure 4](#), CCS/CCUS implementation is concentrated in a few countries such as the USA, China, Canada, Norway, and Australia with different national development pathways. Countries such as Norway, Canada, and Australia emphasize deep saline formations for long-term sequestration, while the USA and China rely more heavily on CCUS-EOR ([Global CCS Institute, 2025](#); [Rijk et al., 2019](#)). Sectoral distribution further reinforces this pattern. Natural gas and LNG industries host the largest number of CCS projects, indicating that CCS development remains strongly embedded within existing fossil-fuel industries.

Overall, the global CCS landscape reveals a paradox. Although the technology has been developed over several decades and investment continues to increase, deployment remains limited, geographically concentrated, and closely tied to fossil-fuel sectors. This further shows that the slow diffusion of CCS cannot be explained by technological readiness alone and emphasizes the importance of broader socio-technical conditions that shape CCS trajectories. This observation highlights that transferring CCS to developing countries such as Indonesia requires a holistic approach beyond technological learning and their capacity to operate.

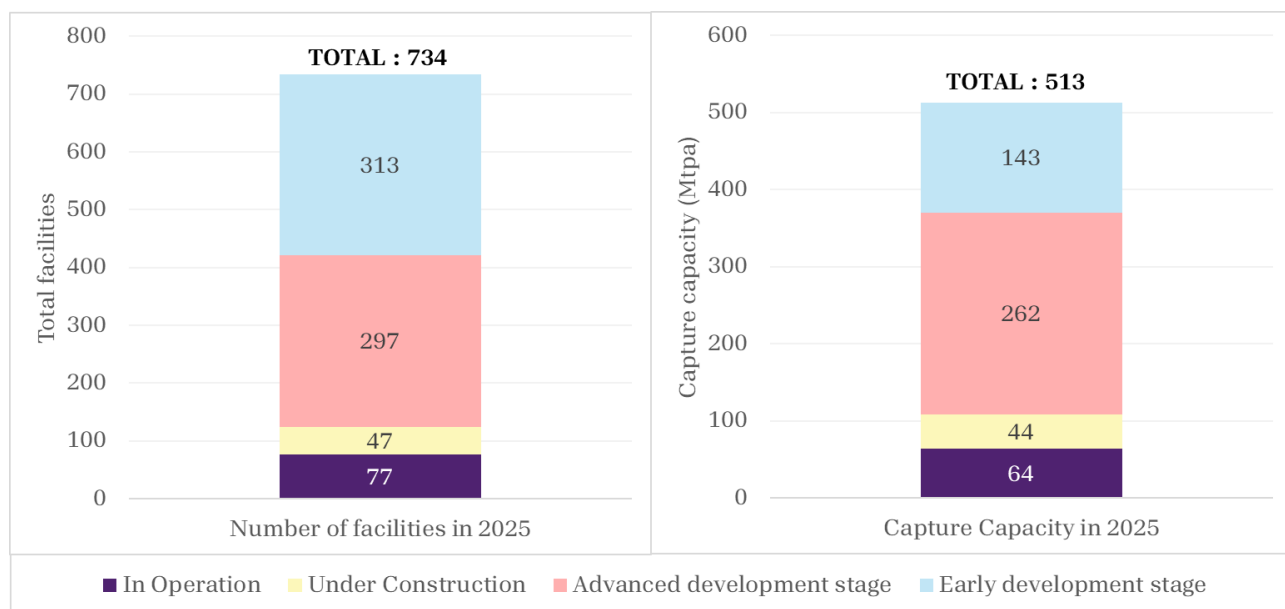


Figure 5. CCS/CCUS facilities status by number and capture capacity

Source: adapted from ([Global CCS Institute, 2025](#))

2.2.2 Learning from Commercial CCS Projects

Commercial CCS projects (see [Table 1](#)) provide insights into conditions required for scaling CCS, and it depends not only on technical feasibility. Experiences from leading countries show that projects have emerged where regulatory frameworks, supporting policies, financial incentives, and institutional commitment collectively alleviate the risks associated with CCS ([Osazuwa-Peters & Hurlbert, 2020](#); [Rijk et al., 2019](#); [L. Yang et al., 2016](#)). Canada provides an illustrative example of how different governance arrangements support different CCS deployment pathways. The Weyburn CCS project illustrates industrial integration through shared CCS infrastructures, although its economic model relies on EOR mechanisms ([Ma et al., 2022](#)). In contrast, Quest and Aquistore focus on permanent CO₂ storage utilizing deep saline formations as a climate strategy. These projects differ in economic models; while Aquistore is incentivised through research partnerships and public funding for dedicated CCS technology learning and development, Quest

received financial support from the government for initial operation and emission reduction incentives ([Alberta Department of Energy, 2023](#)). These projects highlight that commercial CCS can operate under diverse business models but consistently requires supportive policy instruments and strong collaboration between government, industry, and research institutions.

Table 1. Integrated commercial CCS projects in operation

CCS Project	Country	Type	Start operating	Remark
Quest	Canada	Capture: CO ₂ removal from hydrogen manufacturing units. Storage type: deep saline aquifer	2015	Joint venture between Shell, Canadian Natural Upgrading Limited, and Alberta Limited. 1.3 Mtpa-CO ₂ /year. Capex: \$ 874 M. Revenue stream from Alberta funding support and carbon offset credit
Aquistore	Canada	Capture from Sask's Boundary Dam, flue gas from coal combustion. Storage type: deep saline aquifer	2014	Managed by the Petroleum Technology Research Centre (PTRC), total cost is \$ 32,2 M, obtained through collaboration between government and industry. Revenue stream comes from research partnership funding, as it is intended for CCS learning purposes.
Snøhvit	Norway	Capture: LNG and natural gas processing. Storage: offshore deep saline formation (0.7Mtpa)	2007	Capex: \$191 M. Operated by Equinor as part of the Snøhvit LNG facility, integrating CCS directly with offshore gas infrastructure. Revenue stream comes from avoidance cost on carbon tax
Sleipner	Norway	Capture: natural gas processing. Storage: offshore deep saline formation (1.2 Mtpa)	1996	Capex: \$106M. Operated by Equinor in Sleipner Gas field as the first commercial-scale CCS project. Revenue stream comes from avoidance cost on Norway's carbon tax
In Salah	Algeria	Capture: natural gas processing, Storage: deep saline formation (1.2 Mtpa)	2004	Incremental cost: \$100M. Joint venture between BP, Equinor, and Sonatrach. Revenue driver: enabling production of CO ₂ -rich natural gas that would otherwise be uneconomic to process.
Gorgon	Australia	Capture: LNG and natural gas. Storage type: deep saline formation with 2.2 Mtpa	2019	Capex: \$ 3.1 billion integrated into LNG facility, operated by Chevron with joint venture partner. Revenue stream: regulatory compliance and carbon reduction required for LNG production approval; this is to continue the LNG project and reduce its carbon intensity
ADM Illinois	USA	Capture: ethanol and biomass fermentation process. Storage type: deep saline formation with 1 Mtpa	2017	Capex: \$ 208 M supported by the US Department Energy of Industrial CCS system. Operated by Archer Daniels Midland (ADM) at its ethanol facility. Revenue stream from US 45Q tax credit.
Weyburn	Canada	Capture: coal gasification plant, pre-combustion. Storage EOR 2.4 Mt/year	2000	Capex: \$127 M (10.19/tCO ₂) Opex: \$23.6 M (\$9.85/tCO ₂). Operated as CCUS-EOR with the largest world scientific research facility for CCS. Revenue stream comes from EOR.

Source: adapted from ([Almendra et al., 2011](#); [Global CCS Institute, 2025](#); [Ma et al., 2022](#); [Zhang, 2021](#))

Norway provides another example of policy-driven CCS through the Sleipner project, which has been operating since 1996 for permanent CO₂ storage in saline formations ([Wettestad et al., 2024](#)). The project was enabled by strong carbon pricing mechanisms, including Norway's carbon tax (EUR 106 in 2024), an emission cap-and-trade policy, and the European Union Emissions Trading System (ETS) with carbon prices ranging between EUR 60-80 in 2025 ([Chau, 2024](#)). These policy instruments create strong economic incentives that make storing CO₂ more attractive than direct emissions. This example further emphasizes how carbon policy clarity and strong economic incentives can drive active industry participation in CCS deployment

Comparative studies (see [Table 1](#)) consistently identify three enabling conditions for successful commercial CCS projects. First, sustained investment in robust knowledge ecosystems such as dedicated research institutions for CCS technology innovation to strengthen knowledge development, learning processes, and coordination across the CCS system ([Ma et al., 2022](#)). Second, effective governance of CCS requires non-fragmented institutional arrangements and regulatory frameworks that provide clear guidance on governing the lifecycle of CCS implementation, including risk allocation, safety monitoring, and financial matters. Integrated policies in Europe, for example, establish both clear substantive and procedural requirements in CCS development covering site characterization, operation, closure, and post-closure obligations ([Shirmohammadi et al., 2020](#); [Zhang, 2021](#)). Third, strong political commitment, reflected through carbon pricing, public funding support, and alignment with national decarbonization, provides long-term certainty required for commercial investment ([Ma et al., 2022](#); [Shirmohammadi et al., 2020](#)).

Collectively, these global experiences further reinforce that commercial CCS cannot be explained by technological readiness alone, but successful projects depend on governance arrangements over long project lifecycles. This becomes more challenging for developing countries, where the challenge extends beyond their capability of technological learning to establishing strong governance mechanisms for sustained deployment.

2.2.3 Learning from CCS Project Failures

While successful projects demonstrate the importance of supportive governance, failed CCS projects show the consequences of its absence. Existing studies suggest that many CCS projects failed not because capture, transport, and storage were technically infeasible, but because governance arrangements were unable to sustain CCS long-term investment, manage stakeholder needs, and address implementation risks ([Brunsting et al., 2011](#); [Rasool & Moiz Hashmi, 2025](#); [D. M. Reiner, 2016](#); [Rijk et al., 2019](#); [Wang, 2020](#)). This further reinforces that scaling CCS requires state capability in coordinating economic, political, social, and technical dimensions.

One of the most common challenges is the lack of stable political commitment and financial security. **The ROAD project** in the Netherlands, for example, one of Europe's flagship CCS demonstrations, was cancelled despite being technically feasible. The project heavily relied on public funding support under the EU NER300 programme, which was ultimately not granted due to shifting priorities to renewable investment ([Rijk et al., 2019](#)). Similarly, **the Petra Nova project** in the United States and **the Alberta Carbon Trunk Line (ACTL)** revealed that CCS projects linked to EOR became highly vulnerable to global oil price fluctuations ([Rasool & Moiz Hashmi, 2025](#)). These experiences demonstrate that CCS deployment must be supported by long-term and stable financial security that is resilient to changing political priorities and market conditions.

Societal legitimacy represents another critical governance challenge. **The Barendrecht project** in the Netherlands was cancelled due to strong public opposition, despite meeting technical requirements. This was mainly driven by limited stakeholder engagement and poor communication regarding project risks and storage safety ([Brunsting et al., 2011](#); [Rijk et al., 2019](#)). This experience showed that public distrust subsequently can escalate into political resistance, constraining CCS implementation.

In addition to governance challenges, technical risks remain a critical aspect. **Algeria's In Salah project** shutdown and **Australia's Gorgon** delayed operation show the importance of strong risk

monitoring and modelling because high-pressure CO₂ injection can induce seismicity, fault reactivation, or caprock fracturing if reservoir conditions are insufficiently understood (Rasool & Moiz Hashmi, 2025; Wang, 2020). Rather than showing engineering problems, these cases emphasize the importance of governance mechanisms in identifying risks earlier and managing technical uncertainty.

Taken together, failed CCS projects reinforce the learning from commercial CCS projects. Stable policy support, resilient financial incentives, meaningful public consultation, and adaptive risk governance are all essential for sustained CCS deployment. These lessons are particularly relevant for developing countries, where institutional capacity and governance structures are evolving.

2.2.4 CCS Implementation in Developing Countries

Experiences from developing economies demonstrate that scaling CCS involves challenges that differ from those observed within developed countries. While successful commercial CCS projects in countries such as Norway and Canada benefit from mature institutional arrangements, stable policy environments, and well-developed carbon markets, developing countries often introduce CCS while these enabling conditions are still emerging (Almendra et al., 2011; Ibe & Nwosi-Anele, 2024; X. Yang et al., 2019). As a result, the challenge extends beyond technology development to building governance capacity for long-term CCS applications.

Observations from China, South Africa, Iran, Vietnam, and Brazil reveal several recurring governance challenges. **China** has made substantial investment in CCS research and demonstration, yet fragmented political support and unclear long-term liability constrain its development, forcing investors to bear all the risks (X. Yang et al., 2019). Similarly, **Brazil** has developed research partnerships in CCS and successfully initiated CCS pre-salt commissioning, yet the limited expertise in long-term risk monitoring and alignment with national climate efforts constrains the deployment (Mascarenhas et al., 2019). **Iran** also faces similar constraints, where geological monitoring expertise is lacking and access to CCS complementary technologies is restricted (Shirmohammadi et al., 2020). **South Africa** shows a different challenge where weak institutional coordination and strong influence from incumbents constrain CCS deployment despite the availability of international funding support (Ko et al., 2021). Similarly, **Vietnam** shows that weak political commitment to CCS and absence of coordinating bodies for CCS planning contribute to low CCS participation (Ha-Duong & Nguyen-Trinh, 2017).

Across these cases, three common patterns were observed: (1) early CCS implementation depends heavily on state-supported programs including research and technology demonstration; (2) fragmented or incomplete regulatory frameworks generate uncertainties regarding long-term liability and business risks, which discourage private investments; (3) institutional coordination and sustained political commitment are critical to determine whether CCS pilot programs translate into scalable deployment. These highlight that the challenge is not adopting CCS technology itself, but establishing governance systems capable of coordinating multiple actors, reducing uncertainties, and aligning with national decarbonization efforts. This is relevant to Indonesia, as a developing country, where recent policies have positioned CCS as a strategic pathway for industrial emission reductions despite limited experience in CCS operation (MEMR, 2024a; Ramadhan et al., 2024). Understanding whether Indonesia has the required socio-technical and governance conditions to move CCS projects beyond demonstration therefore becomes an interesting research gap in this study.

2.3 Socio-Technical Challenges in CCS Implementation

The experiences discussed in the previous section show that both successful and unsuccessful CCS projects are shaped by factors beyond technological feasibility. Recurring CCS challenges in global experiences include fragmented institutional arrangements, weak political commitment, financing uncertainty, and social acceptance (Markusson et al., 2012; Sara et al., 2015). These recurring challenges emphasize that CCS should be understood as a socio-technical transition, where technological advancement co-evolves with institutions, markets, policies, and societal legitimacy (Kern et al., 2016; Meadowcroft & Langhelle, 2009).

Socio-technical perspectives argue that diffusion of complex technologies depends on interaction between technological system and their broader institutional environments rather than technological advancement alone (Geels, 2019; Sovacool et al., 2025). Unlike other low-carbon technologies, CCS has a more complex system as it is characterized by its long-term horizon, requiring the simultaneous development of technology components together with regulatory frameworks, long-term political commitment, business models, public legitimacy, and contingency planning for failures (Osazuwa-Peters & Hurlbert, 2020; Pihkola et al., 2017; Swennenhuis et al., 2024). As a result, the adoption of CCS is shaped by alignment of multiple technical and non-technical aspects. This complexity is reflected through the interdependencies of socio-technical challenges. High capital investment of CCS requires stable carbon pricing or long-term financial support for reducing business uncertainty (Osazuwa-Peters & Hurlbert, 2020; Zhang, 2021). Long project life cycle demands clear regulatory frameworks including permitting, risk mitigation, monitoring, liability, and post-closure stewardship. Additionally, political commitment and public acceptance influence whether CCS projects are secured for long-term investment (Bäckstrand et al., 2011; Brunsting et al., 2011; Kern et al., 2016). These components are interconnected, indicating that weaknesses or absence in one component may constrain CCS projects regardless of technological capability.

The studies suggest that CCS deployment cannot be understood through engineering performance or economic competitiveness only, but it represents a broader socio-technical transition that demands coordinated actors, policies, and institutions (Kern et al., 2016; Pihkola et al., 2017; Swennenhuis et al., 2024). Understanding these interactions is therefore essential to understand why CCS has scaled in many countries but is stagnating in other countries. This perspective provides theoretical foundations for employing the Multi-Level Perspective (MLP) in this study to understand broader socio-technical interactions in shaping CCS development in Indonesia.

2.4 Governance of CCS Implementation

Learning from global experiences, CCS projects are strongly influenced by governance readiness level to implement them, and the socio-technical challenges associated with CCS translate into distinctive governance demands that extend beyond conventional regulatory approaches. Moreover, coordinating complex infrastructures and stakeholders requires governance arrangements that operate in multiple dimensions. Drawing on CCS governance and policy studies (Bäckstrand et al., 2011; IEA, 2022; Kern et al., 2016; Markusson et al., 2011a; Upham & Roberts, 2011; Wilson et al., 2009; X. Yang et al., 2019; Zhang, 2021), this section discusses the governance challenges to sustain long-term CCS implementation.

Existing literature identifies several recurring governance challenges. First, Regulatory foundations that are specifically developed to govern CCS implementation. Common uncertainties observed surrounding CO₂ classification, the permitting system, the liability framework across the CCS lifecycle, and CCS operation obligations, including monitoring, measurement, and verification (MMV) (IEA, 2022; Zhang, 2021). If CO₂ is transported across national boundaries or stored in a regional storage hub, clarity on the cross-border regulatory framework then becomes critical. Governance of CCS also evolves across the entire CCS project lifecycle. As illustrated in Figure 6, each stage from resource assessment to post-closure stewardship introduces distinct regulatory considerations that must be addressed in the CCS regulatory framework to ensure safe and accountable deployment.

	Description	Regulatory Consideration
 Resource Assessment	Process to identify and study CO ₂ storage resources in a region with the aim of identifying resources that can be developed into storage sites	A. Regional screening, site screening, site selection, site selection, initial and detailed characterization B. Ownership of pore space C. Other cross-cutting issues: interaction with other surface and subsurface resources
 Site Development	Project planning aimed at ensuring a site has completed all development and design activities	A. MMV plans B. Storage site inspections C. Defining operational liabilities and financial security D. Other cross-cutting issues: environmental impact assessments, permitting, public engagement, project-specific legislation, preferential rights and projects, shared storage infrastructure
 Construction	Construction of surface facilities, connection to transport lines, expansion of MMV instrumentation and drilling of any additional wells	
 Operation	Period of time during which CO ₂ is actively injected into the subsurface	
 Site Closure	Injection has ceased; Decommissioning of infrastructure not required to monitor the site; Abandonment and closure of any wells not required for monitoring	A. Site closure process and certification B. Long-term responsibility post-closure (e.g. maintenance of storage site and long-term liabilities) C. Financial assurances of long-term site stewardship
 Post Closure and Beyond	Period after injection ceases where the CO ₂ plume is still actively being monitored; Remediation activities as required; Transfer of site responsibility, if applicable	

Figure 6. Regulatory considerations for CCS implementation

Source: adapted from (IEA, 2022)

Second, effective CCS implementation demands governments with sufficient capabilities to coordinate multiple stakeholders, align CCS with broader national climate mitigation, and provide long-term policy direction (Wu et al., 2015). These capacities indicate the strong political commitment in dealing with CCS and its long-term horizon nature, providing security for investors and the affected public for CCS deployment (Kern et al., 2016; Wu et al., 2015; X. Yang et al., 2019). As highlighted by CCS project failures and constrained deployment examples, weak political

commitment and uncoordinated stakeholders contribute to slow adoption of CCS. Third, risks and liability associated with long-term operational CCS must be managed adequately (Wilson et al., 2009; Zhang, 2021). Drawing on Beck's (1992) theoretical concept of risk society, CCS exemplifies "manufactured risks"² that require dedicated institutional mechanisms for assessment, management, and communication. The absence of liability arrangements creates significant barriers to investment and public acceptance, as private sectors are reluctant to assume indefinite responsibility for long-term risks (De Figueiredo, 2007; Wilson et al., 2009). Key challenges in managing risks include intergenerational responsibility to manage and deal with CCS risks, and one CCS project failure can undermine public trust in other projects (Markusson et al., 2011a).

Lastly, governance challenges also extend beyond formal institutions to include knowledge development and societal legitimacy (Markusson et al., 2011a; Upham & Roberts, 2011). Legitimacy is actively constructed through transparency, accountability, and stakeholder engagement (Suchman, 1995), where in CCS it is built through multiple levels; CCS is seen as a legitimate climate mitigation, CCS project is perceived as appropriately sited and managed, and Actors who manage CCS are seen as competent and trustworthy (Ashworth et al., 2010; Brunsting et al., 2011; Upham & Roberts, 2011). Experiences such as the Barendrecht project show that poor public engagement can undermine a technically feasible project, while jurisdictions from Canada and Australia show how institutionalized knowledge sharing, development, and public participation can strengthen CCS deployment.

These studies highlight that governance is a multidimensional system that enables the coordination of legal, institutional, technical, political, and societal aspects throughout the CCS lifecycle. Building on these insights, this study synthesizes the governance literature into a Governance Readiness Framework (discussed in Chapter 3) that guides the analytical basis to assess Indonesia's readiness to deal with large-scale and high-risk CCS technology.

2.5 Knowledge Gap and Research Positioning

Existing CCS literature has identified a range of CCS barriers and enablers, including financial constraints, institutional complexity, public acceptance, and technology performance (Markusson et al., 2012; Pihkola et al., 2017; Sara et al., 2015; Van Alphen et al., 2010). Building on these findings, socio-technical transition studies conceptualize CCS as a complex system that requires alignment across technological development, market dynamics, policy frameworks, and social dimensions to enable sustained CCS deployment (Pihkola et al., 2017; Van Alphen et al., 2010). In parallel, governance-oriented studies emphasize the importance of political commitment, regulatory frameworks, and institutional arrangements in advancing CCS development (Bäckstrand et al., 2011; Osazuwa-Peters & Hurlbert, 2020; X. Yang et al., 2019).

However, these two literature orientations have largely evolved separately. Socio-technical studies often treat governance as one of the contextual factors, while governance-focused studies rarely examine how governance interacts with broader socio-technical transition dynamics. This fragmentation leaves a conceptual gap in understanding the co-evolution of governance readiness and socio-technical transitions, particularly for large-scale and high-risk technology such as CCS.

² Manufactured risks refer to risks that are created by human decisions, technology, and modern industrial systems, rather than nature.

This limitation becomes particularly important in developing countries, where markets, infrastructures, and governance arrangements are still evolving. Although the Multi-Level Perspective (MLP) provides a useful framework for understanding how CCS as a newly introduced technology emerges through interaction between niche learning space, existing regimes, and broader landscape pressure, it offers limited analytical depth for systematically evaluating governance readiness. This limitation is evident in Indonesia, where CCS has gained policy attention and growing investment interest, yet the existing studies primarily focus on technical potential, policy development, or economic feasibility (Adisaputro & Saputra, 2017; Amelinda & Soekarno, 2023; A. A. Putra et al., 2018; Ramadhan et al., 2024; L. A. Yusgiantoro & Bagus, 2023). There remains limited research that systematically examines how governance readiness, political conditions, and stakeholder coordination interact with socio-technical transition processes to shape CCS development trajectories.

Addressing this gap, this study develops an integrated analytical framework that combines the Multi-Level Perspective (MLP) as a socio-technical evaluation, CCS governance readiness assessment, and diagnostic intervention framework. This integrated perspective enables a deeper analysis of how governance structures, institutional coordination, and policy development interact with socio-technical factors to shape the technology trajectory of CCS within broader socio-technical pathways.

Methodology and Theoretical Framework

3.1 Research Design

This study adopted a qualitative approach using Indonesia's CCS system as a case study to understand the empirical context of CCS implementation in a developing country. This enables an in-depth exploration of CCS socio-technical dynamics and understanding CCS complexities in Indonesia's ecosystem. The study was operationalized using the workflow shown in [Figure 7](#) through six different phases to achieve the outcomes, with the overall design presented by [Figure 30](#) (see [Appendix A](#)) showing how the research questions were addressed to achieve the research outcomes. The study combined desk-study and stakeholder interviews, guided by three analytical frameworks discussed in [Section 3.2](#). While desk research was used to understand CCS dynamics through documents and literature, stakeholder interviews aimed to validate findings and provided insights into the reality of practical challenges, institutional dynamics, and strategic perspectives.

The sub-research questions in the study were operationalized through the approach as follows:

Sub-Research Question 1: Actor and Network

What actors are involved in Indonesia's CCS development, and what roles and relationships characterize the current actor network of CCS implementation?

This question was addressed through mapping key actors involved in Indonesia's CCS system, including how they interact in shaping CCS trajectories. The analysis covers the interaction dynamics between CCS actors and potential CCS actors, understanding actor influences in developing CCS. Stakeholder interviews were used to validate the findings from literature, strengthening the validity of the outcome.

Sub-Research Question 2: Socio-Technical Conditions

What socio-technical conditions shape the existing development phase of CCS in Indonesia?

This question was guided by the Multi-Level Perspective (MLP) framework developed by Geels (2002) to understand the socio-technical dynamics of CCS implementation through landscape, regime, and niche levels (see [Section 3.2.1](#) for framework discussion). Stakeholder interviews (see [Section 3.3.2](#)) were also used to validate the findings and provided insights into the analysis, understanding which aspects are perceived as critical by stakeholders.

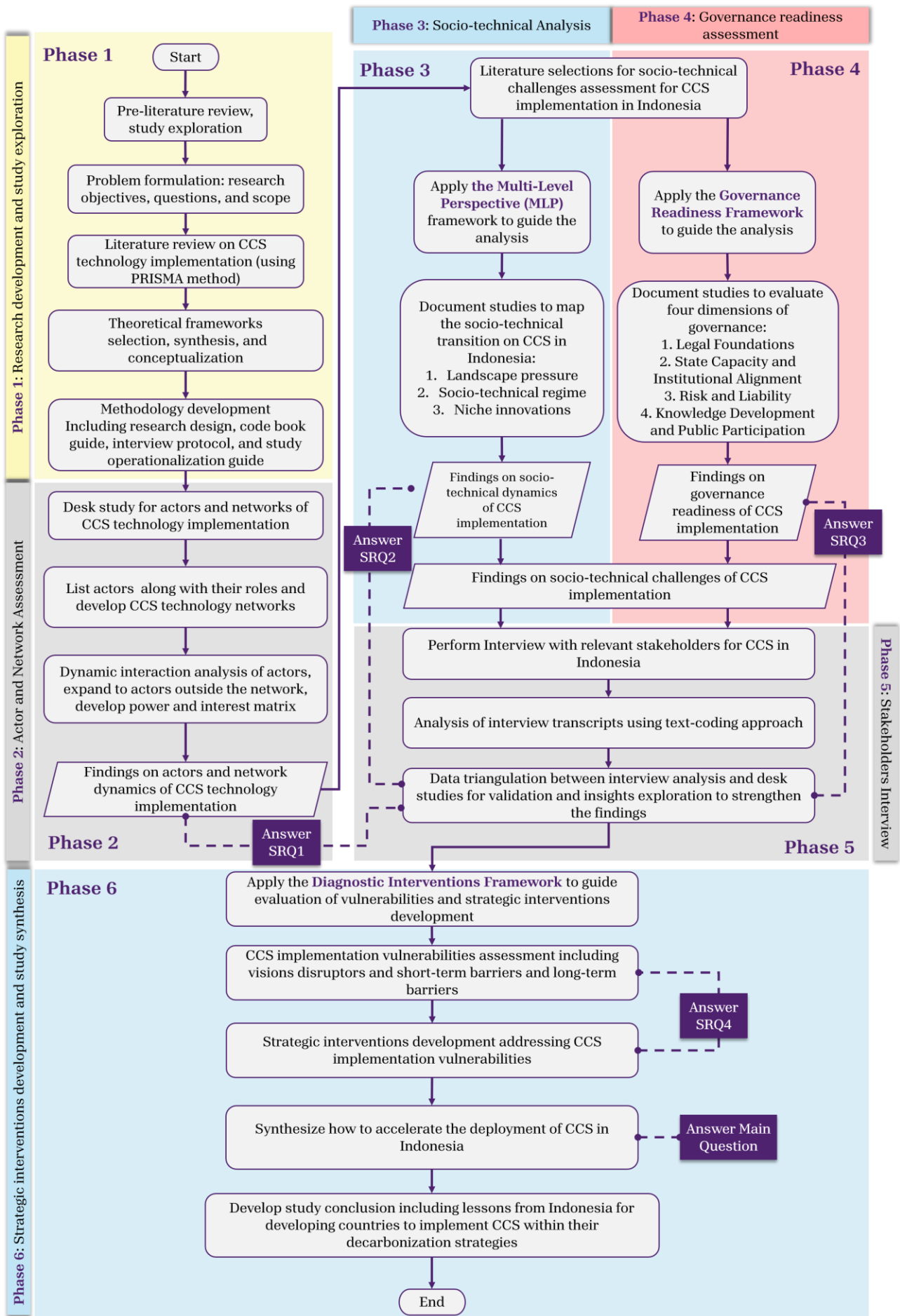


Figure 7. Research workflow diagram

Sub-Research Question 3: Governance Readiness

What governance conditions enable or constrain the development of CCS in Indonesia from demonstration level to large-scale implementation?

This question was operationalized using a Governance Readiness Framework synthesized in this study (see [Section 3.2.2](#)). The framework integrates four key governance dimensions and corresponding indicators identified from CCS governance literature to assess CCS governance conditions at national and corporate levels. Stakeholder interviews were employed to validate the findings from the desk study and provided additional insights on the reality of governance applications.

Sub-Research Question 4: Barriers and Interventions

What strategic interventions could accelerate the deployment of CCS in Indonesia at national-level and corporate-level?

This question was addressed by adapting the diagnostic intervention framework proposed by Malekpour et al (2017) (see [Section 3.2.4](#)). Building on SRQ-2 and SRQ-3, socio-technical challenges were identified as a basis to understand technology vision disruptors and barriers. Rather than addressing barriers individually, the proposed interventions in this study prioritize critical barriers with strong systemic influence, where resolving them is expected to provide improvements across multiple aspects of CCS deployment, subsequently improving other barriers. Learning from global CCS experiences and other low-carbon technologies was also incorporated when developing interventions. Lastly, stakeholder interviews were also used to obtain insights on the critical conditions and interventions required in accelerating CCS deployment.

3.2 Theoretical Framework

3.2.1 Socio-technical Analysis Using the Multi-Level Perspective (MLP)

The Multi-Level Perspective (MLP) provides a structured diagnostic tool for understanding CCS technology as embedded within a broader socio-technical context. Geels (2002) developed the MLP framework to emphasize how radical innovation unfolds within broader socio-technical transitions shaped by interacting multiple stakeholders who interact and engage in multiple activities. The activities associated with technology dynamics include learning, debating, policymaking, negotiating, capacity building, and goal setting. MLP is particularly suitable for this study because it allows systematic mapping of opportunities, constraints, and interactions across multiple levels, particularly when technology ecosystems and markets are still evolving.

As illustrated in [Figure 8](#), MLP conceptualizes that socio-technical transitions can occur through the interaction between multiple levels, including niche-level, regime-level, and landscape-level. The interactions between each level shape how the technology can be developed and accelerated as a dominant technology choice. These three analytical levels are further described below.

1. Niche: Micro-Level Learning Spaces

Niches are protected space act as incubation rooms where innovations emerge and develop, often characterized by experimental practices, unstable sociotechnical configurations, and initially low technology performance (Geels, 2012, 2019). This includes research, subsidies, pilot projects, and a small niche market where adopters have specific demand to use new technology.

Kemp (1998) distinguishes three processes that potentially happen in the technology niche learning space:

- Learning process on various dimensions. This is associated with imperfection of technology performance, organizational issues, early market formation, early users' behaviour, and infrastructure requirements to support the technology.
- The articulation of technology expectations or visions. This drives the internal innovation of technology while trying to attract investors to advance the technology development.
- The building of social networks for the technology, expanding the social resource base for niche innovations.

Mapping niches highlights the ongoing learning processes in CCS demonstration, local experimentation, and potential pathways for scaling to commercial technology. This also includes the support from groups within and outside the networks to advance the technology exploration.

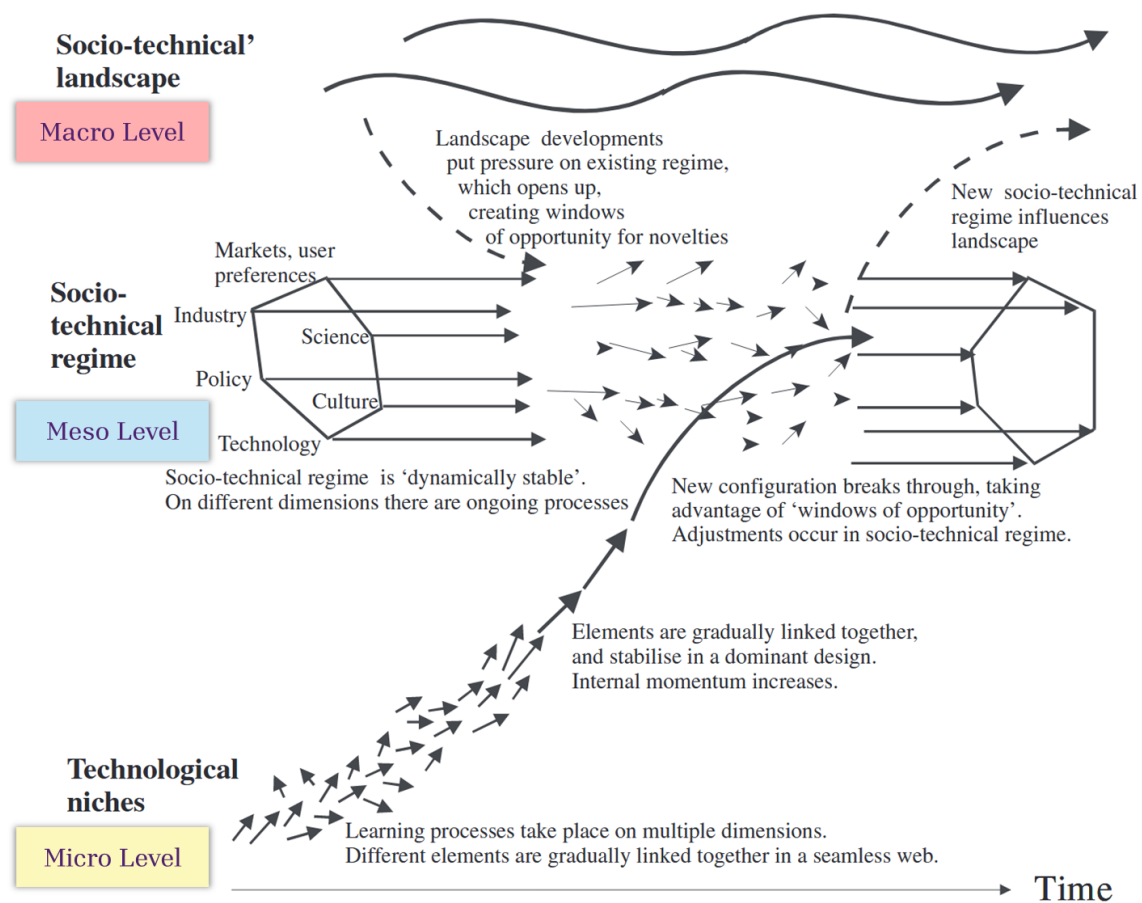


Figure 8. Multi-level perspective framework on technology transition
Source: (Geels, 2002)

2. Regime: Meso-Level Structures

The sociotechnical regime is the meso-level dominant structures, practices, actor networks, shared routines, and institutions that shape the existing ecosystem. In the regime, emerging technology will interact with the incumbent technologies and actor networks that may resist or complement the adoption of the technology. The existing technology regime is dynamically stable,

where innovations are mostly incremental due to lock-in mechanisms and path dependence³ (Geels, 2019). As shown in Figure 8, multiple actors and their interests are observed to understand how the emerging technology can interact with the existing regimes. The pressure from landscape and niche innovation opens the opportunity window to destabilize the existing regime for new technology to disrupt current dominant practices. In the context of CCS, this includes energy and industrial practices, regulatory and policy frameworks, infrastructure systems, resistance or support from existing regimes, market conditions, and technical capacities. Mapping regime characteristics helps to identify patterns that enable or block CCS adoption and understand how CCS is currently situated in the socio-technology dynamics in Indonesia. At this level, the interaction of CCS with other technology alternatives-regime is also analysed as technological options for carbon abatement.

3. Landscape: Macro-Level Pressures

Landscape pressures are macro-level factors that create environments for socio-technical transition but are beyond the direct control of actors. This includes cultural patterns, political development, macro-economic trends, socio-economic trends, and the media landscape that influence regimes and niches (Geels, 2012). Landscape pressure influences the regime and niche dynamics and allows opportunity windows to emerge for new technologies to develop within existing regimes (see Figure 8). For the CCS case, these include international climate agreements, national decarbonization policies, and geopolitical situations. In this study, landscape mapping focuses on the identification of macro-level drivers and constraints relevant to CCS implementation, highlighting pressures that create windows of opportunity for CCS to accelerate.

Finally, the MLP framework emphasizes the interaction between different levels where niche innovation level builds up momentum through the learning process and performance improvement, landscape-level environment creates pressures for regime, and destabilization of regime creates room for niche-level technologies to emerge in the socio-technical transition (Geels & Schot, 2007). Understanding these interactions in the Indonesian CCS systems allows the study to identify structural barriers and enabling conditions.

3.2.2 Governance Readiness Framework

Lessons from global CCS experiences consistently emphasize that governance plays a central role in accelerating CCS deployment from demonstration stage to commercial scaling. This refers to the extent to which institutional, regulatory, and policy arrangements are in place, ensuring safe, effective, and legitimate CCS deployment (Kern et al., 2016; Markusson et al., 2011b; Upham & Roberts, 2011; Zhang, 2021). While these governance elements are widely discussed throughout the CCS literature and international guidance, they are often presented as individual considerations rather than as an integrated assessment framework.

To address this gap, the study synthesizes the recurring governance elements identified in CCS governance studies and international guidelines developed by the IEA (2022) into a **Governance Readiness Framework**. The framework name is inspired by the concept of *readiness assessment*, which has been widely applied to technology readiness in innovation studies; however, the synthesized framework evaluates the readiness of the governance system in supporting broader

³ Path dependence is the situation where technology users and innovation are highly influenced by early technological choice, and it defines what feels “normal” or “standard” for users.

CCS implementation. Building on the knowledge discussed in [Chapter 2](#), specifically [Section 2.4](#), the Governance Readiness Framework operationalizes governance aspects into four diagnostic dimensions as shown in Figure 9. The dimensions include: (1) legal foundations for CCS; (2) state capacity and institutional alignment; (3) risk and liability governance; (4) knowledge development and public participation. Table 16, [Appendix A](#) provides further detail on each dimension, including indicators that are considered during operationalization.

Existing CCS governance predominantly examines governance from a national or regulatory perspective. However, the successful deployment of CCS also depends on corporate actors that make investment decisions, integrate CCS into business development strategies, and coordinate implementation across the CCS value chain ([Braunreiter & Bennett, 2017](#)). This study therefore extends the synthesized framework (see Figure 9) to include corporate governance perspectives along with national-level governance. This extension acknowledges that corporate governance remains embedded within national governance while recognizing that both jointly shape the readiness of the broader CCS deployment. Incorporating both perspectives allows a more comprehensive assessment of governance conditions and supports the development of strategic interventions applicable to policymakers, CCS adopters, and potential adopters.

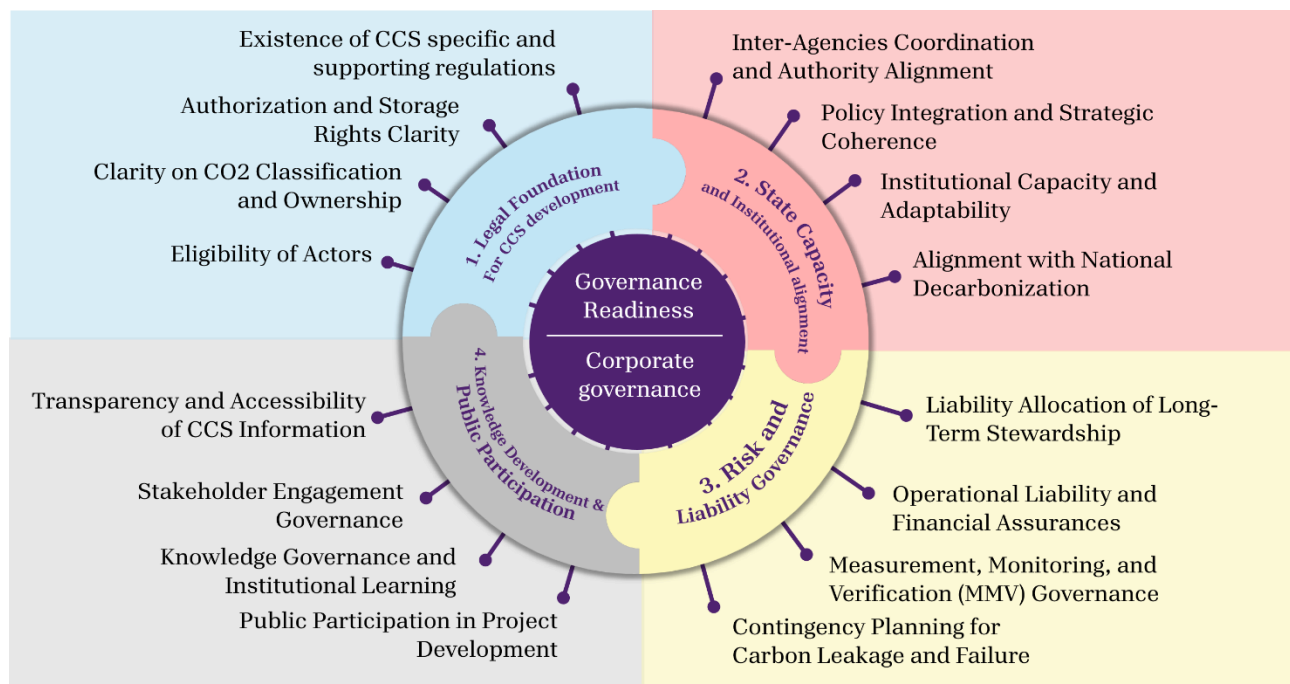


Figure 9. Governance readiness framework for CCS implementation

Source: synthesized by author from literature and international standards

The governance assessment also adopts a maturity assessment, inspired by a manufacturing assessment by Wagire et al ([2021](#)), where each dimension's performance will be compared through the assessment using point scales as follows.

Level 0: Absence of indicator; there is no evidence of the indicator, or it is not yet considered.

Level 1: The indicator is acknowledged or emerging; the provision is unclear or poorly implemented.

Level 2: The indicator is established more strongly, and it's functional; it still has considerable gaps

Level 3: The indicator is relatively advanced, strongly implemented, considered mature or robust

3.2.2.1 Legal foundation for CCS

The legal foundation dimension encompasses the availability of the legal frameworks used that define who can develop CCS projects, what rights and permissions are required, and how access to geological storage is managed. Insights from global CCS experiences emphasize that the availability of dedicated CCS regulations significantly strengthens investor confidence, while ambiguous legal frameworks increase project risks and delays. IEA (2022) also highlights that dedicated CCS regulations should govern the full lifecycle of CCS resource assessment, site characterization, operation, site closure, and post-closure stewardship. It also should ensure fair access to shared CO₂ geological storage because unclear access rules or monopolistic control can create broader implementation barriers.

Accordingly, this dimension analyses the availability and clarity of specific CCS regulations governing CCS system activities from exploration to post-closure. The assessment considers authorization requirements for each component of the CCS value chain—capture, transport, and storage. Additionally, clear classification of CO₂, whether it is treated as a waste, commodity, or hazardous pollutant, is critical to determine regulatory obligations and how industrial actors perceive the value of CO₂ within the industrial chain (Osazuwa-Peters & Hurlbert, 2020). Lastly, to enable broader deployment of CCS, this dimension includes clarity on eligibility rules for actors to take part in CCS projects. The inclusive regulation allows CCS projects not limited to a certain sector but fosters cross-sector collaboration in technology development (IEA, 2022).

3.2.2.2 State Capacity and Institutional Alignment

The state capacity and institutional alignment dimension assesses the ability of governments to design, implement policies, and monitor CCS project implementation. While regulatory frameworks provide formal guidance, their effectiveness depends on the state capacity and institutional coordination across multiple sectors and government bodies. Governance theory emphasizes that large-scale infrastructural development and industrial transformation depend not merely on political commitment but also on the ability of the state to coordinate actors and implement policy effectively (Fukuyama, 2013).

This dimension evaluates four governance elements. First, it examines the availability of inter-agency coordination mechanisms and their effectiveness, such as inter-ministerial task forces and collaboration between relevant authorities. Coordination capacity is a critical governance component, particularly in complex policy domains such as CCS (Wu et al., 2015). Second, it evaluates the policy integration and strategic coherence across sectors, particularly alignment of CCS-related policies within energy, industrial, environmental, and climate frameworks, as conflicting policies can create uncertainties for project developers and investors (Markusson et al., 2012). In addition, the political commitment level in supporting CCS is evaluated as it provides a foundation for investors to consider their involvement in CCS deployment. Finally, the dimension evaluates whether CCS technology is explicitly integrated into national climate strategies, as it signals that CCS is not treated as a peripheral technology but as one of the core components in national climate mitigation pathways.

3.2.2.3 Risk and Liability Governance

The risk and liability governance dimension addresses how regulatory frameworks allocate, manage, and mitigate CCS risks and liabilities. The development of CCS is characterized by unique governance challenges due to long-time horizons, subsurface uncertainties, and potential intergenerational risks. Clear responsibility allocation across the CCS lifecycle is therefore critical in enhancing public trust and investors (X. Yang et al., 2019). Potential risks should also be clearly managed, such as carbon leakage, induced seismicity, groundwater contamination, and long-term pressure effects on the subsurface.

This dimension evaluates the four aspects of risk and liability management. First, legal allocation of long-term liability, particularly whether operators must be responsible in perpetuity or there are defined conditions where carbon storage responsibility can be transferred to authorities. This includes clarity on site closure procedures and post-closure stewardship responsibilities. Second, operational liability and financial security imposed on operators during CCS development and operation. Third, effective measurement, monitoring, and verification (MMV) as part of risk mitigation, including reporting requirements and monitoring standards, as the ambiguity in MMV obligations allows companies to use low-cost approaches that potentially undermine risk identification (Rasool & Moiz Hashmi, 2025). Finally, it also evaluates contingency planning and response mechanisms for potential leakage and operational failures to ensure that CCS operations have well-established procedures for detecting, managing, and remediating risks.

3.2.2.4 Knowledge Development and Public Participation

The knowledge development and public participation dimension examines how CCS governance ensures transparency, enables stakeholder engagement, and facilitates institutional learning. While public acceptance is critical for obtaining social license, institutional learning across CCS networks accelerates technology development by incorporating lessons from CCS experiences during development and experimentation (Ashworth et al., 2010; Brunsting et al., 2011; Ma et al., 2022).

This dimension evaluates four key points. First, transparency of CCS data and public access to CCS information. This helps stakeholders, including local communities, researchers, and policy makers, to assess the effectiveness of CCS projects, particularly in mitigating potential risks. Second, stakeholder engagement mechanisms that allow affected groups to participate meaningfully in decision-making processes. As shown in Australia's case, where mandated public consultation is part of the requirement for CCS operators to obtain a storage site permit, strengthening institutional accountability (IEA, 2022; Romasheva & Ilinova, 2019). Additionally, this dimension will evaluate institutional learning and cross-project evaluation. As many CCS projects are situated in demonstration phases, this can accelerate continuous learning for technology development. Lastly, this dimension considers the inclusion of civil society in the governance process to strengthen accountability.

3.2.3 Integrating Governance Readiness into MLP

The Multi-Level Perspective (MLP) framework conceptualizes the socio-technical transition as dynamic interactions between niche innovations, dominant regimes, and landscape pressure. Within MLP, governance is embedded in the socio-technical regime as one of the institutional

conditions that shape technology development and diffusion. However, MLP is primarily designed to explain transition dynamics rather than systematically assess the governance conditions required for technology implementation (Geels, 2019; Markard & Truffer, 2008). As a result, while MLP identifies governance as an important component of the regime, it provides limited guidance for assessing governance readiness in the context of CCS implementation. To address this limitation, the study integrates the synthesized Governance Readiness Framework into MLP's analytical structure. As the framework is developed specifically to understand the CCS governance system, its dimensions are positioned within the socio-technical regime as illustrated in Figure 10. This integration provides a comprehensive assessment of socio-technical dynamics for CCS technology, combining a system-level understanding of socio-technical transitions with an operational assessment of governance readiness.

The integrated framework strengthens the analysis in this study in three ways. First, it allows for a more comprehensive assessment of socio-technical dynamics by explicitly examining governance in detail and how they shape interaction between CCS innovations and the existing regime. Second, it offers a systematic tool in diagnosing governance barriers within CCS systems, enabling the identification of institutional barriers that constrain the diffusion of CCS in the market and moving beyond the niche level. Lastly, this integration allows the study to capture the co-evolution between policy framework and technology development. This integration is important in the context of CCS study, as large-scale technology deployment does not depend on technological and market readiness but also on the credibility and robustness of governance arrangements.

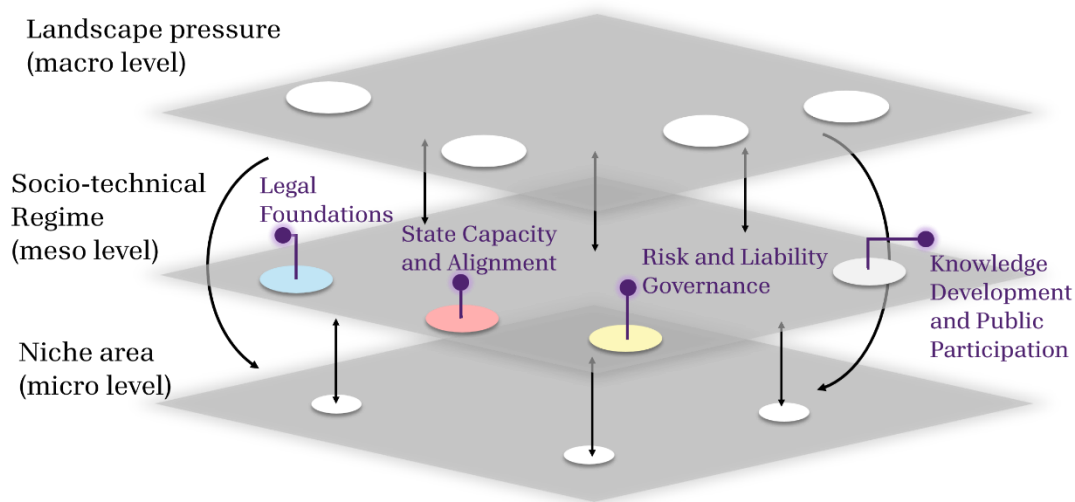


Figure 10. Governance readiness framework embedded in MLP framework

3.2.4 Diagnostic Intervention Framework

Building on the findings from socio-technical analysis and governance readiness assessment, this study identifies the barriers and develops strategic interventions to accelerate broader implementation of CCS in Indonesia. To support this, the study adopts a **Diagnostic Strategic Planning Intervention Framework** proposed by Malekpour et al. (2017) (See Figure 31 in Appendix A) to guide the development of interventions required for CCS acceleration. The framework provides a structured approach for translating complex system challenges through two stages: identifying key vulnerabilities and developing coping strategies. Given the long-term horizon characteristics, complexity, and uncertainty associated with CCS, this framework is appropriate for designing interventions that address systemic rather than isolated barriers.

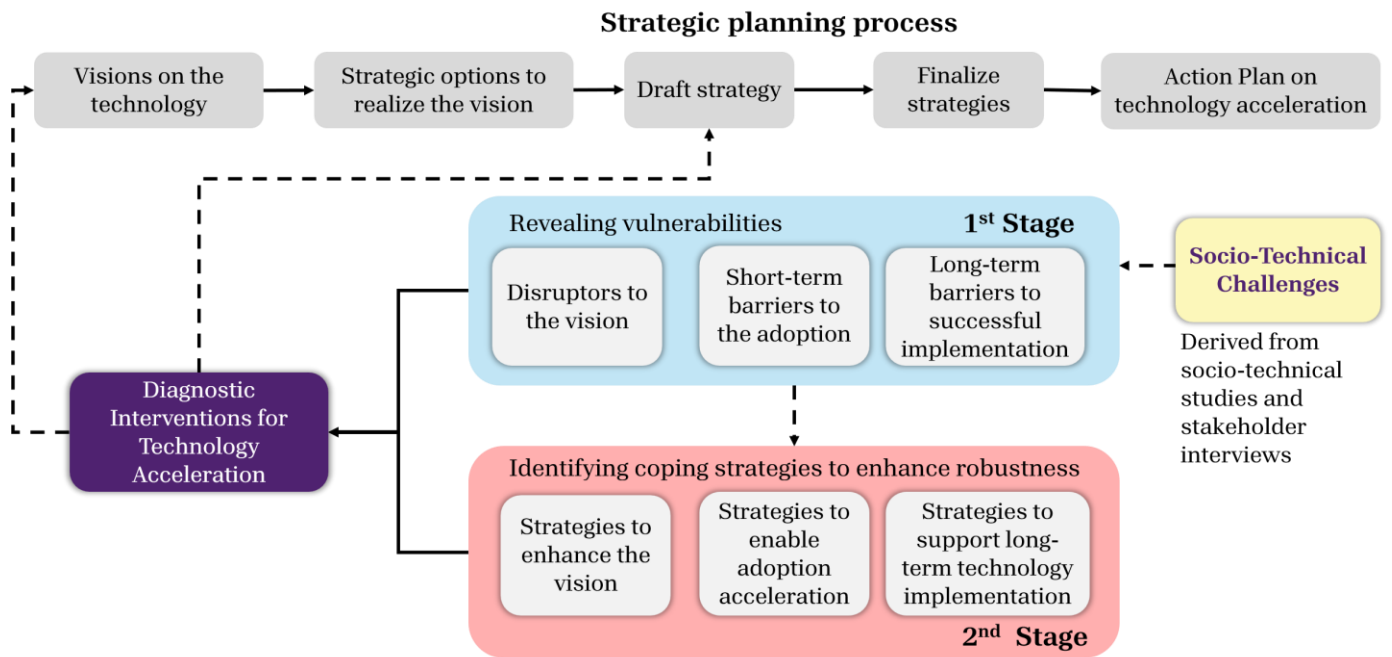


Figure 11. Strategic Interventions development process

Source: adapted from (Malekpour et al., 2017) with modifications for the study context

Table 2. Key vulnerabilities exploration steps to identify CCS deployment barriers

No	Key Vulnerabilities	Description
1	Exploring disruptions to the visions	Identify conditions that may paralyze the technology vision. Understanding CCS technology vision, assess whether CCS is embedded within national development strategies and recognize risks from changing political priorities.
2	Exploring short-term barriers	Identify immediate constraints affecting CCS implementation. Focus on the current business practices and conditions that require immediate intervention.
3	Exploring long-term barriers	Identify structural challenges affecting long-term scaling of CCS technology. This requires creativity in identifying the barriers, as the challenges may not be seen in the current business practices.

Table 3. Strategic Intervention Development for CCS acceleration

No	Strategies development step	Description
1	Exploring strategies to enhance visions	Through understanding the disruptors on the visions, strategies are developed to guide how to address the disruptors
2	Exploring strategies to strengthen technology adoption	Barriers identified for the short-term impacts will be addressed in this part by understanding the effect of barriers on technology adoption
3	Exploring strategies to support long-term success	In this part, long-term disruptors will be addressed by identifying strategies with long-term impact on CCS implementation

The framework is used and modified in this study, particularly in the first stage on vulnerability identification, to align with the analytical framework used in this research (see Figure 11). In the original framework, Malekpour et al (2017) used a workshop guided by PESTLE analysis ⁴ in identifying vulnerabilities. In this study, vulnerabilities are derived from the integrated MLP and Governance Readiness analysis, complemented by stakeholder interviews, particularly to identify technology vision disruptors and short-term barriers. This adaptation ensures that the proposed

⁴ PESTLE is analytical framework referring to Political, Economy, Social, Technology, Legal, and Environment.

interventions are grounded in the empirical findings generated throughout the study, while adopting the diagnostic logic of the original framework for developing strategies.

Stage 1: Revealing vulnerabilities (technology implementation barriers)

In this part, barriers are identified through the analysis from the socio-technical analysis, governance assessment, and stakeholder interviews, and they will be mapped into key vulnerabilities as shown in [Table 2](#). Barrier identification prioritizes critical vulnerabilities that have broad influence on CCS implementation at both national and corporate levels.

Stage 2: Identifying coping strategies for technology acceleration

In this part, the barriers identified from the vulnerabilities mapping will be further tested and addressed by developing effective strategies. The proposed interventions incorporate insights from stakeholder interviews and the global practices for CCS and other low-carbon technology adoptions. Interventions are further evaluated for their applicability in Indonesia's context and formulated for both national and corporate levels (see [Table 3](#)).

3.3 Data Collection Approach

This study employed multiple qualitative data collection methods to develop a comprehensive understanding of CCS dynamics in Indonesia. Data were collected through a combination of literature review and stakeholder interviews.

3.3.1 Desk Study Analysis

A systematic literature review was performed to gather secondary data from academic journal articles, policy documents, industrial reports, as well as publications from NGOs, media, governmental institutions, and private companies. [Table 4](#) presents the desk study approach and documents used to address the research questions. In Indonesia's policy documents, CCS and CCUS are addressed through the same regulation and policy frameworks; while the analytical focus on standalone CCS as climate mitigation, relevant documents for CCUS were also used to understand CCS ecosystem complexity in Indonesia.

Table 4. Literature search process used for socio-technical challenges assessment in this study

No	Search Type	Database	Publication selected	Search Query / Remark
1	Targeted literature search	Scopus	15	(Carbon capture storage Indonesia) AND (Assessment) LIMIT TO (Indonesia) LIMIT TO (Carbon sequestration)
2	Targeted literature search	Google Scholar	5	((("Carbon Capture and Storage" OR "CCS") AND "Indonesia" AND ("socio-technical transition" OR "political-economy" OR "challenges" OR "economic evaluation" OR "barriers"))
3	Targeted literature search	Google Scholar	9	(Low carbon development AND "Indonesia" OR ("Net Zero Emissions" OR "Decarbonization" OR "Transition"))
4	Targeted literature search	Institutions database	7	Related to national development plan, carbon market dynamics evaluation, energy and economic performance, update on CCS, and decarbonization pathways
5	Regulation document	Indonesia's regulation database	9	Regulations related to CCS, carbon pricing, carbon abatement, environmental, and energy businesses
6	Grey Literature	Media websites, Institution websites	10	Related to public perspectives, CCS updates, carbon pricing implementation, transboundary collaboration.

3.3.2 Stakeholder Interviews

This study employed semi-structured stakeholder interviews to address Sub-Research Questions 1-3, which include actors and networks, socio-technical conditions, and governance readiness. The interviews had two complementary objectives. **First**, they were used to validate findings from the desk study by examining whether literature-based assessments reflect the current reality of CCS in Indonesia. **Second**, they provided stakeholder perspectives on the relationship between actors, implementation challenges, governance conditions, and critical strategies required to strengthen Indonesia's CCS ecosystem. The interview findings therefore complemented the desk study by incorporating practical insights that could not be obtained from documentary sources alone. The interviews were performed during Phase 5 of the study (see [Figure 7](#)), guided by an interview protocol (see [Appendix F](#)) to ensure consistency.

Table 5. Stakeholders involved in interviews

Label	Stakeholder	Category	Role	Role in CCS system	Contribution to research questions
S1-G	Main Regulator Bodies	Government	Policy Analyst and Development	Policy design, regulation, permitting, national climate targets	Insight to policy objectives, regulatory frameworks, institutional coordination
S2-R	CoE-ITB – Centre of Excellence for CCS / CCUS - ITB	Knowledge Actor	Researcher	Knowledge production, technical assessment, policy advice	Understanding technology readiness, R&D gaps, cost ranges, long-term potential
S3-OGP	(Private) Oil and Gas	CCS Adopter	CCS Project Manager	Strategic investment decisions, project development	Insight to market formation, investment barriers and risks, institutional constraints, CCS corporate governance
S4-OGP	(Private) Oil and Gas	CCS Adopter	CCS Lead Engineer	Technology implementation, operational feasibility	Practical assessment, infrastructure readiness, human capital readiness, operational challenges, CCS corporate governance
S5-OGS	(SOE) Oil and Gas	CCS Adopter	CCS Senior Engineer	Technology implementation, operational feasibility	Practical assessment, infrastructure readiness, human capital readiness, operational challenges, CCS corporate governance
S6-NOGP	(Private) High emitter	Potential CCS Adopter	Climate Risk Analyst	Cross-sectoral CCS development, low-carbon project development	CCS technology diffusion, non-oil and gas perspectives on CCS adoption, low-carbon corporate governance
S7-NOGS	(SOE) High emitter	Potential CCS Adopter	Business Development	Cross-sectoral CCS development, low-carbon project development	CCS technology diffusion, non-oil and gas perspectives on CCS adoption, low-carbon corporate governance
S8-IO	ASEAN Centre for Energy (International organization)	Intergovernmental Actor	Technical Analyst and Advocacy	Intergovernmental governance, strategic coordination within Southeast Asia	Intergovernmental dynamics, Indonesia's position compared to neighbouring countries for low carbon and CCS projects
S9-NTT	ICCSC – Indonesia CCS Centre – National Think Tank and Coordination	Knowledge Actor	Consultant and Advocacy	Cross-actor coordination, knowledge diffusion	Insight into coordination mechanism, actors' collaboration, system-level bottleneck

The semi-structured interviews were conducted online with stakeholders who were directly involved in, or had expertise on, CCS development in Indonesia. As shown in Table 5, the stakeholder groups included government, knowledge actors, CCS adopters, potential CCS adopters, and international organizations. Participants were recruited through the snowball method; some were mediated through personal connections, and others were recruited through social media such as LinkedIn. However, public representatives in the interviews were not obtained because securing public representation proved difficult—both public affairs representatives from companies and affected members of the public were reluctant to engage, as public-related issues around extractive industries remain sensitive in Indonesia due to several historical social injustices. To mitigate this limitation, public participation and community-related issues were also discussed with all interview participants, enabling perspectives on these topics from multiple stakeholder groups.

3.4 Data Analysis

3.4.1 Interview Analysis: Text-Coding

The interview transcripts obtained from semi-structured interviews will be coded using Atlas Ti through a thematic approach to extract the insights from stakeholders about socio-technical dynamics of CCS implementation in Indonesia. This study adopted a combined deductive-inductive text coding approach. The deductive codes were adapted from CCS socio-technical studies as presented in Table 6, particularly Swennenhuis et al (2024) on system-level modelling of CCS dynamics and Markusson et al (2012) about a socio-technical framework capturing uncertainties in CCS deployment. These predefined codes provide analytical clarity and ensure alignment with the study's conceptual design. However, CCS system real-world context can extend beyond predefined codes; therefore, inductive coding was incorporated to capture emergent concepts and insights that were not covered in the initial code book. This combined strategy strengthens the analytical gap and supports the broader research approach in understanding CCS system dynamics. The final code used for this study can be found in Table 27 [Appendix E](#), combining deductive and inductive codes.

3.4.2 Validity and Reliability

This study applied a qualitative exploration approach guided by multiple frameworks. To ensure the rigor of the research, specific strategies were employed to enhance the validity and reliability of the study.

The study adopted methodological and data triangulation to strengthen the construct validity and findings. Multiple data sources from literature reviews and stakeholder interviews were analysed and compared to identify converging and diverging patterns. The semi-structured interviews were also used to validate findings from the literature review and provide practical perspectives to deepen the analysis. This reduces reliance on a single method and data resource, increasing the confidence level of findings in the study. Theoretical validity in this study was enhanced through the understanding and combining multiple frameworks that provide multiple lenses in understanding CCS implementation. The clear linkages between research questions, data sources, and developed constructs further support the internal validity.

Reliability of the study was ensured through the adoption of transparent and systematic data processes. Clear documentation was then performed for data collection and analysis procedures, including literature review selection, interviewee selection, and qualitative data coding processes.

To ensure reliability in applying multiple frameworks, a study operationalization document was developed to guide the findings synthesis through literature review. Additionally, an interview protocol was also developed to standardize the stakeholder interview process. This includes core questions to guide the semi-structured interview process, allowing for insights comparability across the interviews. Taken together, these approaches reinforce the robustness of the research design and strengthen the credibility of the study analysis.

Table 6. Code book used for deductive text-coding as an initial guide

Theme	Code	Description
Governance and Regulatory Support	Shared responsibility	Climate change mitigation in the country is shared between government, industries, and the public.
	Political support	Government backing to implement CCS as the climate mitigation strategy, including policies and incentives
	Long-term liability	Refers to the long-term commitment and risk associated with CCS, creating specific challenges in regulatory development and business planning
	Monitoring, measurement, and verification (MMV)	This refers to the activities that ensure the safety of CCS operation, especially geological storage. This includes monitoring, measurement, and verification of the CCS technology performance
	Policy supports	Regulatory and policy frameworks that are developed to govern CCS across its value chain: capture, transport, and storage
Decarbonization and CCS commitment	Government commitment	Developing and enforcing regulation to support long-term implementation of CCS
	Industries commitment	The ability of industries to make timely decisions regarding CCS projects, following through on the long-term stability of CCS implementation
Benefit and Economic Viability of CCS	Regional economic benefits	The implementation of CCS provides positive impacts in the region where it is deployed, including job creation, economic growth, and increased investment
	Business profit opportunity	CCS creates business profit through lower operational costs by reducing carbon tax payments or obtaining profit from storage fees or other mechanisms
	Value of GHG avoidance	The value associated with the benefits and avoided costs because of avoiding GHG
	Economic viability	This refers to the economic performance of CCS implementation, the level of economic benefit received by the operators from business perspectives
CCS Innovation and Development Dynamics	Carbon leakage	Unintended increased emissions in one region due to emission reduction in other regions. Also, the potential leak of carbon from the transport and storage activity, especially when it is located in the high populated area
	Seismic activity	CCS risk that potentially induces seismic activity, raising public concern, especially those who live in active seismic areas
	Consumers cost	The cost of implementing CCS is passed down to the customers
	Collaboration	Collaboration with parties that have a good reputation to implement the CCS, also to gain public trust for implementing this high-risk technology
	Variety of pathways	The available alternative options for decarbonization, including renewable energy, that may influence how CCS effectiveness in climate mitigation is perceived
	Technology integration	How each chain in CCS is connected and integrated, also refer to the implementation of CCS with the connection to other industrial sectors
	Public support	The social acceptance and endorsement for CCS to deploy
	Public awareness and knowledge	The level of understanding of the role of CCS in decarbonization strategies
	Public engagement	Active involvement of the public in CCS decision-making and implementation
	Institutional learning	Learning from experiences within the national CCS system as well as adopting experiences from other institutions to strengthen CCS policy, knowledge, and decision-making
	stakeholder knowledge	The level of technology understanding of CCS across stakeholders

Source: adapted from (Markusson et al., 2012; Swennenhuis et al., 2024)

Socio-Technical Conditions of CCS Implementation in Indonesia

This chapter discusses the actors and network within the CCS system in Indonesia, as well as the Multi-Level Perspective (MLP) conditions of CCS implementation as national carbon emission reduction efforts.

4.1 Actors and Network

The development of CCS in Indonesia is shaped by a diverse network of actors from government, industry, research institutes, international organizations, and civil societies. However, the current network is not evenly distributed. The current CCS ecosystem is dominated by oil-and-gas actors that have regulatory authority, technical expertise, and control over subsurface resources (Karki, 2026; Ramadhan et al., 2024). Although in 2024 new regulations allow broader CCS implementation beyond the oil-and-gas sector, participation from other industrial sectors is still limited, resulting in an actor network characterized by both path dependency and emerging contestation.

Figure 12 shows a network of actors within the CCS system in Indonesia, while Table 17 Appendix B explains the role of actors involved in Indonesia's CCS systems. Government institutions play an important role in accelerating CCS through strong political commitment and clear regulation and policy frameworks. Ministry of Energy and Mineral Resources (MEMR) occupies the most influential position as the main regulator of CCS in Indonesia because they have high political power in storage site exploration and operation, as only permit holders approved by MEMR can perform such activities. MEMR is also the main authority responsible for Indonesia's energy security, including both fossil-fuel and renewable-based energy. Ministry of Environment and Forestry (MEF) is responsible for enforcing carbon pricing policies and climate mitigation efforts. These regulatory frameworks create opportunities for financial incentives in carbon abatement initiatives, including CCS. Currently, the governance of the carbon pricing mechanism is coordinated by a dedicated steering committee led by the Coordinating Ministry of Food Affairs (CMFA), which is also responsible for MEF. For green investment, the Ministry of Finance (MF), Danantara (managing State-Owned Enterprise assets), and the Ministry of Investment and Downstream Industry (MIDI) together are responsible for green investment in Indonesia, aligning international and public funding mechanisms to support low carbon project including CCS (MEMR, 2024a; A. D. Setiawan & Cuppen, 2013; Wijaya et al., 2025). Additionally, as storage sites are state assets, MF together with MEMR are also responsible for managing the storage sites transferred to the state after the CCS site closure. Finally, the National Development Planning Agency (NDPA) coordinates the strategic agendas in supporting national development key priorities, including green economy transition where CCS is considered as one of the long-term strategies.

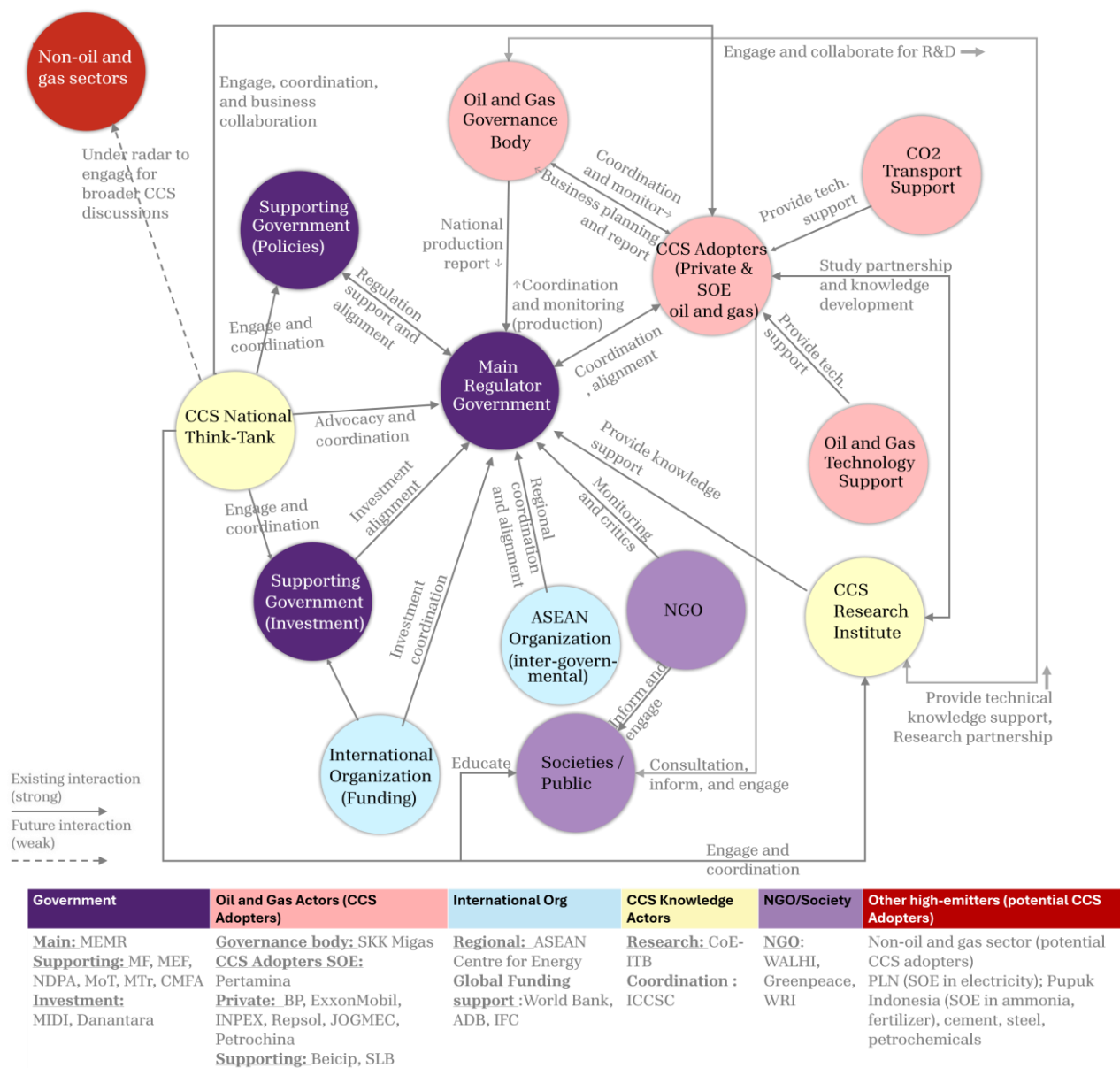


Figure 12. Network of actors within CCS systems in Indonesia⁵

Actors within the oil and gas industry contribute to the CCS demonstrations in Indonesia as this sector becomes a focal point for CCS introduction. SKK Migas, as the oil-and-gas task force under MEMR, is responsible for upstream activities, mainly for initiatives associated with production enhancement, including CCUS-EOR. Pertamina, as a state-owned oil and gas company, leads several CCS and CCUS initiatives and is mandated to monetize depleted oil and gas fields for continued hydrocarbon production while also securing geological storage for the international and domestic market. International oil and gas companies contribute through project development, geological assessment, and investment. Some CCS projects are under these international players collaborating with Pertamina. Supporting oil-and-gas actors such as SLB and Beicip Franlab, offer technology supply, advisory, and technical evaluation, while providers of CO₂ transport technology

⁵ MEMR: Ministry of Energy and Mineral Resources; MF: Ministry of Finance; MEF: Ministry of Environment and Forest; NDPA: National Development Planning Agency; CMFA: Coordinating Ministry Food Affairs; MIDI: Ministry of Investment and Downstream Industry; JCM: Japan-Credit Mechanisms; ADB: Asian Development Bank; IFC: International Funding Coordination; ICCSC: Indonesia CCS Center; CoE: Centre of Excellence

such as pipeline and shipping are also critical in supporting CCS value chain development (ICCSC, 2025a; Pertamina, 2026).

MEMR and oil-and-gas actors form the dominant coalition within Indonesia's CCS ecosystem in extending hydrocarbon production, maintaining revenues and avoiding structural changes in the energy system. They have strong capacity to use CCS narrative to prolong the lifetimes of oil and gas fields through CCUS-EOR, potentially limiting CCS applications in broader sectors. Additionally, with strong control over subsurface data, licensing, and early CCS project pipeline, these actors can frame CCS in policy documents as a pragmatic and effective option for large-scale emission reduction to strengthen the policy of oil and gas continuation (MEMR, 2024a; WALHI, 2024).

However, this dominance is increasingly contested by high emitters outside oil and gas. Potential future CCS adopters include SOEs such as Perusahaan Listrik Negara (PLN) in the electricity sector and Pupuk Indonesia Holding in the fertilizer and petrochemical industry, alongside private actors in the cement, steel, and petrochemical sectors. These industries recognize CCS as a potential emission mitigation within their industrial activities and have growing interest in exploring its technical and commercial feasibility (Bokka & Lau, 2023). However, they remain peripheral within the current CCS ecosystem, where governance arrangements and early project implementation are concentrated within the oil-and-gas sector. As a result, the oil-and-gas-centric framing of CCS limits broader industrial participation, despite these sectors representing the greatest demand for CCS (Kuckshinrichs & Hake, 2015).

Within these evolving CCS interactions, a dedicated national think tank and coordination network, Indonesia CCS Centre (ICCSC), acts as an intermediary institution to facilitate policy dialogues, actor coordination, and capacity building among CCS stakeholders (ICCSC, 2025a). Additionally, a dedicated research centre named Centre of Excellence for CCS/CCUS led by Institut Teknologi Bandung (CoE-ITB), contributes to CCS knowledge development and early policy-making processes (CoE-ITB, 2022). LEMIGAS, as a national oil and gas research centre, is also engaged, as they already know, in oil and gas operation-related research. Both CCS-dedicated institutions, ICCSC and CoE-ITB, support CCS acceleration through strengthening the knowledge ecosystem and collaboration with existing and potential CCS adopters.

International organizations and regional institutions further expand Indonesia's CCS network by providing financial support, technical expertise, and regional collaboration opportunities. Organizations such as the World Bank, Asian Development Bank (ADB), and International Finance Corporation (IFC) support CCS feasibility studies and its funding (Almendra et al., 2011; ICCSC, 2025a; Pertamina, 2026). At the regional level, the ASEAN Centre for Energy (ACE) facilitates intergovernmental cooperation on CCS, including cross-border CCS operation. These partnerships have also influenced Indonesia in developing a cross-border regulatory framework (MEMR Regulation 16/2024, 2024).

In promoting large-scale CCS deployment, CCS technology must align with national development plans and national project priorities developed by NDPA. Together with MEF, this actor has strong power and influence in framing CCS technology, whether it is considered a national technology priority in carbon abatement. The CCS expansion will also require government actors outside the network, such as the Ministry of State-Owned Enterprises (MSOE) and the Ministry of Industry (MoI), to integrate CCS technology within national industrial development (JETP, 2025; RJPMN, 2025). This also includes alignment within related SOEs to support CCS adoption; for example,

finance sectors can perceive CCS as a strategic project supported by the government, resulting in lower risk perception in investment mechanisms.

At the same time, renewable energy actors raise objections to a CCS-heavy pathway because it potentially moves investment from renewable energy development, where they also rely on international funding support for low-carbon development. Prioritizing CCS as a key decarbonization pathway is seen as reinforcing fossil fuel lock-in and delaying structural reforms in the national energy landscape with a higher contribution of renewables. Their influence is weaker in the CCS policy-making process but visible in public discourse. The same opposition is also voiced by environmental NGO such as WALHI and Greenpeace, arguing that CCS projects should not be advanced, undermining the state's capacity in managing long-term CCS risks (WALHI, 2024). Although these actors have relatively limited influence over current CCS policymaking, they play an important role in shaping public discourse and challenging the legitimacy of CCS-led climate mitigation.

4.2 Landscape-Level Pressures for CCS in Indonesia

Building on the actor-network discussed in Section 4.1, the following MLP analysis examines how interactions among these actors are shaped by landscape pressures, contested within the socio-technical regime, and contributed to emerging niche development. This section discusses landscape pressures that shape low-carbon development in Indonesia, including CCS.

4.2.1 Global Climate Governance and Decarbonization Pressure

Under the Paris Agreement, Indonesia updated its Nationally Determined Contribution (NDC) in 2022, targeting unconditional emission reduction by 31.89% (917 MtCO₂e) and conditional reduction of 43.2% (approximately 1,139 MtCO₂e) by 2030 in comparison with the business as usual (BAU) scenario. To achieve these targets, Indonesia prioritizes energy sector emission reduction, particularly fossil-fuel-dependent industries (S. Setiawan et al., 2021), as 85% of the national energy landscape is dominated by fossil fuel (see Figure 1). To strengthen this commitment, Indonesia also submitted the Long-Term Strategy for Low Carbon and Climate Resilience (LTS-LCCR). However, CCS is not explicitly prioritized in the NDC and is only positioned in LTS-LCCR as a long-term option for coal-fired power plants despite Indonesia's high geological storage potential (LTS-LCCR, 2021).

Interview findings reveal contrasting perceptions regarding how global climate governance influences CCS development in Indonesia. While all stakeholders generally acknowledge the existence of climate pressure, they differ in whether the pressure originates from climate commitment or market dynamics.

Most industrial stakeholders, both CCS and potential CCS adopters, argue that the motivations often come from global market pressure for decarbonization, including the European Carbon Border Adjustment Mechanism (CBAM) that increases the demand for blue ammonia and low-carbon steel and growing regional carbon market demand for geological storage as the primary drivers to participate in CCS investment. All the interviewed stakeholders agree that global market incentives are more influential than domestic climate commitments in motivating high-capital firms to participate in CCS and other low-carbon projects.

"We see potential international market for CCS especially from Singapore, Korea, Japan. We participate in the tender of Singapore-Hub for carbon storage. For domestic, companies associated with joint-venture from Korea or Japan show interest" (S5-OGS)

“The international market is promising for blue ammonia and CCS because we get high incentives from them. Meanwhile, domestic incentives are low, making CCS more reliant on foreign markets than domestic” (S2-R)

These changing global market dynamics also shape regulatory acceleration. Several stakeholders, particularly CCS adopters, observed that the regional competition has encouraged the government to establish enabling CCS regulations to secure Indonesia’s strong position within the Asia-Pacific market. The growing demand from other countries such as Singapore, Korea, and Japan that have stronger climate policies motivates the government to develop cross-border CCS operation (see Figure 13) (Wahyudi, 2024). ASEAN regional climate framework further strengthens cross-border collaboration opportunities, identifying CCS as a potential option for regional climate mitigation (ASEAN Centre for Energy, 2025).

“I can see governments move faster when we show that neighbouring countries are more progressive than us in securing legal foundations for CCS. This is more convincing than showing the potential of rejection from the global market due to weak legal supports” (S3-OGS)

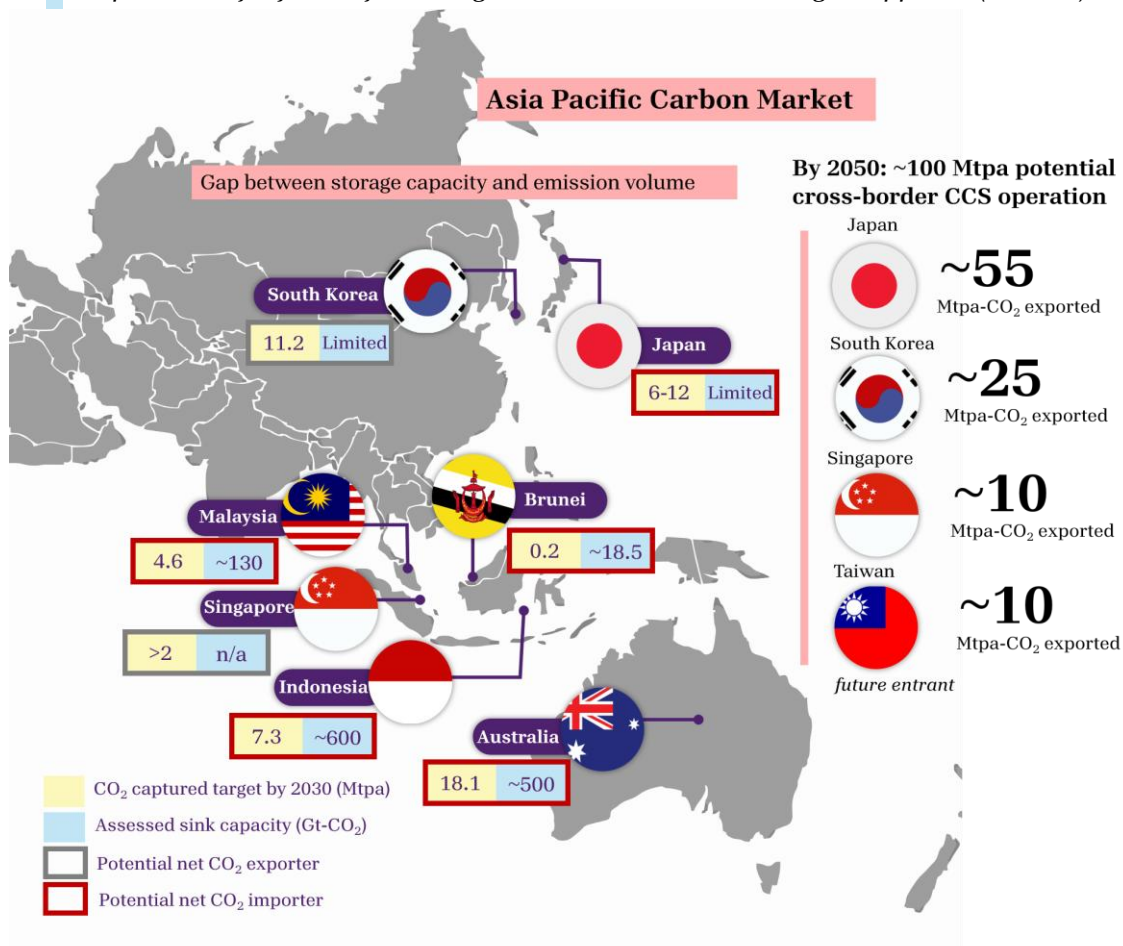


Figure 13. Market potential for Indonesia as regional storage hub
 Sources: adapted from (ICCSC, GMDC, BCG)

In contrast, several stakeholders such as CCS Manager, Technical analyst from ICCSC, and Climate Risk Analyst from potential CCS adopter perceived the broader climate change narrative itself has weak influence on domestic low-carbon project motivation. They argued concerns over global warming, the Paris Agreement, or Indonesia’s NDC commitment are insufficient to mobilize industrial actors toward low-carbon investments, unless they are translated into tangible business opportunities through trade, investment, or carbon markets. As one stakeholder noted,

“In my opinion, decarbonization efforts are a money game, including CCS. Government and other actors pursue it because of foreign markets, but I don’t see they are motivated to do the same for domestic, [...] So, it’s seen as a business opportunity and money game in decarbonization rather than a push for national decarbonization” (S6-NOGP)

The findings indicate that global climate governance influences Indonesia’s low-carbon investment through market-based economic pressure, where demand reshapes industrial priorities rather than as a climate commitment. The global climate policies reshape export markets, investment opportunities, and regional competition, creating commercial incentives for CCS adoption. As a result, global climate pressure is not translated as an obligation to reduce emissions but rather as an opportunity to maintain industrial competitiveness and access emerging low-carbon markets.

4.2.2 Indonesia’s National Development Priorities

Indonesia’s long-term development pathways are guided by the National Long-Term Development Plan 2025-2045 (RPJPN), which positions green economic transformation as one of strategic priorities toward *Golden Indonesia 2045*. This vision is operationalized through the National Medium-Term Development Plan (RPJMN) 2025-2029, translating long-term ambitions into concrete development targets and national priority projects. Beyond being planning instruments, both RPJPN and RPJMN also function as political signals to communicate Indonesia’s priorities to attract strategic investments, including low-carbon projects. When projects are listed within national key priorities, they have a stronger position in securing foreign and private investment as they are perceived with high political legitimacy (Voelker et al., 2008).

Building on the actor-network discussed in [Section 4.1](#), NDPA (BAPPENAS) plays a critical role in framing the national priorities, while MEMR translates them into energy policies. Within this framework, CCS is increasingly viewed as a long-term strategic solution to manage both climate mitigation and achieving national energy security targets (BAPPENAS, 2025). However, among the listed 77 national priority projects in RPJMN, only one CCS/CCUS project is listed in the document: Tangguh CCUS developed by BP (RPJMN, 2025). Although this project is often framed as the CCS major entry point in Indonesia, the project primarily reflects CCUS-EGR, where hydrocarbon production is the main motive instead of decarbonization. Nevertheless, this government framing introduces institutional legitimacy for CCS investment and signals growing government recognition of CCS within national development planning, although it is still limited to energy production. Interview findings support this interpretation; most stakeholders perceive RPJMN and RPJPN as political tools to promote low-carbon projects to attract investors, especially when they are formally recognized in the national priorities. However, industrial stakeholders also noted a gap between these formal commitments and their implementation, arguing that political support for the low-carbon transition remains inconsistent.

“The problem is, even though the governments say, “this is the priority for net zero 2050”, then become net zero 2060, this is not visible in practice. After all, it depends on which political power will support those efforts, even though it is said priority; without political support it’s going nowhere” (S3-OGP)

These findings suggest that national development priorities create political legitimacy for CCS, but this legitimacy is selectively reinforced through dominant actors in the energy sector. Instead of broadening CCS as a national climate pathway across hard-to-abate sectors, current development priorities continue to favour projects aligned with Indonesia’s existing energy and hydrocarbon targets, reinforcing oil-and-gas-centric development identified in the actor-network analysis.

4.2.3 Weak Sustainable Finance and Investment Ecosystem

Low-carbon development funding in Indonesia relies on a mixed funding structure with approximately 34% from domestic public funding, and the remaining 66% will be mobilized from private and international support (Ministry of Finance, 2020). This structure strengthens the need to improve Indonesia's investment attractiveness as a critical prerequisite to accelerate climate mitigation initiatives. To facilitate climate finance coordination, Indonesia's government developed the Green Climate Fund (GCF) as a focal point mechanism involving key institutions such as the Ministry of Environment and Forestry (MEF), the Ministry of Finance (MoF), National Development Planning Agency (NDPA) (Ministry of Finance, 2020), while international organizations such as the World Bank, ADB, and IFC support project financing, particularly during feasibility studies.

In parallel, the Financial Services Authorities of Indonesia (OJK, *Otoritas Jasa Keuangan*) introduced a sustainable finance roadmap to strengthen the sustainable finance ecosystem (S. Setiawan et al., 2021). Financial incentives have also been introduced, including financial discounts for banks and other credit organizations to participate in low-carbon financing and access international climate funding from global organizations such as the World Bank, ADB, and IFC through green credit mechanisms.

Despite these initiatives, the sustainable finance ecosystem remains underdeveloped, limiting the availability of capital for low-carbon investment, including CCS. Low-carbon projects are often perceived as high-risk investments due to uncertain returns, high upfront capital requirements, and long investment horizons. Consequently, financial institutions impose high financing costs for low-carbon projects, including CCS (Liebman et al., 2019). At the same time, there are limited consequences for banks to support carbon-intensive sectors, weakening the incentives to expand green credit financing (S. Setiawan et al., 2021). The expansion of green finance is further constrained by higher transaction and assessment costs with sustainable lending. Sustainable lending also requires additional environmental and social assessments, increasing transaction costs while providing very limited financial returns compared with conventional lending (Yuniar et al., 2025). Finally, the absence of national standard criteria for green project classification creates uncertainty within the financial sector. Banks often struggle to determine eligibility for green financing due to a lack of definitions regarding project categories, scales, and environmental performance indicators (S. Setiawan et al., 2021). This ambiguity constrains the development of a robust green finance market and discourages banks from promoting green-credit mechanisms.

The underdeveloped green finance market therefore creates systemic constraints on the scaling of emerging low-carbon technologies, including CCS. CCS exemplifies this finance challenge because its high upfront investment, uncertain revenue stream, and long payback period amplify investor risk perception. Consequently, only firms with high capital availability, such as well-capitalized oil-and-gas companies and big state-owned enterprises, can be involved in the project development, while potential adopters from other industrial sectors face barriers to participating, reinforcing the actor dynamics discussed in Section 4.1.

Across interviewed stakeholders, sustainable finance ecosystems were consistently regarded as one of the most influential landscapes in shaping the pace of low-carbon development, highlighting the importance of strengthening green finance ecosystems to promote application of low-carbon projects.

4.2.4 Political-Economic Contestation in Decarbonization Policy

Indonesia introduced carbon pricing regulations in 2021, such as Presidential Regulation No 98/2021 and Law no 7 of 2021, along with a carbon trading platform named Indonesia's Carbon Exchange (IDX Carbon). Since then, the carbon market has remained limited to coal-fired power plants (CFPPs) with a hybrid mechanism combining cap-and-trade and a fallback carbon tax. After three years of implementation, the carbon market performed below expectations mainly due to a lack of clarity in measurement, reporting, and verification (MRV), unclear trading procedures, political resistance, and business pushback (Yustika, 2025). To strengthen the framework, Indonesia's government issued an updated legal umbrella for carbon pricing (Presidential Regulation No 110/2025) to improve cross-ministerial collaboration coordinated by a dedicated steering committee led by CMFA.

Despite these regulatory initiatives, carbon tax policy implementation has faced significant political contestation, fragmented institutional support, and competing political-economic interests (Sunanda et al., 2025). Limited political commitment across government institutions has constrained the prioritization of carbon pricing policy within the national policy agendas. This resistance is further reinforced by strong influence by fossil-fuel industrial actors in policy-making given their significant contribution to national economic growth (Dyarto & Setyawan, 2021). Interview findings show that many business actors tend to oppose stronger carbon pricing, including carbon taxes. Political resistance is also evident within parliament, where business elites account for 61% of members in the 2024-2029 legislative (Indonesia Corruption Watch, 2025), raising concerns about potential conflict of interest in carbon pricing policy development. Most stakeholders in interviews position this political contestation as the most influential in low-carbon project progress, constraining its implementation due to weak carbon pricing mechanisms.

"The carbon regulation issue is not a new one [...] there have been many lobbying to postpone, 2021, then to 2025 with minimum price. The ones doing the lobbying are, of course, business associations. So, I personally haven't seen a "way out." With the current state of industry and government, I don't think there's any authority that can provide a definitive answer" (S2-R)

These political-economic dynamics are further intensified by persistent concerns over corruption and weak institutional transparency. Corruption increases transaction costs by creating incentives to obtain permits, licenses, or approvals through informal channels, encouraging business actors to secure political connections rather than productive investments (WHITE, 2006). While large corporations often have the financial resources and political connections to navigate these conditions, small firms often face barriers to market participation (Alfada, 2019; N. R. Putra & Linda, 2022). Interview findings reveal that while all stakeholders acknowledge the high corruption practices in Indonesia, CCS adopters from large corporations argue that corruption does not necessarily deter investment in Indonesia. This further suggests that corporations with greater institutional experience, financial resources, and government relationships are better positioned to navigate regulatory uncertainty compared to smaller or emerging actors. As a result, corruption does not necessarily discourage large-scale investment but reinforces unequal access to Indonesia's CCS emerging markets while weakening investor confidence more broadly.

"At the business level, the challenges are different. Corrupt practices persist, and regulations are often unclear. Rules can change suddenly, leaving businesses with a sense of uncertainty. This makes them (high emitters) hesitant to invest in new technologies or costly decarbonization efforts." (S5-OGS)

Although CCS receives growing political attention, these political-economic contestations continue to constrain the development of a stable and credible low-carbon investment environment.

4.3 Regime-Level Conditions of CCS Deployment in Indonesia

Building on the actor-network analysis, this section discusses four key regime-level conditions that shape CCS deployment in Indonesia. These conditions reflect the dominant industrial practices, policy priorities, and shared understanding within the actors involved in the CCS system.

4.3.1 Production-Oriented Energy Regime and CCS Development

Building on the actor-network analysis in [Section 4.1](#), Indonesia's socio-technical regime is strongly shaped by the dominant influence of MEMR and oil-and-gas actors. Indonesia's energy policy continues to prioritize domestic oil and gas production as part of the national energy security plan. In 2024, Indonesia's national oil and condensate consumption reached 1.7 million barrels per day (mbpd) while domestic production only covered approximately 51% ([MEMR, 2025a](#)), creating high dependence on imported oil. Addressing this, MEMR has developed a roadmap for oil and gas production targeting 1 mbpd oil and 12 BSCFD gas by 2030, improving national energy security. To realize this, MEMR developed a task-force team focusing on production optimization, including CCUS-EOR and storage site exploration ([EIA, 2025](#); [MEMR, 2025b](#)). Consequently, the government focuses on incentivizing oil and gas industries to increase hydrocarbon production and untap potential of underexplored basins ([Mashari, 2025](#)).

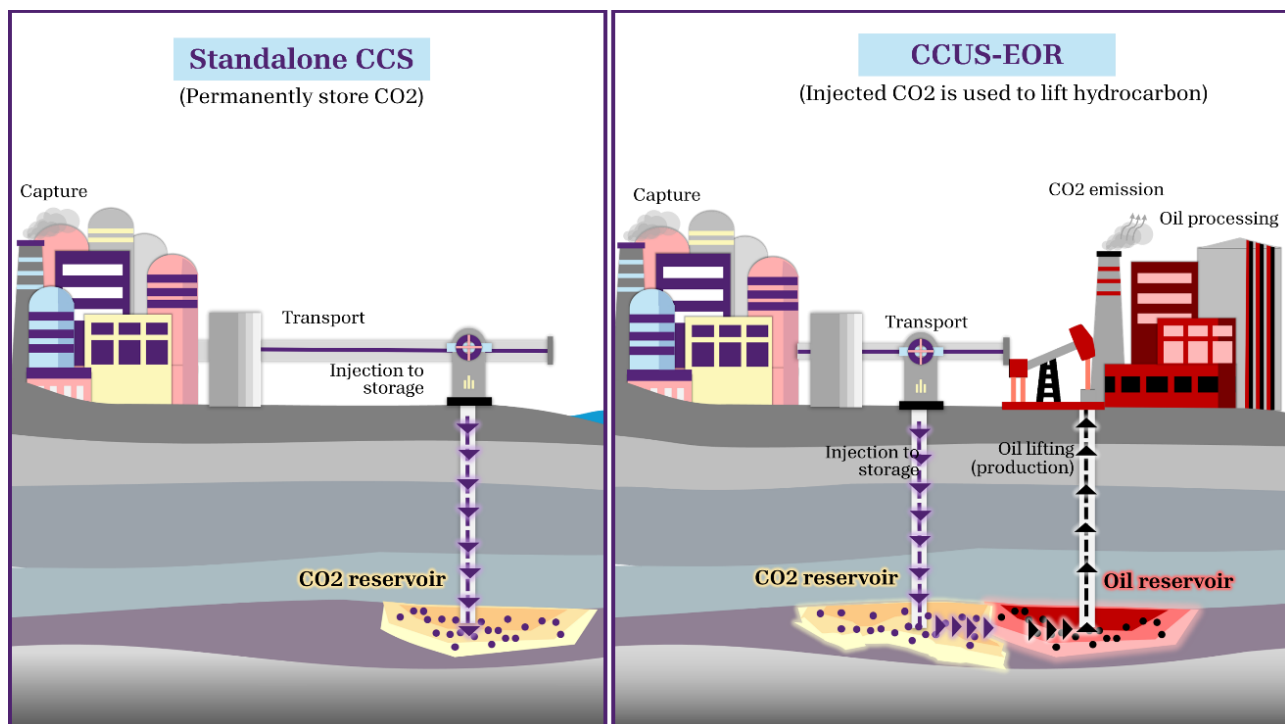


Figure 14. CCUS-Enhanced Oil Recovery (EOR) process compared to standalone CCS

Stakeholder interviews show that production optimization remains institutionally prioritized over decarbonization. Oil and gas stakeholders recognized that emission reduction efforts within the oil and gas sector receive stronger support when they contribute directly to production enhancement or energy security objectives. This orientation is reflected in the structure of MEMR, where dedicated bodies and policy initiatives exist for CCUS-EOR linked to production, while there is no

similar institutional support for CCS as a climate mitigation. This further highlights inconsistencies between the public decarbonization narrative, where they show CCUS as a decarbonization pathway, while in practice they understand CCUS-EOR is valued for hydrocarbon production (see Figure 14 for differences between CCS and CCUS-EOR).

“For the current leadership of the Ministry of Energy and Mineral Resources, one of the main focuses is increasing oil and gas production for domestic needs. This priority is quite high because the goal is clear: reducing dependence on imports.” (S1-G)

“So sometimes flaring isn't even a problem, even though it increases carbon emissions. They even emphasize that emissions shouldn't be reduced if it impacts production; increasing emissions is permissible if it supports oil and gas production” (S3-OGP)

Potential adopter stakeholders from other high emitters expressed less awareness of these institutional arrangements, but they shared a similar interpretation of government priorities. They perceive that government support is generally directed towards projects demonstrating clear economic returns and potential to lower import dependency, rather than viewing climate mitigation as the principal driver.

This production-oriented regime significantly shapes the direction of CCS implementation in Indonesia. Existing projects such as the Abadi CCS project are closely linked to LNG commercialization, as CCS enables the reduction of CO₂ content in feed gas to meet LNG market specifications (N. Putra, 2025). Similarly, CCUS-EOR is considered a more economically viable pathway than CCS standalone, as it generates additional revenue through increased oil production (Rakhiemah & Xu, 2022). CCUS-EOR can both extend field lifetimes and improve recovery factors, enhancing production, which aligns closely with MEMR and SKK Migas priorities. CCS standalone is perceived as not viable due to limited policy incentives (Rasool & Moiz Hashmi, 2025).

As a result, CCS development in Indonesia is largely conditioned by the existing oil and gas business regime. CCS implementation receives strong support when it reinforces the energy security objectives and production targets within the oil and gas sector, rather than as a climate mitigation. As a result, the dominant oil-and-gas actors identified in Section 4.1 continue to shape the direction of CCS development, while broader application remains comparatively limited.

4.3.2 Weak Carbon Pricing and Economic Incentive Structure

As highlighted in the landscape discussion, Indonesia introduced the carbon pricing regulations (see Figure 16) with an entry point limited to coal-fired power plants and forestry due to their high emission contribution. However, the current carbon pricing mechanism remains economically weak. Indonesia's carbon tax is set at IDR 30,000/tCO₂-eq (~EUR 1.8/tCO₂-eq), while the carbon market price reached around IDR 96,000/tCO₂-eq (~EUR 5.5/tCO₂-eq). Both values are lower than Indonesia's fossil fuel subsidies at approximately EUR 7.8/tCO₂-eq, resulting in a negative net effective carbon rate (OECD, 2024). Consequently, this carbon pricing provides weak economic signals for industries to reduce emissions through technological investments such as CCS.

Learning from the commercial CCS projects discussed in Chapter 2, stronger carbon pricing is a key enabler of CCS deployment. Norway, for example, combines a high carbon tax/penalty (EUR 100/tCO₂-eq) with the EU Emissions Trading System (ETS) (~EUR 60-80/tCO₂-eq) (Chau, 2024), creating substantially stronger incentives to engage with CCS (see Figure 15). In contrast, Indonesia's current mechanism makes it more economical to pay the tax rather than invest in CCS.

Interview findings strongly reinforce this concern. Government, industry, and knowledge actors consistently positioned weak economic incentives as the most influential constraint in developing CCS projects. Stakeholders also emphasize that Indonesia lacks both strong penalties for emissions and attractive incentives for low-carbon investments, making standalone CCS financially unattractive for the domestic market.

“I think it's the financial ecosystem is the most important. Because there are two drivers of CCS: reward and punishment—either through incentives or carbon taxes. For example, Norway has a high carbon tax of USD 100/ton, Singapore as well USD35/ton; that's why they are starting so many CCS initiatives, [...] Well, in Indonesia, neither of these exist—neither a strong carbon tax nor incentives. That's why our financial ecosystem is still weak, and that's the most crucial factor” (S9-NTT)

“[...] relying solely on the domestic market makes CCS economically unviable. Industry players would prefer to pay a low carbon tax rather than inject CO₂, as the injection costs are much higher. This is currently one of the main obstacles to CCS development in Indonesia” (S5-OGS)

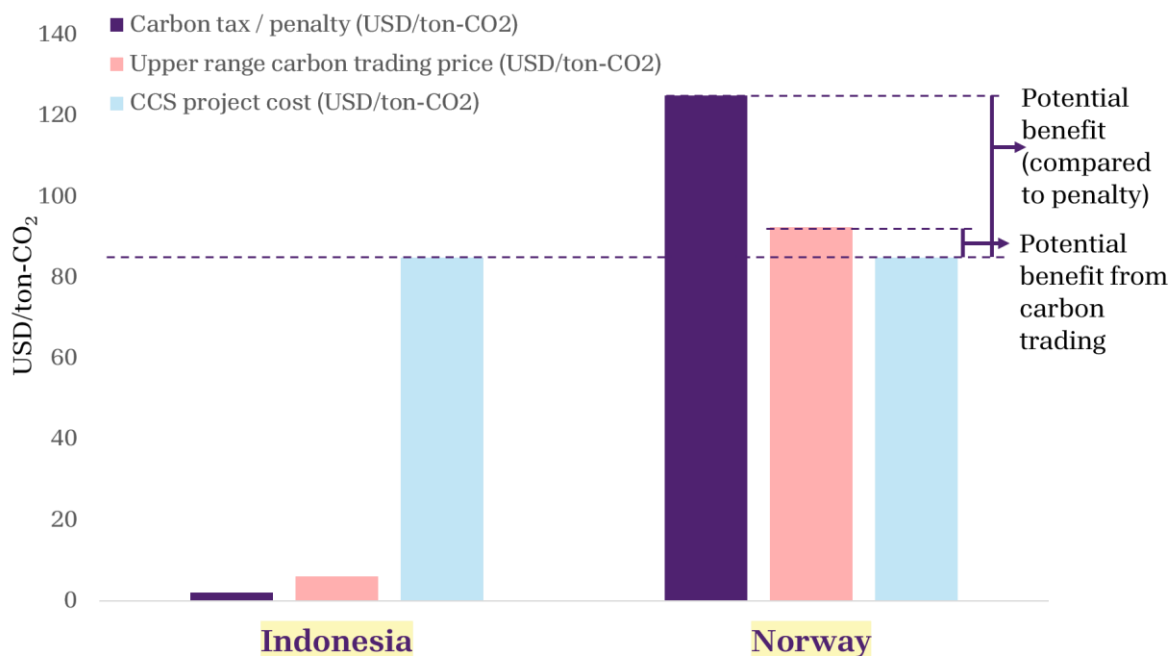


Figure 15. CCS economic comparison between Indonesia and Norway

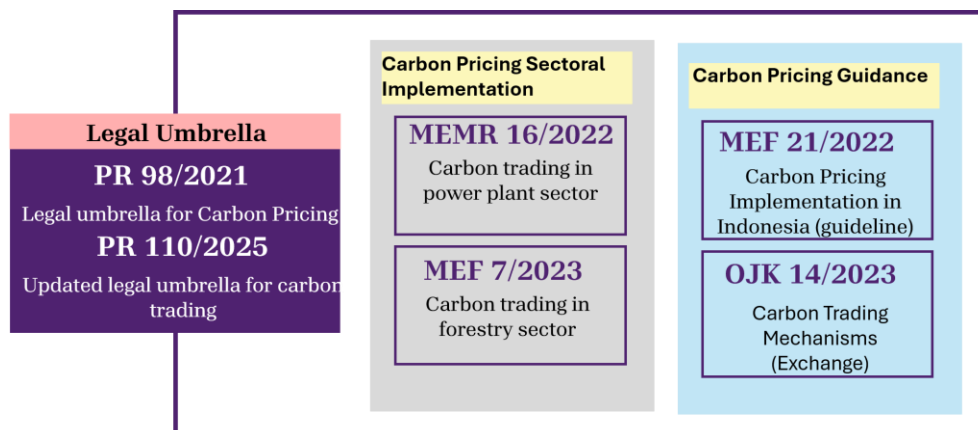


Figure 16. Indonesia key regulatory frameworks for carbon pricing mechanisms

Source: synthesized from (JETP, 2025; PwC, 2024)

For CCS investment, carbon pricing functions as a central mechanism in determining economic viability, particularly for CCS standalone projects. The existing low carbon economic value constrains CCS implementation, especially when it is not integrated with other revenue streams such as additional hydrocarbon production (EOR) and cross-border storage services (Mashari, 2025). As a result, the existing incentive structure further reinforces a regime condition where CCS implementation remains commercially dependent on fossil-fuel production and regional cross-border activities rather than driven by decarbonization incentives alone.

4.3.3 Fragmented Societal and Institutional Understanding of CCS

A key regime condition shaping CCS implementation in Indonesia is the fragmented understanding of CCS across actors. While CCS knowledge is relatively developed among MEMR, oil-and-gas actors, and dedicated CCS institutions, it remains limited across many government institutions, other high emitters, and the wider public.

Fragmented understanding exists at the institutional level. CCS knowledge remains concentrated within oil and gas actors such as MEMR and CCS adopters, while other ministries and other high-emitter sectors often have limited understanding of CCS technology and its role in decarbonization (Rimbono et al., 2025; L. Yusgiantoro et al., 2025). Interview findings show that CCS adopters and knowledge actors frequently need to educate regulators outside MEMR about CCS before discussing strategic technology implementation. Similarly, potential CCS adopter stakeholders have to educate managerial-level actors about CCS technology before moving to strategic discussion on potential CCS adoption for their low-carbon strategies. These conditions create coordination challenges across ministries and slow broader institutional alignment for CCS deployment.

“The problem is, the Ministry of Environment and Forestry doesn't fully understand the concept of CCS. [...] what we're doing now is providing education to the Ministry of Environment and Forestry and other ministries. For the MEMR, they already understand much better because they are the technical ministry for this. But for other ministries, the education process still needs to be strengthened.” (S5-OGS)

Fragmented understanding is also evident at the societal level. Public awareness of CCS remains limited even in highly educated areas such as Jakarta, and is often lower in rural regions where CCS projects are likely to be implemented because they have limited access to information and public discourse about climate change (Mulyasari et al., 2021; Sitinjak et al., 2023). This creates challenges for risk communication, public consultation, and social acceptance, particularly regarding concerns over environmental and health impacts. This concern is voiced by NGOs, criticizing the low transparency to the public regarding potential CCS risks and the robustness level of the mitigation plan (Rimbono et al., 2025; WALHI, 2024). Interview findings further strengthen this; industrial, government, and knowledge stakeholders acknowledge that public understanding is very low not only about CCS but also climate change in general. However, interview findings also indicate that industrial actors generally perceive public awareness as a low priority in CCS development, suggesting that societal acceptance is not yet considered as a major determinant in existing project decision-making.

“In fact, people are already feeling the impacts of climate change [...] However, they don't necessarily understand the causes of this. We need to educate people about emissions and their impact on daily life to create public pressure for low-carbon development.” (S4-OGP)

This fragmented understanding further reinforces a regime condition where CCS implementation remains heavily dependent on incumbent oil-and-gas actors. Knowledge and technical authority are concentrated within a limited group of stakeholders. Broader societal perception and cross-sectoral coordination for CCS as a national climate mitigation pathway remain relatively weak.

4.3.4 Regulatory Institutionalization for CCS Development

Indonesia has recently established dedicated regulatory frameworks for CCS implementation (see Figure 17). In 2024, the Government of Indonesia introduced President Regulation 14/2024 and MEMR Regulation 16/2024, expanding the CCS legal basis for cross-sectoral and cross-border implementation, while the previous CCS framework (MEMR 2/2023) is limited to the oil and gas sector (Draps & Ibnuaji, 2025). The regulations also enable oil and gas contractors to incorporate CCS within existing production contract sharing (PSC) arrangements, thereby facilitating early project development within the incumbent oil and gas actors (MEMR, 2024b; MEMR Regulation 16/2024, 2024). These developments mark a significant shift in expanding the legal basis for broader CCS implementation and provide a stronger foundation for CCS to be Indonesia's long-term climate mitigation (Kurniawan, 2026).

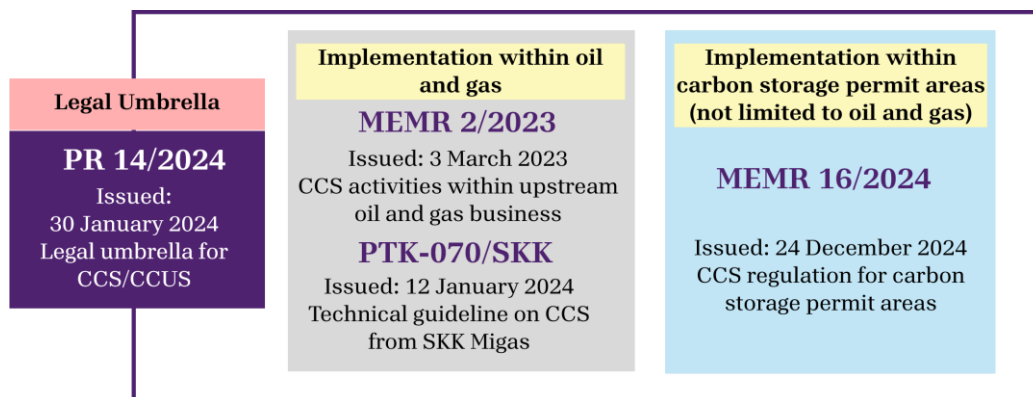


Figure 17. Indonesia regulatory framework for CCS

Unlike the previous regime conditions, stakeholders in interviews consistently viewed regulatory institutionalization as a key enabler for CCS development. The introduction of dedicated CCS regulation frameworks reduces investment uncertainty and strengthens institutional legitimacy, with the current frameworks providing a more comprehensive governance structure for CCS. This is acknowledged by the Global CCS Institute as the most advanced CCS regulatory frameworks in Southeast Asia (ICCS, 2025b), enabling Indonesia's CCS actors in the regional storage hub market, including Singapore's storage hub initiative. However, interview findings also indicate that this regulatory development was largely driven by incumbent large oil-and-gas actors in capitalizing Indonesia's geological storage potential to secure regional carbon market opportunities, rather than by a broader state-led decarbonization agenda.

"We're actually quite advanced in terms of regulations. I mean, at least, regulations specifically for CCS have been issued. [...] So, there was already a framework in place because our company was pushing for it at the time to allow us to participate in the Singapore hub. So, the MEMR issued it. Yes, the ministry was pushed by our company and Pertamina" (S3-OGP)

This indicates that CCS institutionalization in Indonesia remains closely embedded within the existing oil and gas regime. While the regulations strengthen legal certainty on Indonesia's CCS implementation, its deployment continues to be shaped by incumbent oil and gas actors with limited broader domestic decarbonization objectives.

4.4 Niche-Level Development of CCS in Indonesia

This section discusses niche-level development that supports the emergence of CCS in Indonesia. Within the MLP, niches represent protected spaces where experimentation, learning, and network building allow emerging technologies to develop before broader regime adoption.

4.4.1 Expansion of CO₂ Storage Exploration Activities

MEMR has been actively promoting CO₂ storage exploration as an early step of CCS development. These exploration activities focus mainly on saline aquifers and depleted oil and gas fields, where Indonesia's current potential reaches 573 gigatons of CO₂ (MEMR, 2024b) (see Figure 18 for the storage mapping). This potential is estimated to allow carbon storage equivalent to 482 years of Indonesia's current emissions, indicating potential future market for CCS (ITA, 2024). Beyond identifying storage resources, these activities function as early-stage learning processes that reduce technical uncertainty and strengthen confidence in CCS feasibility. Interview findings further indicate that CCS storage site exploration becomes embedded within upstream oil and gas exploration. The researcher stakeholder and CCS adopters explained that new hydrocarbon exploration projects are now expected to evaluate the suitability of geological formations for potential CO₂ storage. MEMR encourages companies to integrate CCS site screening into conventional oil and gas exploration, accelerating CCS knowledge development while reducing CCS site characterization costs. This expansion of storage exploration activities has been enabled by the regulatory institutionalization discussed in Section 4.3.4, allowing geological assessment to move beyond isolated research toward project-oriented development.

“There are two types of oil and gas companies currently active in CCS. First, those that already have large storage opportunities and want to enter. Second, those developing new (oil and gas) fields. Almost all new production fields are now required to undergo CCS site screening” (S2-R)



Figure 18. CO₂ storage distribution of Indonesia sedimentary basin 2024

Source: data from (MEMR, 2024b)

In parallel, growing interest has emerged in developing integrated CCS infrastructure mapping, connecting CCS sites to nearby emitters (Al Hakim et al., 2025). These initiatives aim to improve

CCS economic viability through shared infrastructure. Existing LNG transportation and export infrastructure is also increasingly explored for potential CCS utilization, reflecting ongoing experimentation in adapting existing oil-and-gas infrastructure to support CCS implementation (ICCSC, 2025a). Together, these developments contribute to niche formation by increasing technical capability, infrastructure planning, and institutional learning for CCS in Indonesia.

4.4.2 Early CCS Project Implementation within the Oil and Gas Sector

Early CCS deployment in Indonesia remains largely at the demonstration stage. As illustrated in Table 7, there are 15 key CCS/CCUS projects under MEMR monitoring with different development stages (see Figure 2 for CCS/CCUS mapping). While there are three projects already in the pilot stage, others remain at the study and planning phase, including CCS standalone projects. This indicates that CCS is still undergoing technological and institutional experimentation rather than broad commercial development. Existing pilot operational projects, however, are primarily associated with EOR/EGR for production optimization. One recurring challenge identified from the interviews, particularly from CCS adopters, government, and knowledge actors, is securing CO₂ sources and developing transport connectivity between emitters and storage sites, as one noted.

“The problem in Indonesia, in my opinion, is more about connectivity to CO₂ sources. There may be several CO₂ sources for CCS here, but the applicable fields are scattered everywhere. Our natural gas pipelines aren't even massively connected.”(S1-G)

Table 7. CCS/CCUS project status in Indonesia in 2026

No	Projects	Status	Onstream Target Schedule	Developers
1	Tangguh CO ₂ -CCUS EGR	FEED is set, and POD has received approval; pilot testing	2028	BP, study by CoE-ITB
2	Gundih CO ₂ -CCUS EGR	Phase-2 study for risk & uncertainty mitigation, pilot testing	2030	Pertamina, CoE ITB, JGC, J-Power, JANUS supported by METI Japan
3	Sukawati CO ₂ -CCUS-EOR	Subsurface study, pilot testing	2033	Pertamina, LEMIGAS, JAPEX supported by METI Japan
4	CCS Sakakemang	Site selection & characterization	2028	Rapsol Sakakemang
5	Abadi CCS	Feasibility study	2030	Inpex Masela
6	Blue Ammonia + CCS Dongi	JSA finalization	2031/2032	Pertamina, Panca Amara Utama, JOGMEC, CoE-ITB (study)
7	East Borneo CCS	Pre-feasibility study	2030	Kaltim Parna Industry, CoE-ITB (study)
8	Arun CCS	Preparing JSA	2029/2030	Carbon Aceh, PEMA
9	Ramba CO ₂ - CCUS-EOR	Internal study	2032	Pertamina
10	Central Sumatra Basin CCS/CCUS	Preparing required data	2034	Pertamina, Mitsui
11	Gemah CCUS Jabung	Preparing required data	2031	Petrochina
12	Sunda Asri CCS/CCUS	Subsurface evaluation	2033	Pertamina, ExxonMobil
13	CCU to Methanol - RU V Balikpapan	JSA received approval	2030	Pertamina, Air Liquide
14	Kutai Basin CCS Hub	Internal feasibility study	2031/2032	Pertamina, Chevron
15	CO ₂ Huff and Puff Jatibarang	Internal study	2031	Pertamina, JOGMEC

Source: synthesized from (Bloomberg, 2026; CoE-ITB, 2024; Pertamina, 2026; Ramadhan et al., 2024)

From Table 7, the majority of CCS projects are dominated by oil-and-gas actors, while only one CCS project originates outside the sector, Blue Ammonia and CCS (Dongi). Rather than representing wide technology adoption, the current project portfolio functions as an experimentation platform where technical capability, operational experience, and business model are continuously developed (IEA, 2022). Additionally, most CCS initiatives are dominated by multinational oil and gas companies collaborating with Pertamina, leveraging existing subsurface expertise, geological data, and global CCS experiences to lower implementation risk, reinforcing current CCS projects as learning spaces to strengthen technical capabilities.

Interview findings further show that high-emitter industries outside the oil and gas sector remain “wait and see” toward CCS adoption due to its high cost and technological uncertainty. Potential CCS adopters explained that they are monitoring existing demonstration projects before making investment decisions, expecting successful pilots to reduce technological uncertainty and strengthen confidence in future CCS development within their sustainable transitions.

“With the growing development of CCS projects supported and funded by other countries, ideally, CCS investment and the technology ecosystem will strengthen in the future. That’s where the hard-to-abate sector (us) can begin to actively participate. CO₂ capture technology alone is already incredibly expensive, but at least once the downstream is ready, the upstream will just need to be strengthened” (S6-OGP)

This indicates that early CCS projects contribute to niche development not only through technological experimentation but also by generating demonstration effects for prospective adopters. Successful deployment reduces technical uncertainty and strengthens industrial confidence, creating initial learning processes that support future broader CCS implementation.

4.4.3 International Collaboration and Regional Storage Hub Development

Growing regional carbon storage demand has created new opportunities for CCS development in Indonesia. Supported by its large geological storage (as discussed in Section 4.4.1) and strategic location in the Asia Pacific region (see Figure 13), Indonesia is increasingly perceived as a potential regional CO₂ storage hub by countries with limited storage capacity but stronger climate policies such as Singapore, Japan, South Korea, and Taiwan (Karki, 2026). This growing interest has stimulated experimentation with new cross-border business models and governance arrangements for CCS. As discussed in regime Section 4.3.4, these regional market opportunities have pressured the government to develop a cross-border regulation framework.

Interview findings further reinforce this emerging niche, as CCS adopters highlighted that international demand provides an important commercial opportunity for CCS. They also exposed governance challenges that remain unresolved, particularly regarding clarity of cross-border governance, liability transfer, and carbon accounting.

“The cost of CO₂ injection is very expensive; those willing to pay are usually from abroad. The closest and most potential countries are Singapore, followed by Korea, and Japan. So, these are the three countries we are currently approaching. [...] Particularly important are the issue of liability transfer, accounting mechanisms, and regulations regarding handover points.” (S5-OGS)

This regional interest has been translated into a series of international collaborations in CCS. In February 2024, Indonesia and Singapore signed a Letter of Intent (LoI) to initiate cross-border

cooperation on CCS development, with Pertamina and ExxonMobil Indonesia participating in Singapore-Hub initiatives (Wijaya et al., 2025). There has also been growing interest in cross-border CCS in Borneo Island involving Indonesia, Brunei, and Malaysia, where cross-border CCS is explored, including East Borneo and Kutai Basin Hub to support decarbonization of strong coal-based industrial sectors on the island (Bokka & Lau, 2023). Beyond Southeast Asia, collaboration has expanded to Japan and South Korea. Japan and Indonesia have initiated joint CCS research programs to explore studies in technological feasibility, storage capacity assessment, and potential deployment pathways (Joe, 2025). In April 2026, Indonesia and South Korea signed an MoU for CCS collaboration, including cross-border development, joint research, pilot implementation, and regulatory work (Karki, 2026; Lestari, 2026).

These collaborations expand beyond technological experimentation. They provide learning opportunities for cross-border governance mechanisms, technical coordination, and regional business models for CCS, strengthening Indonesia's capability to be a future regional storage hub.

4.4.4 Increasing Cross-Sectoral Research Interest Beyond the Oil and Gas Sector

While CCS projects remain concentrated within the oil and gas sector, interest in applying CCS across other carbon-intensive sectors is gradually emerging, particularly fertilizer and ammonia. Most initiatives are still at the feasibility study and research stage, indicating cross-sectoral application is still an emerging niche (Bokka & Lau, 2023; Putriyana et al., 2023; Shin et al., 2023). Interview findings highlight that blue ammonia—where CCS is incorporated in the production system—has gained strong support, currently represents the only non-oil-and-gas sector listed in the national key CCS/CCUS project (see Table 7). However, this is largely driven by global market dynamics, where high-carbon ammonia is increasingly restricted and provides lower margins (Shin et al., 2023). The researcher and potential adopter stakeholders highlighted this promising early application of CCS beyond oil and gas.

“Interest from the non-oil and gas sector is already very high—especially from the fertilizer industry. Blue ammonia is indeed very “hot” in Indonesia. [...] competitive, even without a carbon tax.” (S2-R)

“If a company only produces gray ammonia [...] the product can't be sold in certain markets or the price is much lower [...]. But if they produce blue ammonia, the price can double.” (S5-OGS)

Interview findings also indicate that cross-sectoral interests in the domestic market are uneven. Companies with Japanese and Korean parent companies or strategic partnerships demonstrate stronger interest in CCS because they face greater pressure from home-country decarbonization policies, compared to domestically oriented companies who still perceive considerably weaker incentives to explore CCS.

“If the company's stakeholders are from countries like Japan or Korea, the pressure is usually stronger because the parent companies in those countries are already being pushed to reduce emissions. But for a truly local company, the pressure isn't as great.” (S5-OGS)

Beyond ammonia production, CCS is also increasingly being explored for geothermal systems, coal-fired power plants (CFPPs), and other high-emitter sectors such as cement, steel, and petrochemicals. In geothermal systems, integrating CCS in the system could reduce geological risk, considering Indonesia's geothermal basins have supporting conditions (Putriyana et al., 2023). While in CFPPs, CCS is seen as a potential long-term plan to manage both national 100% electricity

demand and decarbonisation, as CFPPs are seen as the fastest way to reach the target considering Indonesia's geographical challenges (Bokka & Lau, 2023).

These growing interests in CCS adoption beyond oil and gas show expanding niche-level experimentation and learning exploration for cross-sectoral application beyond the oil and gas sector. At the same time, it further strengthens that broader CCS interest remains largely driven by international market competitiveness and global industrial pressure rather than domestic climate policy alone.

4.4.5 Development of Dedicated Knowledge and Coordination Networks

The development of dedicated CCS institutions represents an important niche development by strengthening knowledge creation, coordination, and policy learning (Ko et al., 2021; Ma et al., 2022; Mascarenhas et al., 2019). Indonesia has begun establishing institutions specifically focused on supporting CCS development. The Centre of Excellence for CCS/CCUS at Bandung Institute of Technology (CoE-ITB), established in 2017, focuses on CCS research and development, feasibility studies, and scientific support for policy development (CoE-ITB, 2022). Building on this, the Indonesia CCS Centre (ICCSC) was established in 2023 as a dedicated national think tank and coordination platform focusing on policy advocacy and stakeholder engagement (ICCSC, 2025a). Interview findings from CCS adopters, ICCSC, and potential adopters indicate that ICCSC maintains strong institutional links with government despite its non-governmental status, enabling dialogue between policymakers and industrial actors. Interview findings also indicate that CoE-ITB has become a key source of technical expertise for both government and industry, particularly SOE actors, reflecting the gradual accumulation of national CCS capabilities. This is evident in the high involvement of CoE-ITB in several key CCS/CCUS projects (see Table 7) and early CCS regulation development.

“For CCS, if you want an end-to-end approach, you need people from chemical, mechanical, petroleum, geological, and geophysical engineering. And you could say all of those competencies are fully represented here (CoE-ITB), that's why the COE is involved in almost every major CCS study in Indonesia. [...] Our exposure at the industry level is quite strong, and our exposure at the organizational or government agency level is also strong.” (S2-R)

However, industrial actors also highlighted that the emerging knowledge network remains fragmented. ICCSC membership is dominated by oil-and-gas actors, with only one from another high-emitter sector, indicating limited cross-sectoral CCS discussions. Stakeholders such as the CCS manager and the CCS senior engineer also pointed to overlaps and friction between ICCSC and CoE-ITB, particularly regarding coordination and visibility within government-led CCS initiatives.

“There are even indications of friction between the ICCSC and CoE-ITB. Because the COE was already there. When the ICCSC arrived, the CoE was rarely involved in government-led CCS development and coordination. And the ICCSC often claims achievements related to CCS acceleration. Yet, these achievements are the result of hard work by industry players.” (S3-OGP)

These developments indicate that Indonesia is building a dedicated CCS knowledge ecosystem that supports experimentation, learning, policy coordination, and capacity building. However, the niche remains strongly shaped by incumbent oil and gas actors, while limited cross-sectoral participation and fragmented coordination continue to constrain the maturation of a broader CCS innovation network.

4.5 Socio-Technical Transition of Indonesia's CCS

The MLP analysis shows that Indonesia's CCS development is shaped by interaction between increasing landscape pressures, a strong fossil-fuel regime, and emerging niche experimentation. Rather than challenging the incumbent regimes, these interactions have largely reinforced the existing energy regime while creating limited opportunities for broader CCS applications (Wainstein & Bumpus, 2016).

At the landscape level, international decarbonization agendas, growing regional carbon market opportunities, and global demand for low-carbon products increasingly motivate CCS investment in Indonesia, pushing CCS actors to accelerate development and maintain their global competitiveness. National development plans (RPJPN and RPJMN) further provide political legitimacy for low-carbon projects. However, a weak sustainable finance ecosystem and political-economic contestation on carbon pricing policies continue to constrain large-scale development. As a result, CCS is positioned less as a transformative climate mitigation pathway and more as a strategic solution to strengthen economic competitiveness, energy security, and fossil-based economic activity under increasing climate pressure.

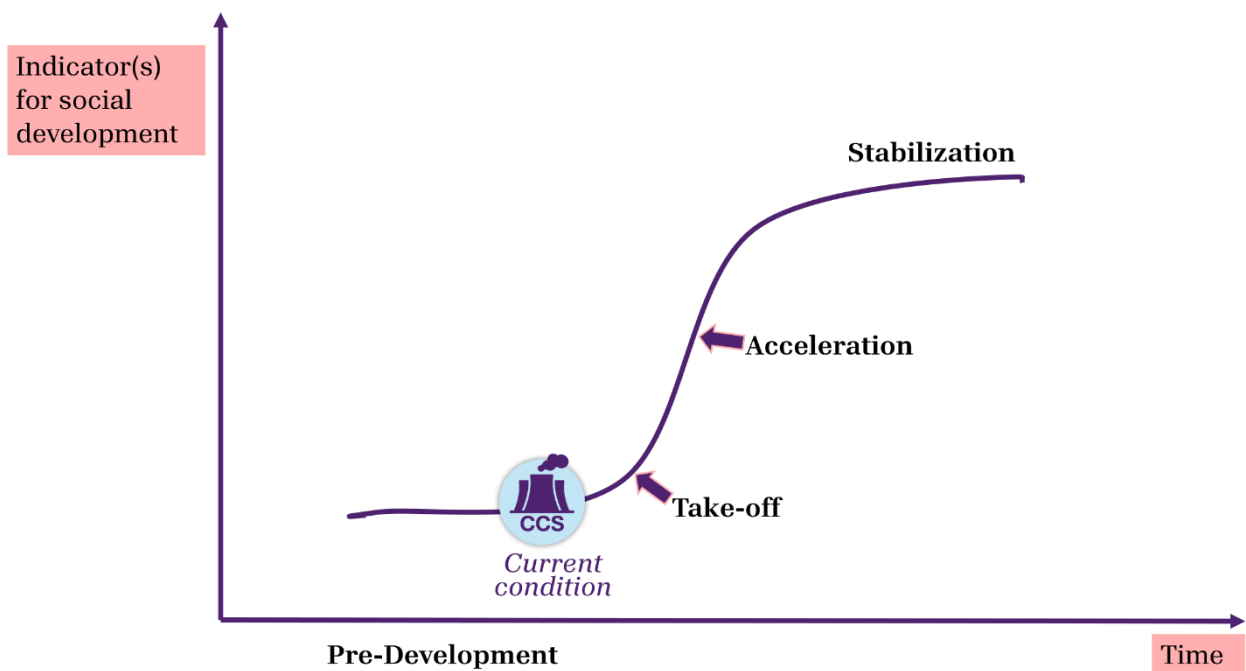


Figure 19. The current phase of CCS technology transition in Indonesia
Source: adopted socio-technical curve by (Rotmans et al., 2001)

Building on the regime discussion in Section 4.3, these landscape pressures are accommodated within the incumbent energy regime that continues to prioritize fossil-fuel production and national energy security, reinforcing that CCS development in Indonesia remains strongly embedded within the existing fossil-fuel regime. Existing policy supports, institutional arrangements, and economic incentive mechanisms favour CCS application that reinforce hydrocarbon production, particularly CCUS-EOR and gas commercialization. At the same time, fragmented understanding across government bodies, high emitters, and society further constrain broader CCS implementation. Although the recent CCS regulation strengthens legal certainty, it is highly influenced by the motive of seeking regional market opportunities rather than domestic climate mitigation. Consequently, the current regime conditions enable CCS development selectively, only when it aligns with

existing industrial interest and energy production priorities rather than transformative climate mitigation.

Within this regime, niche activities (as discussed in [Section 4.4](#)) are expanding through storage exploration, pilot projects, international collaboration, dedicated CCS institutions, and growing interest in cross-sectoral applications. These initiatives strengthen technical capability, institutional learning, and stakeholder coordination, although it is still largely concentrated within incumbent oil-and-gas actors. As a result, niche development complements rather than challenges the existing regime.

Figure 20 synthesizes these interactions across landscape, regime, and niche levels, while **Table 18** ([Appendix B](#)) summarizes the socio-technical conditions. Collectively, the findings explain that Indonesia's CCS transition remains between the late pre-development and early-take-off stage (see [Figure 19](#)). The CCS technology has progressed beyond initial exploration through increasing experimentation and institutional learning but has not yet transitioned into large-scale deployment. Moving towards large-scale deployment will therefore depend on whether future governance arrangements, stronger economic incentives, and broader cross-sectoral participation can enable CCS to expand beyond the oil-and-gas sector ([Markusson et al., 2011b](#); [Osazuwa-Peters & Hurlbert, 2020](#)).

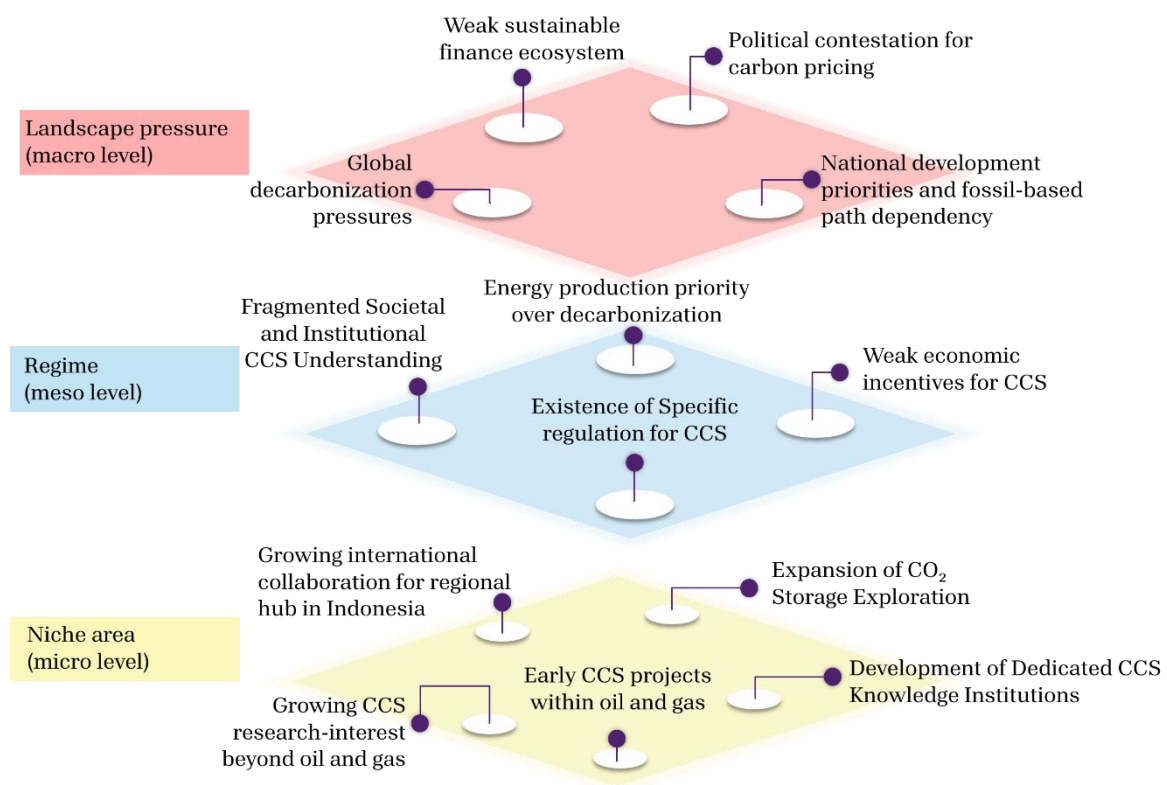


Figure 20. Socio-technical conditions mapping of CCS in Indonesia

Governance Readiness of CCS Implementation in Indonesia

This chapter further examines the governance of CCS implementation, positioned at the regime level within MLP transition analysis. The discussion includes four key dimensions from the governance readiness framework to understand national-level CCS governance as well as corporate-level governance dynamics for CCS implementation.

5.1 Legal Foundations for CCS Deployment

Legal foundations determine whether CCS can be developed with sufficient regulatory certainty. This section examines the availability, scope, and clarity of Indonesia's existing legal framework governing CCS across the value chain and its life cycle.

5.1.1 Existence of CCS-Specific and Supporting Regulations

Indonesia has established dedicated CCS regulatory frameworks through MEMR Regulation No. 2/2023, President Regulation No. 14/2024, and MEMR Regulation No 16/2024, supported by the technical guideline PTK-070 issued by SKK Migas (see [Figure 17](#)) ([Draps & Ibnuaji, 2025](#); [MEMR, 2024b](#)). As discussed in [Section 4.3.4](#) in regime analysis, these regulations strengthen Indonesia's legal readiness by providing a dedicated legal basis for CCS development, including cross-sectoral application and cross-border operation. Compared with many emerging countries, Indonesia has relatively advanced legal arrangements for the early stage of CCS, representing an important governance enabler for early technology development ([Global CCS Institute, 2023](#); [ICCSC, 2025b](#)).

However, interview findings reveal that the existing regulatory frameworks are predominantly influenced by upstream oil-and-gas governance logic. Although the latest regulations formally expand CCS beyond the oil-and-gas sector, many technical requirements continue to rely on PTK-070, which was originally developed to accommodate upstream petroleum operations. The CCS manager argued that this approach does not fully accommodate the commercial and operational characteristics required for CCS.

“The regulations are still very strict when referring to the oil and gas process [...] CCS has to secure the emitter first [...] the margins are minimal, so it can't be treated the same as oil and gas.” (S3-OGP)

CCS adopters and researcher stakeholders further noted that technical requirements designed for oil and gas operations do not always translate directly to CCS, because they have different project risks and commercial structures. For example, storage site certification, where assessment can be more complex compared to production sites (Gaurina-Medimurec & Novak Mavar, 2020). Stakeholders also highlight that while conventional oil and gas can advance without securing buyers, CCS cannot progress without clarity on securing emitters.

The existence of dedicated CCS regulations represents a significant governance strength for Indonesia at the early stage of CCS, although improving technical guidance beyond upstream oil-and-gas practices is increasingly important to allow cross-sectoral CCS implementation.

5.1.2 Authorization and Storage Rights Clarity

Indonesia’s CCS regulatory framework provides a relatively structured and explicit authorization pathway, particularly MEMR Regulation 16/2024. This regulation establishes Carbon Storage Permit Areas (WIPK, *Wilayah Izin Penyimpanan Karbon*) as the primary spatial and legal basis for CCS activities beyond the oil and gas sector. There are two mechanisms for obtaining WIPK rights for CCS activities: (i) participating through auction by MEMR, and (ii) proposing identified WIPK to MEMR through a limited selection process (MEMR Regulation 16/2024, 2024). The requirements differ between mechanisms as summarized in Table 19 (Appendix C). Designated WIPK for CCS exploration activities may be located within: (a) open areas; (b) mining business permit; (c) oil and gas work areas with the production sharing contract (PSC) business mechanisms. For oil and gas actors, they can update their current permit (PSC scheme) to include CCS activities within their work areas (PR 14/2024, 2024). The differences between the WIPK and PSC scheme in CCS adoption are summarized in Table 20 (Appendix C). This design is expected to lower entry barriers for incumbent extractive industrial actors while simultaneously opening participation to new entrants.

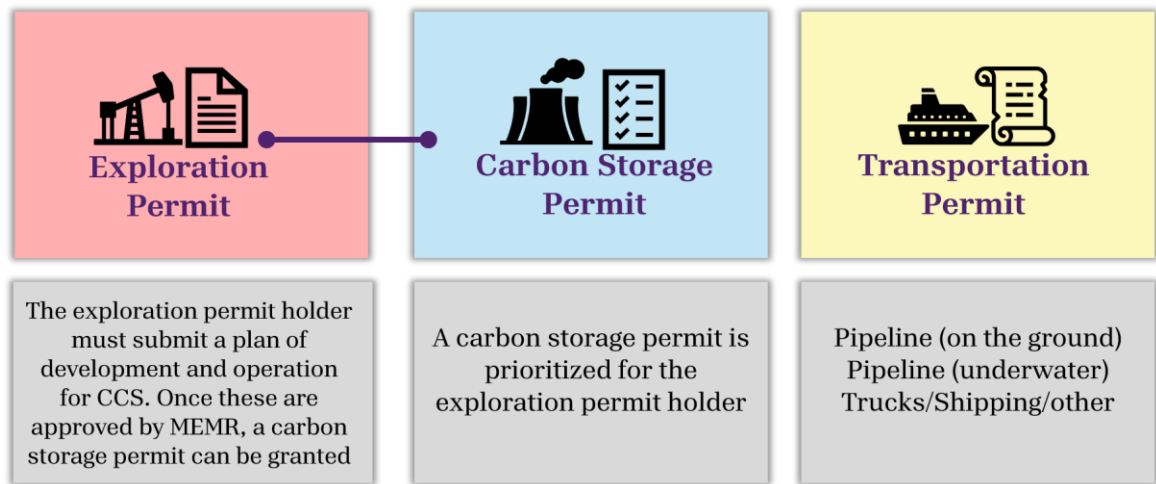


Figure 21. Permit types in Indonesia’s CCS regulatory framework

Source: synthesized from (MEMR Regulation 16/2024, 2024; PR 14/2024, 2024)

There are three types of permits regulated for CCS activities in Indonesia, including exploration permit, transportation permit, and storage permit (as shown in Figure 21). Each permit has specific validity periods and extension mechanisms (see Table 19 and section C.1 in Appendix C for details). These provisions provide relatively high regulatory certainty for project authorization. However, the exploration permits are limited to companies with experience in the oil and gas, mining, or

geothermal sector, reinforcing institutional preferences for CCS exploration. The exploration permit holders will be granted a CCS operation permit upon approval of the plan of development by MEMR ([MEMR Regulation 16/2024, 2024](#)). These mechanisms offer advantages for incumbent oil and gas actors, while potentially limiting the early-stage participation from non-oil-and-gas firms. As a result, CCS operation permit holders are likely to be from oil and gas companies.

While the frameworks provide legal foundations for CCS deployment, they still lack clarity on governance across the CCS value chain, including the boundaries of responsibility and obligations within capture, transport, and storage. For example, the frameworks emphasize that any leakage during cross-border CO₂ transportation must not be added to Indonesia's GHG accounting, but it is not explicitly mentioned which permit holders must ensure this compliance ([PR 14/2024, 2024](#)). Such ambiguities may complicate CCS coordination, particularly for cross-border operation and where capture, transport, and storage are operated by different companies. Additionally, the frameworks implicitly position subsurface pore spaces as a state-controlled resource, where permit holders must transfer the assets to the state after the permit expires. While this arrangement is common in CCS global practices, the existing regulations provide limited guidance on how state oversight will be exercised after transfer, creating uncertainty in long-term arrangements post-site transfer to the state ([IEA, 2022](#); [Osazuwa-Peters & Hurlbert, 2020](#)).

5.1.3 Clarity on CO₂ Classification and Ownership

Indonesia's CCS regulatory framework does not provide an explicit legal classification of CO₂, creating uncertainty over how different regulatory frameworks apply throughout the CCS value chain. Although regulations to utilize and monetize CO₂ exist, they do not formally define whether CO₂ should be treated as waste, hazardous materials, commodity, or state-controlled substances. This creates ambiguity in determining the framework application in relation to environmental liability, transport regulation, commercial utilization, and cross-border operations ([IEA, 2022](#); [Wilson et al., 2009](#)). Consequently, this lack of specificity leads to inconsistent interpretation across projects, creating alignment challenges between industry players and authorities.

This governance gap is also strongly voiced by CCS adopters and knowledge actors in the interview; cross-border CCS feasibility is constrained by ambiguities of CO₂. The absence of a common legal interpretation of CO₂ has resulted in differing views among stakeholders. Interview findings highlight that some ministries, including MEF, perceive CO₂ as waste subject to import restrictions, whereas ministries in energy and industry, such as MEMR and MoI, regard CO₂ as a commodity because it is already imported for industrial applications, such as carbonated beverages, and is increasingly traded within carbon markets.

"It's not clear now (CO₂ classification). Actually, if you look further, Indonesia has also imported CO₂ for certain industrial needs, for example for carbonated drinks. So, the understanding could actually be in that direction—that CO₂ isn't always synonymous with waste" (S5-OGS)

"If CO₂ is considered 'waste,' [...] regulations prohibit waste imports. Therefore, one of the decisions made was to classify CO₂ as B3 (hazardous and toxic), not as waste. With the B3 classification, CO₂ can still be imported, but the permitting process remains stringent. However, if CO₂ is categorized as a commodity, the import process will be much simpler and less complicated than importing B3" (S9-NTT)

Similar ambiguity concerns also exist for CO₂ ownership. The existing regulations do not explicitly specify ownership transfer of CO₂ across the CCS value chain, including capture, transport, and storage (MEMR Regulation 16/2024, 2024; PR 14/2024, 2024). This gap is critical in the context of the carbon market and cross-border CCS operation, where ownership is closely tied to liability, accounting, and rights to claim carbon credits in the carbon market (N. Liu, Zhan, et al., 2025).

With the absence of a definition, CO₂ may implicitly shift between these classifications, generating legal uncertainty (Osazuwa-Peters & Hurlbert, 2020). This potentially hinders investment decisions, complicates contractual arrangements, and reduces confidence in carbon accounting mechanisms.

5.1.4 Inclusiveness of Actor Eligibility

While the existing regulatory frameworks formally allow participation beyond the oil and gas sector, the practical eligibility requirements continue to favour incumbent extractive industries, limiting the role of non-oil and gas as only CO₂ suppliers (MEMR Regulation 16/2024, 2024). As discussed in Section 5.1.2, to be eligible in an auction or limited selection process for a storage site, participants are required to demonstrate relevant subsurface experience in oil and gas, mining, geothermal, or CCS activities. Because exploration permit holders are subsequently granted storage operation permits, actors with existing subsurface knowledge have a significant institutional advantage over new entrants (Draps & Ibnuaji, 2025; MEMR Regulation 16/2024, 2024; PR 14/2024, 2024).

Interview findings further reinforce that this regulatory design strengthens participation from established oil and gas companies while limiting other high emitters from being involved. Although industries such as petrochemicals, cement, steel, power generation, and fertilizer are expected to become future CO₂ suppliers, they currently have limited institutional role in CCS regulation development. This reinforces the actor-network and regime observed in Chapter 4, where CCS development remains concentrated among incumbent oil and gas actors despite growing interest from other sectors. To attract beyond oil and gas players, a gradual transition toward a more inclusive framework—without compromising safety and technical standards—will be critical in fostering competition, innovation, and long-term investment in the CCS system (Kaarstad et al., 2011).

“There is no hard-to-abate sector, yet [...] CCS knowledge ecosystem now is dominated by oil and gas companies, but other hard-to-abate sectors do not have a well-developed ecosystem or are not yet involved” (S6-NOGP)

This reflects a trade-off in Indonesia’s governance approach. Prioritizing experienced actors in subsurface operation reduces technical and operational risks during early-stage CCS development and supports the government in accelerating regional storage hub development. At the same time, this institutional design limits broader participation and potentially constrains cross-sectoral CCS expansion (Kaarstad et al., 2011; N. Liu, Zhan, et al., 2025).

5.2 State Capacity and Institutional Alignment

This dimension examines the government's capacity to coordinate institutions, align cross-ministerial policies, and provide consistent political commitment to support CCS development. Beyond the existence of regulations, effective CCS implementation also depends on how actors enforce and monitor policies and regulations, translate them into implementation, and coordinate across sectors.

5.2.1 Inter-Agencies Coordination and Authority Alignment

CCS implementation spans multiple jurisdictions—onshore and offshore—requiring coordination across ministries governing energy, environment, land uses, and marine (Osazuwa-Peters & Hurlbert, 2020; Romasheva & Ilinova, 2019). Indonesia's current regulations recognize this need through coordination across multiple ministries, including the Ministry of Environment and Forestry (MEF) for carbon reduction efforts, the Ministry of Agrarian Affairs and Spatial Planning (MAASP) for land use across the CCS value chain, and the Ministry of Marine Affairs and Fisheries (MMAF) for offshore CCS infrastructure development. Additionally, CCS permit holders are required to engage a third party approved by MEMR to perform site certification (MEMR Regulation 16/2024, 2024; PR 14/2024, 2024). This creates a multi-layered governance structure where CCS implementation depends heavily on cross-ministerial alignment.

This multi-layered and complex governance structure is a common practice in Indonesia, as one of many issues contributing to inefficient bureaucracy process (Turner et al., 2022). This concern is also raised by all stakeholders in the interview, where the challenge lies less in the absence of coordination mechanisms but in how coordination operates. Stakeholders consistently described the existing inter-ministerial coordination as strongly hierarchical and dependent on political authority. As noted by the knowledge actor, while technical-level officials generally reach alignment on addressing CCS implementation issues, strategic decisions often require approval from senior leaders whose priorities differ across ministries. Stakeholders also highlight that this mechanistic approach contributes to fragmented understanding across ministries, and coordination becomes slow as ministries continue prioritizing their own institutional agendas unless strong directives are issued from higher political leadership (Kuswati et al., 2023; Turner et al., 2022).

"But the problem arises when coordination moves to a higher level. At the working level, we usually have a shared understanding and agreement on what needs to be done. The challenge is whether people at this working level can escalate the issue to their leaders [...] These leaders certainly have their own priorities." (S9-NTT)

"Unless the president directly states an absolute mandate [...] each ministry will inevitably try to exercise its own authority, pursuing its own targets. That's what makes it so difficult." (S1-G)

These governance characteristics contribute to lengthy bureaucratic processes and reduce policy predictability for investors (Isaac, 2026). This is also voiced by the international organization actor in the interview, where Indonesia has lower competitiveness in terms of governance alignment for foreign investment compared to other neighbouring countries such as Malaysia.

"The bureaucracy is long, [...] The process is long, multi-layered, and often time-consuming. [...] If we want to compete globally and attract investors, that's a core issue that must be addressed." (S2-R)

“Honestly, there's a lot of bureaucracy in Indonesia. Formulating a policy can take years. [...] In Indonesia, the bureaucracy is quite extensive and sometimes complex. [...] Malaysia also has a bureaucracy, but compared to Indonesia, Indonesia still feels the most complicated.” (S8-IO)

To strengthen cross-sectoral coordination in green economy transition, Indonesia has developed a special task force team called Energy Transition and Green Economy Task Force in 2025 (Satgas TEH, *Satuan Tugas Transisi Energi dan Ekonomi Hijau*) for coordinating energy transition and green investment initiatives, particularly following the JETP commitment (JETP, 2025). MEMR, as CCS main regulator, is a member of Satgas TEH, responsible for industrial decarbonization, particularly in coal-fired plants, upstream and downstream oil and gas business. However, the task force team primarily functions to coordinate investment mobilization and maintain foreign investor confidence rather than integrated decarbonization governance (ICEL, 2025). CCS itself remains peripheral on the task force's agenda because it is not a central focus of the JETP investment, reflecting CCS's weak integration into current national transition planning.

Overall, Indonesia demonstrates the formal presence of inter-agency coordination mechanisms for CCS development, but their effectiveness remains constrained by hierarchical decision-making and fragmented institutional authority. Consequently, coordination depends strongly on sustained political leadership to align competing ministerial priorities, limiting the state's capacity to implement CCS as a cross-sectoral climate mitigation.

5.2.2 Policy Integration and Strategic Coherence

As discussed in Section 4.3.2, Indonesia has progressively integrated CCS within broader climate and carbon pricing policies. The new updated umbrella (President Regulation 110/2025) strengthens the policies through mechanisms for carbon trading, carbon tax, and result-based payment (see Figure 22). The frameworks also allow international carbon trading and provide a dual registry system for NDC effort tracking and carbon trading activities (JETP, 2025; PwC, 2024; PR 110/2025). CCS operations must comply with the registry systems, and carbon credits can be traded through an offset trading mechanism (see Figure 23).

Despite this formal integration, interview findings reveal substantial policy incoherence across sectors. While the government often frames Indonesia as having strong alignment between CCS and climate efforts in media, the interviews highlight different realities. Stakeholders, particularly industrial actors and the researcher, consistently highlighted inconsistencies between climate, industrial, and energy policies. For example, while CCS regulations support cross-border CO₂, other regulatory frameworks treat CO₂ differently, treating it as a waste which subject to import restrictions, creating uncertainty about cross-border CCS operation. More fundamentally, as discussed in Section 4.3.1, energy policies continue to prioritize fossil-fuel production and climate policies are absent an emission threshold limit, further constraining CCS implementation, with climate mitigation driving force (Kern et al., 2016). Another incoherence is also observed within industrial decarbonization strategies, where CCS is absent from the existing plan, although it is often acknowledged as promising climate mitigation for industries in climate effort documents.

“One issue that has emerged is that in the KBLI classification, CO₂ handled through CCS is still considered a waste, not a commodity. This is one of the regulatory challenges currently being discussed.” (S5-OGS)

“Our carbon emission threshold is unclear, with no significant penalties for high emissions, and no attractive incentives for reducing emissions. This needs to be clear, [...] to encourage companies to participate in carbon trading.” (S7-NOGS)

Pricing Type	Description
 Carbon Tax	Tax rate (IDR 30,000/ton-CO ₂) / (USD 2/ton-CO ₂) Specific for coal-fired power plant (CFPP) as the first sector
 Carbon Trading	There are two mechanisms a. Allowance / cap-and-trade mechanisms (PTBAE-PU) b. Offset trading (SPE-GRK) Through IDX Carbon; Price: IDR 60,000-100,000/ton-CO ₂ (USD 3-6/ ton-CO ₂)
 Result-Based Payment (RBP)	Paid based on the result on carbon reduction. It is paid by International climate funders, and specifically for forestry and land use sector

Figure 22. Carbon pricing options for Indonesia’s low carbon projects

Source: Author documentation synthesized from (JETP, 2025; PwC, 2024; PR 110/2025)

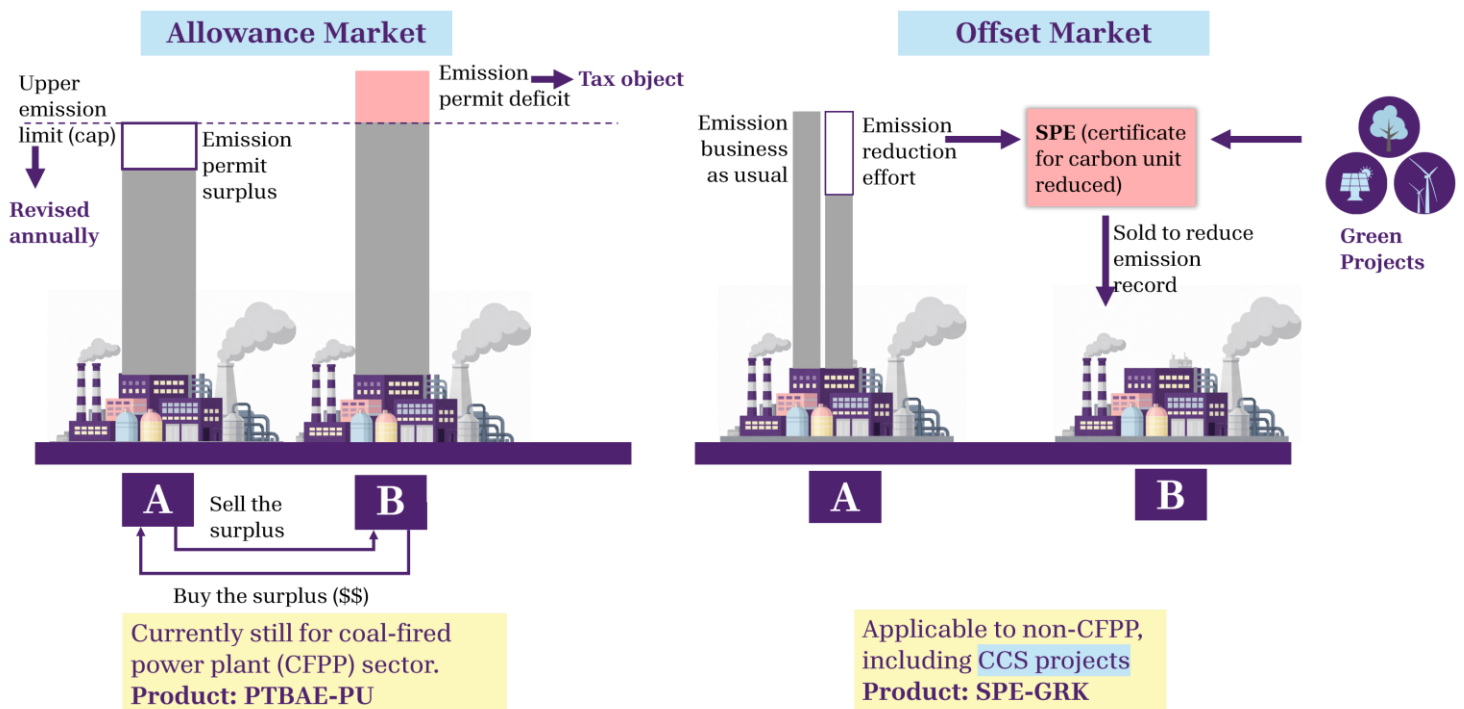


Figure 23. Carbon trading options in IDX Carbon

Source: synthesized from (IDX Carbon)

CCS adopters also emphasized the political difficulty in strengthening carbon pricing. While stronger carbon policies will benefit CCS viability, they expressed concern that increasing carbon cost could be passed on to consumers through higher energy and commodity prices, creating societal dynamics that in turn lower CCS acceptance (Swennenhuis et al., 2024). Given Indonesia’s

strong dependence on fossil-fuel subsidies and concerns over energy affordability, stronger carbon pricing is still perceived as both economically necessary for low-carbon projects and politically difficult to implement (Aprianto et al., 2024).

These findings suggest that Indonesia's challenge is not the absence of climate policies but achieving coherence across competing policy objectives. While there is a growing presence of CCS-related policy instruments, they remain weakly integrated across industrial competitiveness, climate mitigation, energy security, and social affordability policies.

5.2.3 Institutional Capacity and Adaptability

Indonesia is increasingly strengthening its institutional capacity for CCS governance through international collaboration and policy learning (MEMR, 2024b). As discussed in the actor-network analysis, MEMR remains the central authority responsible for CCS governance, while technical expertise is supported by dedicated knowledge institutions and multinational companies. Interview findings highlight that, given Indonesia's limited experience in CCS, policymakers and industrial actors actively learn from countries with stronger experiences and knowledge in CCS governance, particularly Norway, Japan, and Singapore. This capacity gap is reflected in the dominance of multinational actors within current CCS projects (see Table 7), companies such as ExxonMobil, BP, Repsol, JOGMEC, and INPEX provide knowledge and expertise that are not yet strongly developed domestically (Bloomberg, 2026; Pertamina, 2026; Ramadhan et al., 2024).

"The most frequent we learn from Japan and Norway, as well as Singapore for policies and governance arrangements [...]and they usually start with studies with Indonesia before committing to major funding." (S1-G)

These findings are consistent with the document analysis, which shows that Indonesia has invested considerably in institutional learning (ICCSC, 2025a; Nugroho Dukut, 2026; Wahyudi, 2024). However, interview findings reveal that the main challenge is not the willingness to learn, but the ability of institutions to translate new knowledge into governance and organizational changes.

All stakeholders consistently described Indonesian public institutions and state-owned enterprises as having a strongly hierarchical and risk-averse organizational culture. The decision-making process in these institutions is strongly shaped by top-down political directives, while failed or financially unprofitable projects may later be interpreted as "state losses" with potential legal consequences (Apriliyanti & Kristiansen, 2019). This organizational culture further discourages officials from engaging with high-risk innovation such as CCS unless they receive strong explicit political backing from senior leadership levels (Esvandi, 2026).

"There are consequences to the "state loss" narrative. [...] make the process slower. Because the accountability risks are high, [...] people at lower levels don't have ownership over their work. They literally have to wait for direction from their superiors" (S9-NTT)

Institutional adaptability is further constrained by the political transition cycle. Because decision-making remains highly centralized, changes in presidential leadership or ministerial appointments frequently reshape policy priorities and interrupt ongoing initiatives (Bhattacharya et al., 2017). Government, industrial, and knowledge stakeholders emphasized in the interview that CCS received stronger political attention under the previous administration compared to the current

administration. Consequently, institutional continuity depends less on sustained political commitment.

“There is a previous government that strongly encouraged the development of CCS, [...] The current government, I'm not sure it has the same commitment.” (S7-NOGS)

“The government changes every five years, and this significantly impacts the consistency of political commitment. Furthermore, there are also sectoral egos, when a new minister [...] often desires to replace or alter many of the previous ones.” (S9-NTT)

Overall, Indonesia demonstrates moderate institutional capacity for CCS governance through international learning and technical collaboration. However, adaptive governance is still limited by strong mechanistic decision-making, political dependency, and institutional risk aversion, resulting in high vulnerability to leadership changes and high external expertise dependency.

5.2.4 Alignment with National Decarbonization

Indonesia's CCS implementation partially aligns with the national decarbonization agendas. Document analysis shows that CCS is acknowledged within Indonesia's LTS-LCCR 2050, where CCS and BECCS are identified as long-term mitigation options for the energy sector, particularly the power sector (LTS-LCCR, 2021). However, this is not complemented with clear intermediate targets, sectoral roadmap, or operational strategies. CCS also remains largely absent from industrial decarbonization planning despite its growing discussions on CCS potential for high emitter industries such as cement, petrochemicals, and steel (Nugraha, 2024; Sihite, 2023).

This gap is particularly reflected in Indonesia's updated NDC, where CCS has not yet been formally included as a national climate strategy (NDC, 2025). Interview findings explain this inconsistency. Industrial actors indicate that limited understanding of CCS, particularly within the Ministry of Environment and Forestry (MEF), has contributed to the perception that CCS is not sufficiently mature for inclusion in the NDC. From the interview, CCS adopters stated that there have been growing efforts to strengthen institutional understanding of CCS within climate governance bodies to include CCS in the upcoming NDC revision.

“Regarding CCS, in the most recent NDC submission, CCS wasn't included. They saw that the CCS aspect was still unclear, so it couldn't be included. However, they stated that in the next NDC cycle [...] CCS will likely be included in the 2030 edition.” (S5-OGS)

Another weak alignment within climate planning is observed in LTS-LCCR. Although CCS is framed as a future rapid emission reduction strategy for coal-fired power plants, major state-owned emitters such as PLN (SOE in electricity) are not yet fully engaged in the current CCS network (LTS-LCCR, 2021; Rimbono et al., 2025). This further reinforces actor-network findings where CCS is largely concentrated within oil and gas actors.

Overall, Indonesia has established an initial policy foundation that links CCS to long-term climate ambitions. However, alignment across national climate mitigation pathways remains weak, resulting in fragmented implementation across climate planning and industrial strategies.

5.3 Risk and Liability Governance

This dimension examines how risks and liability associated with CCS throughout its lifecycle are governed, including long-term liability stewardship, operational obligations and financial security, MMV, and contingency planning.

5.3.1 Liability Allocation of Long-Term Stewardship

In existing CCS frameworks, operators are still obligated to conduct monitoring, measurement, and verification (MMV) for 10 years after the storage permit expires, supported by annual contributions to a joint government-operator fund for post-closure activities ([MEMR Regulation 16/2024, 2024](#)). Compared with well-established frameworks such as Australia (15 years) and Norway (20 years), Indonesia's post-closure period is relatively short ([Global CCS Institute, 2023; IEA, 2022](#)). While this design reduces long-term obligations for operators and may attract CCS investment, it also shortens the period to verify long-term storage stability and potentially risks transferring unstable geological sites, as CO₂ migration, pressure dissipation, and caprock integrity may require multi-decade observation ([Carpenter, 2023](#)). This stewardship concern becomes particularly important for Indonesia's geological context. Given its active tectonic belt, long-term reservoir behaviour, pressure evolution, and caprock integrity require more careful observation ([Soehaimi et al., 2025; Song et al., 2023](#)). This concern is also voiced by government stakeholders, questioning whether a 10-year period is sufficient for ensuring storage security under Indonesia's geological conditions.

"In fact, countries with active tectonic plates like us should be more vigilant. That's why Japan was also careful regarding the monitoring period" (S1-G)

Interview findings also reveal fragmented understanding regarding long-term responsibility. While SOE actors assumed it would be automatically transferred to their responsibility, the private adopters expect they can continuously extend their permit, reducing the perceived importance of long-term liability transfer arrangements. These contrasting interpretations suggest that existing governance does not yet provide sufficient clarity regarding long-term stewardship.

"Ultimately, once the post-closure phase has arrived, it's usually a state-owned enterprise (SOE) that is asked to intervene, take over the responsibility." (S5-OGS)

"The expectation is that the CCS could last hundreds of years. It will continue to be extended, not just finished and then shut down. There's an expectation for continued extension." (S3-OGP)

The current governance structure further reinforces this uncertainty through relatively limited closure requirements, where site-closure guidelines remain administratively oriented rather than safety-oriented. As summarized in [Table 24 \(Appendix C\)](#), the closure is primarily triggered by operational conditions, such as the end of injection activities or permit expiration, with limited emphasis on geological safety as a site closure standard. In contrast, mature frameworks such as EU Directive require evidence of technically stringent criteria such as CO₂ plume stabilization, caprock integrity, and long-term predictability models ([IEA, 2022; Zhang, 2021](#)). The limited safety thresholds introduce flexibility for operators to define scope and depth of site closure assessment, potentially creating risks of premature site closure without sufficient long-term geological verification ([Koornneef et al., 2012](#)).

As a result, Indonesia's long-term stewardship framework remains institutionally underdeveloped. Although financial resources for post-closure monitoring are available, the current arrangement

does not clearly define responsibilities after post-closure stewardship ends, establish technically stringent criteria, or specify under which conditions storage sites can be transferred to the state. These ambiguities are particularly critical for Indonesia's tectonically active geological landscape and may undermine investor confidence (Koornneef et al., 2012; Wilson et al., 2009). Additionally, the shorter stewardship, while it may improve short-term investment appeal, also reflects business-oriented governance with potential risk transfer to affected communities.

5.3.2 Operational Liability and Financial Assurances

Indonesia's existing regulations provide relatively comprehensive requirements for operational liability across the CCS value chain. As summarized in Table 21 (Appendix C), operators must meet minimum criteria during the exploration activities, including geological assessment, economic evaluation, technical study, risk management, and MMV. As the exploration permit holder will be granted an operation permit, they must establish a plan of development and operation that covers expected minimum aspects (see Table 21) to ensure safe CCS operations. For carbon transportation, permit holders are responsible for maintaining compliance with the approved limits and ensuring safety. Additionally, the current governance structures limit cross-border CCS is only for maximum of 30% of the capacity (MEMR Regulation 16/2024, 2024). Overall, these provisions indicate a relatively robust framework for managing operational risks and liabilities.

While operational responsibilities are relatively well defined, financial assurance mechanisms remain weak. Given the substantial upfront investment, long operational timeframes, and post-closure financial obligations, Indonesia's current carbon pricing provides poor economic returns to offset these costs (PwC, 2024; S. Setiawan et al., 2021). Consequently, commercial viability relies largely on the storage fee, which is currently only feasible for the international market through cross-border CCS. Interview findings reinforce this imbalance. Although cross-border operation is perceived as the current most promising business model, CCS adopters noted persistent uncertainty regarding carbon accounting mechanisms, liability handover point across the CCS value chain, and international-domestic (30:70) allocation clarity, whether referring to storage capacity or operational activities. These contribute to lower confidence from international partners such as Singapore (Wijaya et al., 2025).

"The first problem is carbon accounting; we must determine whether to use a specific international standard, whether a third party is needed, and what the MRV mechanism is [...]. There is a regulation that the allocation for cross-border CCS is 70% international and 30% domestic. However, the interpretation remains confusing about whether it is based on capacity or injection volume [...]. The next issue is the handover point—where does the responsibility for CO₂ transfer? This is directly related to: emissions accountability, GHG inventory recording, who bears the losses, who is responsible for leaks at surface facilities." (S5-OGS)

The imbalance between strong operational control and weak financial incentives creates situations where projects may be technically feasible but economically unattractive, which potentially slows the adoption of CCS as a large-scale decarbonization option (Osazuwa-Peters & Hurlbert, 2020).

5.3.3 Measurement, Monitoring, and Verification (MMV) Governance

The existing frameworks provide a structured MMV system covering monitoring, reporting, and verification activities (see Table 22 - Appendix C). Monitoring requirements include comparing the actual CO₂ behaviour with modelling during pre-injection, observing CO₂ flow dynamics within the

subsurface, and identifying potential risks such as leakage, groundwater contamination, and storage integrity issues. These monitoring activities are mandated during exploration, operation, and up to 10 years post-closure (MEMR Regulation 16/2024, 2024; PTK-070, 2023). Reporting obligations demand that operators submit regular reports every six months and incident-based reports, which should cover the volume of CO₂ captured, transported, and stored (PTK-070, 2023). The report is subsequently verified to ensure accountability and environmental safety.

However, the monitoring guidelines remain at a relatively high level, lacking detailed technical guidance on critical CCS parameters such as plume behaviour, caprock integrity, wellbore stability, and long-term containment performance (IEA, 2022). Similarly, acceptable risk thresholds and monitoring benchmarks remain underdefined. This introduced high flexibility for operators to define their own monitoring approaches and acceptable risk, which potentially leads to a cost-minimising strategy with lower capability for early detection of system failures (Kuckshinrichs & Hake, 2015; Zhang, 2021).

Interview findings, however, reveal a different perspective. While literature emphasizes standardized monitoring criteria to ensure consistency, CCS adopters prefer a risk-based approach, where monitoring requirements are adapted to the geological characteristics of individual storage sites.

“From an industry perspective, we always encourage a risk-based approach. So, there's no need to be rigid about A, B, C, or D. Every field has different risks. Post-injection monitoring must be tailored to the risk profile of each field” (S3-OGP)

Overall, while Indonesia has established the MMV governance arrangements, it still relies heavily on operator preferences. Strengthening the guidance and standardized risk criteria is critical to improve monitoring consistency, regulatory certainty, and site integrity (Anzola & Baines, 2025).

5.3.4 Contingency Planning for Carbon Leakage and Failure

Indonesia's risk mitigation guideline is provided by Table 23 (Appendix C). To comply with current regulations, operators are expected to perform regular monitoring, risk assessment, ensure storage site integrity, provide comprehensive operational data, and maintain trained personnel to respond to emergency situations. While these show the recognition of leakage and failure mitigation, they remain largely administrative in nature and lack detailed technical standards such as a clear definition of leakage, acceptable risks, threshold that triggers intervention (MEMR Regulation 16/2024, 2024; PTK-070, 2023). This provides discretion for operators to perform and define their risk mitigation standards, potentially resulting in inconsistent contingency practices across projects. This lack of detailed technical guidelines on risk mitigation across the CCS value chain is also reinforced by CCS adopters during interviews as a governance challenge.

“There needs to be a clear emergency response and risk management protocol, especially for: leakage on ships, leakage at terminals, leakage at injection facilities, [...] All of this is still under discussion and does not yet have a final standard.” (S5-OGS)

While the institutional basis for contingency planning is available, the detailed technical standards remain underdeveloped. This potentially reduces consistency in risk management and increases uncertainty regarding environmental protection and emergency mitigation readiness, positioning the surrounding public at higher risk (Kern et al., 2016; Wilson et al., 2009).

5.4 Knowledge Development and Public Participation

This dimension examines how Indonesia's CCS governance arrangements support knowledge generation, information transparency, stakeholder engagement, and public participation, which are essential for institutional learning and long-term CCS legitimacy.

5.4.1 Transparency and Accessibility of CCS Information

Indonesia's existing governance provides limited provisions for public transparency and data accessibility. Existing reporting obligations are primarily directed toward government authorities, while explicit requirements for public disclosure of CCS operational performance, monitoring, and incident reporting remain underdeveloped ([MEMR Regulation 16/2024, 2024](#); [PR 14/2024, 2024](#)). Unlike Indonesia's SRN-PPI platform, which provides public access to information on NDC implementation, CCS lacks a centralized database containing project status, operational progress, and performance data. This limits public oversight of CCS implementation. Compared with more mature CCS jurisdictions, particularly Europe, transparency is embedded as a core principle. Permit holders in the EU area are required to disclose relevant information beyond regulatory reporting, including monitoring results and any incidents ([Brunsting et al., 2011](#); [IEA, 2022](#)). Such transparency supports independent evaluation by researchers, fostering knowledge creation, and builds trust among stakeholders as well as reducing information asymmetry for investors ([Rijk et al., 2019](#); [Upham & Roberts, 2011](#)).

The limited accessibility of CCS systems potentially constrains institutional learning, public trust, and lowers CCS attractiveness for investors ([Upham & Roberts, 2011](#); [Zuch & Ladenburg, 2023](#)). Without accessible and standardized data, external actors—including researchers, civil society organizations, and potential adopters—face difficulties in participating to evaluate CCS performance and environmental accountability ([Larkin et al., 2019](#)). This limits institutional learning, reinforcing a governance system in which knowledge remains concentrated among incumbent CCS actors rather than across researchers, civil society, and potential CCS adopters.

5.4.2 Stakeholder Engagement Governance

Stakeholder engagement in Indonesia's current CCS system remains largely driven by industrial and expert networks rather than institutionalized participatory governance mechanisms. Interview findings highlight that interactions are often initiated by key incumbent actors, such as Pertamina engaging multinational companies to learn from their global CCS projects, while ICCSC facilitates dialogues through conferences and stakeholder forums ([ICCSC, 2025a](#)). Although MEMR is responsible for coordinating with local governments in CCS sites, this coordination is primarily administrative rather than participatory in nature ([MEMR Regulation 16/2024, 2024](#)). However, given the strong hierarchical dominance, such coordination often becomes substantively limited, as the higher-power actors tend to steer the process according to their political interests ([Apriliyanti & Kristiansen, 2019](#)).

Formal requirements for broader stakeholder engagement remain limited. Beyond public hearings within Environmental Impact Assessment (AMDAL), there is no explicit mandate for continuous stakeholder engagement or public communication throughout the CCS project lifecycle ([Anindarini, 2021](#)). Consequently, continuous stakeholder dialogue often depends on voluntary initiatives rather than institutional requirements, and AMDAL consultations are often treated as procedural checklists rather than a platform for meaningful dialogues.

Interview findings show that, in the absence of stronger participatory mechanisms, trusted knowledge institutions such as CoE-ITB become important intermediaries for stakeholder communication. A researcher from CoE-ITB noted that, as a neutral knowledge actor who is often involved in the CCS feasibility study, they can balance industrial narratives and communicate both the opportunities and constraints without political influence.

“But one thing that does need to be considered is capacity building across all agencies. We shouldn't give people in ministries or other institutions false hope. Sometimes things are packaged too beautifully, when in fact, the technical details still pose many challenges. That's also our job—to provide a comprehensive perspective, not just the positive side.” (S2-R)

Overall, stakeholder engagement remains largely network-based rather than institutionally embedded. This may reduce opportunities for trust-building, early conflict identification, and inclusive decision-making (Leiss & Larkin, 2019). As a result, CCS discussions remain concentrated among core government, industrial, and technical actors, limiting cross-sectoral knowledge diffusion and wider societal participation.

5.4.3 Knowledge Governance and Institutional Learning

Knowledge development for CCS in Indonesia is active but only partially institutionalized. Interview findings and literature review indicate strong willingness among government, industry, and research organizations to learn from domestic projects and international experience (Karki, 2026; Ramadhan et al., 2024). However, mechanisms for systematically capturing, disseminating, and evaluating knowledge across projects remain weak. Current learning largely occurs through project collaboration, international partnerships, and professional networks such as the Indonesia Petroleum Association and ICCSC conferences (ICCSC, 2025b; Pertamina, 2026). CCS developers frequently collaborate with research institutions and multinational companies to strengthen technical capability and reduce implementation uncertainty.

“We need R&D support and technology adoption. We do have an R&D team, but for a multi-billion-dollar project, research support must be much stronger. We have benefited greatly from collaborations with companies like ExxonMobil, as their R&D has proven strength and experience.” (S5-OGS)

Despite the strong willingness to learn, learning activities remain project-based rather than institutionally embedded. In the introduction of new technology, cross-sectoral learning plays a critical role in accelerating adoption (Markard & Truffer, 2008). This is a gap observed within Indonesia's knowledge development governance, where lessons learned and standardized best practices are weakly institutionalized for knowledge dissemination across CCS projects. As a result, knowledge generated from one project is not consistently translated into broader institutional capacity.

5.4.4 Public Participation in CCS Development Process

Public participation currently plays a limited role in shaping CCS decision-making in Indonesia. While public consultation is required through the AMDAL process, interview findings show that societal acceptance is not regarded as a critical determinant of project continuation. Instead, political and regulatory approval, particularly from MEMR, is more influential for CCS project continuation (Keir et al., 2014; Sitinjak et al., 2023), reinforcing that public engagement is

procedural rather than a mechanism for influencing project design. The limited influence of public participation is reinforced by low public understanding of CCS as discussed in [Section 4.3.3](#). CCS adopters in the interview explained that the low level of community knowledge makes public discussions about long-term storage risks difficult. As a result, engagement often focuses on immediate socioeconomic benefits rather than informed deliberation about project risks.

“It's difficult because the public's level of knowledge is still low. Moreover, the areas where we develop are usually in remote areas. So, it's natural that their focus is: “What incentives will we get if this project goes ahead?” [...] Their concerns aren't about technical risks either. [...] They're more about whether this project will impact their livelihoods” (S3-OGS)

The discussed conditions make operators prioritize a pragmatic approach rather than investing heavily in long-term risk communication. As CCS adopters explained in the interview, public engagement strategies primarily address local expectations through employment opportunities, immediate compensation, or community programmes. Similar observations were reported in the CCS Gundih Project, where socioeconomic benefits became the dominant concern during community engagement ([Mulyasari et al., 2021](#)). While addressing public concerns through immediate benefits may facilitate project acceptance in the short term, it does little to strengthen informed public understanding in long-term CCS governance ([Leiss & Larkin, 2019](#)).

5.5 Corporate Governance for Supporting CCS as Climate Mitigation

This dimension examines the corporate governance embedded within national-level governance dimensions in supporting low-carbon development projects, including CCS.

5.5.1 Low Carbon Business Development Governance

Large companies have increasingly institutionalized low-carbon development through dedicated business units responsible for evaluating decarbonization investments, including CCS ([ExxonMobil, 2026](#); [Ika et al., 2022](#); [Pertamina, 2026](#)). Interview findings show that this organizational capacity is well established among large actors in CCS and is gradually emerging among potential CCS adopters. However, industrial actors further emphasized that these units remain subject to corporate priorities. Within SOEs, low-carbon initiatives continue to compete with national energy security priorities, while multinational actors are strongly driven by global climate commitments and stricter international emission standards.

Outside the oil and gas sector, low-carbon governance is also largely driven by business rather than regulation ([Nurdifah, 2025](#)). Potential CCS adopters explained that firms strengthen ESG performance and establish decarbonization projects primarily to maintain export competitiveness and access sustainable loans for business development. The existing domestic regulatory pressure alone was generally considered insufficient to motivate dedicated low-carbon investment.

“That's important. Again, the driver is business. For example, in my company, the driver is the funder, the sustainability loan. If you look closely, our company has the best ESG rating. One reason is that if we improve decarbonization and ESG, we can obtain a sustainability loan as a corporate loan for business growth. Without profit motivation, it's difficult to create a dedicated team to develop low-carbon businesses, unless there's a government regulatory compliance requirement.” (S6-NOGS)

Differences are also observed in organizational governance between SOEs and private companies. SOEs tend to demonstrate slower and more cautious decision-making towards high-risk technologies such as CCS due to strong hierarchical structure, high political influence, and accountability pressure (Apriliyanti & Kristiansen, 2019; Ayu, 2024). SOE actors in the interview emphasized that the concerns over the “state-loss” narrative discourage managerial risk-taking, even when projects are technically feasible. In contrast, private actors showed a greater autonomy to pursue commercially attractive low-carbon development opportunities and adapt more rapidly to emerging market conditions.

“Please note that SOE is under the Ministry of SOE; the minister has strong power to remove or assign a CEO. What normally happen, when the CEO cannot accommodate the political interest, they will be removed, although what they convey is business-grounded. Other ministers can also have power to influence SOE businesses” (S7-NOGS)

“[...] there are consequences to the “loss to the state” narrative. The impact isn't that they stop innovating, but rather that they make the process slower and more cautious. Because the accountability risks are high, many decisions—even relatively small ones—end up having to be delegated to external parties.” (S9-NTT)

Overall, corporate readiness for low-carbon development is growing among major industrial companies, but governance remains uneven. While multinational actors and large incumbents have institutionalized low-carbon business functions, broader corporate transformation still depends on international market exposure, commercial incentives, and—in the case of SOEs—political priorities.

5.5.2 Internal CCS Knowledge Development and Innovation

Current CCS adopters have begun institutionalizing internal knowledge development through dedicated CCS teams and collaboration with research institutions such as CoE-ITB. This is evident in Pertamina’s case, which was also confirmed in the interview, where CCS and CCUS-EOR are separated through different business units. CCS is within PHE Carbon Management to explore business viability in decarbonization using CCS as an independent business segment (Pertamina, 2026).

“At Pertamina, CCS and CCUS are separated. CCUS-EOR is within the oil and gas development team [...]. Meanwhile, CCS is considered a new business because it does not increase oil and gas production. Therefore, a special unit called PHE Carbon Management is established.” (S5-OGS)

Interview findings indicate that both SOEs and multinational actors are actively strengthening CCS capabilities, although they rely on different learning pathways. SOEs, particularly Pertamina, strongly collaborate with CoE-ITB and international partners to build technical capacity (Nugroho Dukut, 2026). At the same time, a CoE-ITB researcher observed that SOEs have shifted to exclude fundamental research, participating only in technology application and commercialization studies, increasing their dependence on CoE-ITB or external actors for early-stage studies.

“COE does collaborate at all levels. With Pertamina, for example, we've been working together on various CCS studies. [...] I've noticed a decline in their R&D activities over the past two years. There was a unit called Pertamina Research and Technology Innovation. Now the “R” has been removed. [...] they prefer to play at the application or development level, not fundamental research.” (S2-R)

Interview findings highlight that multinational companies demonstrate a more established learning system by leveraging their global CCS experiences, cross-country knowledge exchange, and internal technical standards. Compared to SOE, they have a more developed knowledge ecosystem for technology innovation. This provides advantages in technical familiarity, operational standards, and project management compared to domestic actors (Adisaputro & Saputra, 2017).

“We certainly have standards, but we still have a lot to learn from well-established CCS companies like Northern Lights. Our team has been there for a comparative study. [...] We also learned from our company's project in Danbury, US. Pertamina also contacted us to learn, and they also came to Danbury, US, to study CCS.” (S4-OGP)

In contrast, CCS knowledge development among potential CCS adopters outside the oil and gas sector remains limited. Although interest in CCS is gradually emerging, most firms continue to adopt a *wait-and-see* approach because commercial incentives remain weak and successful domestic demonstrations are still limited (Putriyana et al., 2023; Shin et al., 2023). As an ICCSC actor noted, the main barrier is not resistance to CCS but the absence of urgency and business incentives.

It's not because they (non-oil and gas and high emitters) refuse, but because they don't yet see the urgency of CCS and don't feel the need to get involved. So, the barrier is more a lack of initiative and awareness on their part, not because there's an explicit rejection. For example, mining and palm oil companies—they're also high emitters, but it's difficult to invite them into the CCS network” (S9-NTT)

Overall, corporate learning capacity is expanding, but it remains highly uneven. While leading oil and gas firms are building a knowledge ecosystem strongly through international collaboration, CCS learning capability has not yet diffused across other industrial sectors, reinforcing the concentration of expertise within incumbent oil and gas networks.

The corporate governance around low-carbon projects and CCS is summarized in Figure 24. Overall, corporate governance readiness for CCS remains uneven across sectors and organizational types. Among current CCS adopters, low-carbon business development is increasingly institutionalized, including CCS governance, through dedicated business units, international partnerships, and growing technical capabilities. However, these developments are still concentrated among a limited group of actors. Outside the oil and gas sector, interest in CCS and low-carbon projects is still largely driven by international market exposure, ESG expectations, and access to sustainable finance rather than domestic climate policy. These findings further reinforce the governance patterns identified in the previous sections, where CCS developments continue to be shaped by incumbent oil and gas actors, business competitiveness, and political priorities rather than cross-sectoral climate mitigation. Consequently, these uneven corporate governance and commitment to CCS further constrain the development of CCS as broader climate mitigation.

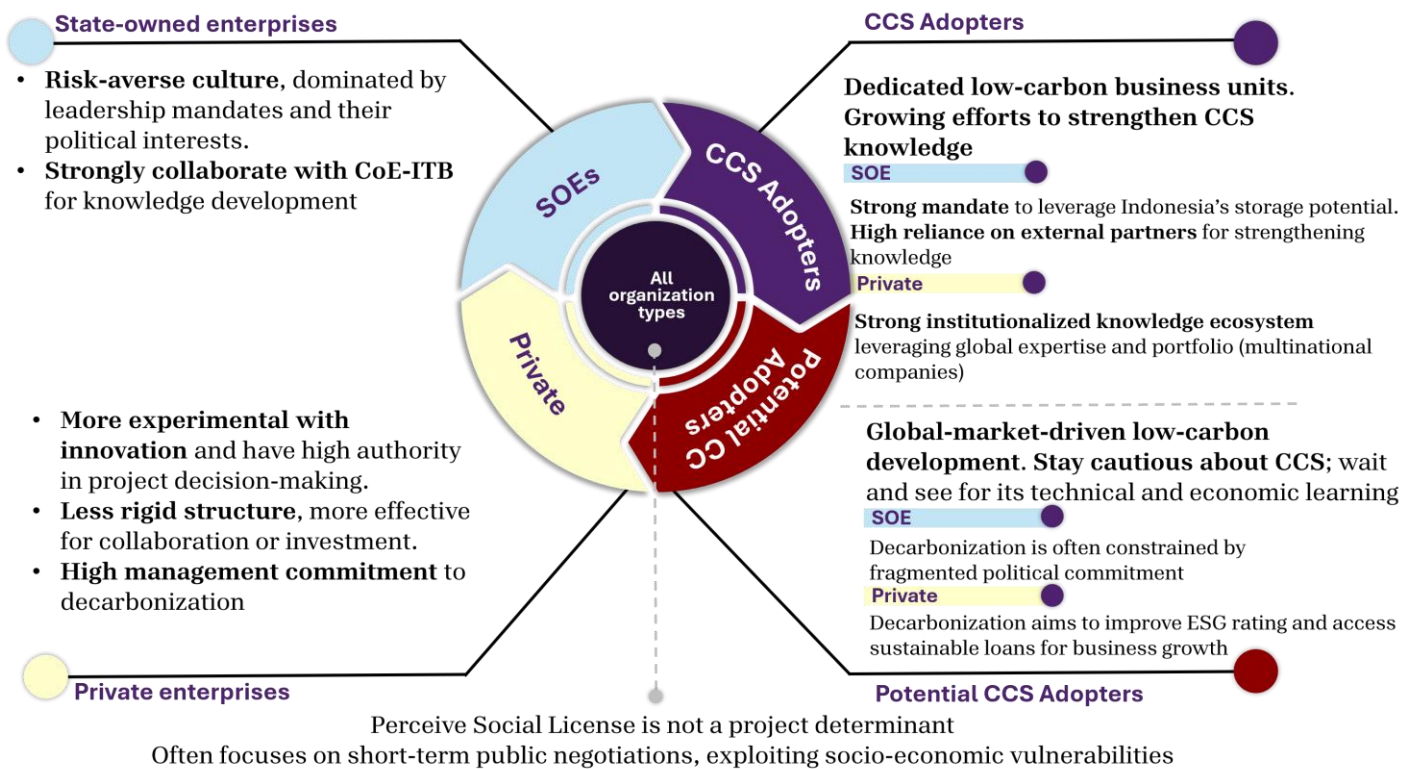
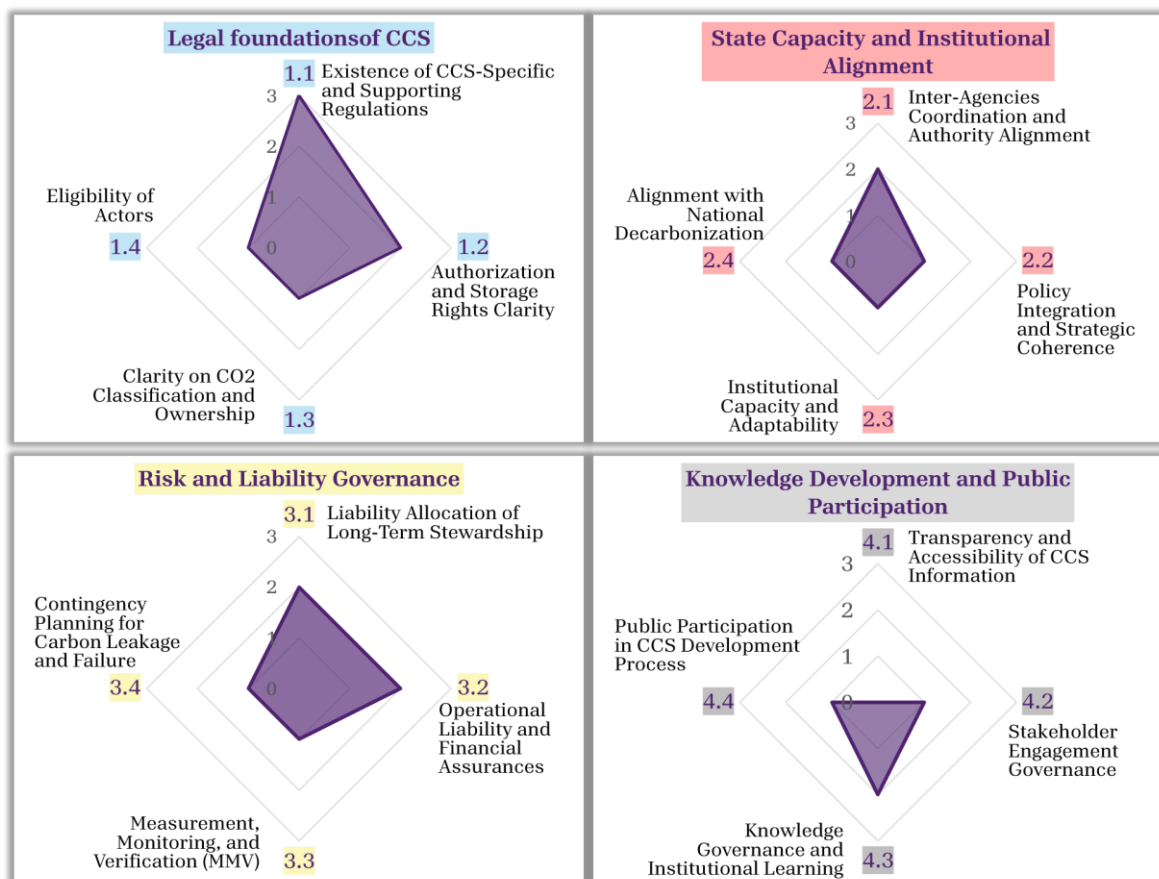


Figure 24. Corporate governance summary for low-carbon projects

5.6 Governance Readiness Overall Assessment

The governance readiness assessment shows that Indonesia has made substantial progress in establishing the institutional foundations for CCS, but governance readiness remains uneven across dimensions. As illustrated in Figure 25, building on comparative evaluation discussed in Section 3.2.2, legal foundations show the strongest performance, while knowledge development and public participation demonstrate the weakest dimension. State capacity and institutional alignment, together with risk and liability governance, occupy an intermediate position, indicating the governance arrangements are established with substantial gaps. Overall, the governance system is sufficiently developed to initiate early CCS development, but remains less prepared for large-scale, cross-sectoral implementation as a long-term climate mitigation pathway.

The uneven performances across dimensions reflect the priorities shaping CCS implementation in Indonesia. Legal foundations have progressed rapidly to provide regulatory certainty and attract investment, particularly by accommodating incumbent oil and gas actors and strengthening Indonesia's position within the emerging regional carbon market (MEMR, 2024b; Wijaya et al., 2025). In contrast, governance dimensions that require broader institutional transformation, including inter-agency coordination, long-term liability management, public participation, climate policy alignment, and cross-sectoral knowledge development, have received comparatively less attention. Consequently, the current governance is predominantly designed to facilitate investment and early project implementation rather than comprehensive long-term governance mechanisms for climate mitigation.



Remark

- 0: Absent, no evidence of the indicator's existence
- 1: Emerging, unclear provision, poorly implemented
- 2: Established: functional with gaps
- 3: Strong existence, relatively advanced

Figure 25. Governance readiness overall comparison

Figure 26 integrates the governance assessment with the MLP analysis in Chapter 4. As emphasized in Section 3.2.3, the governance readiness functions as part of the socio-technical regime, mediating how landscape pressure influences niche development. Although enabling conditions, particularly the existence of CCS-specific regulation and dedicated low-carbon units within corporate structure, support niche development, they are outweighed by constraining conditions such as fossil fuel path dependency, fragmented institutional and societal understanding, weak CCS incentives, legal ambiguities on CO₂ classification and exclusively eligible actors, fragmented political commitment, limited public participation, weak standardized MMV and risk mitigation, and uneven policy coherence. As a result, the findings further reinforce the MLP analysis, where Indonesia's CCS transition remains in the late pre-development to early-take-off phase, where niche learning activities are expanding through demonstration projects, storage exploration, international collaboration, dedicated CCS institutions, and growing institutional learning, but they have not yet developed sufficient regime transformation for large-scale CCS development. Therefore, to understand how CCS can be accelerated as cross-sectoral national climate mitigation, the identified governance gaps should be addressed to allow niche developments to be more prepared for scaling.

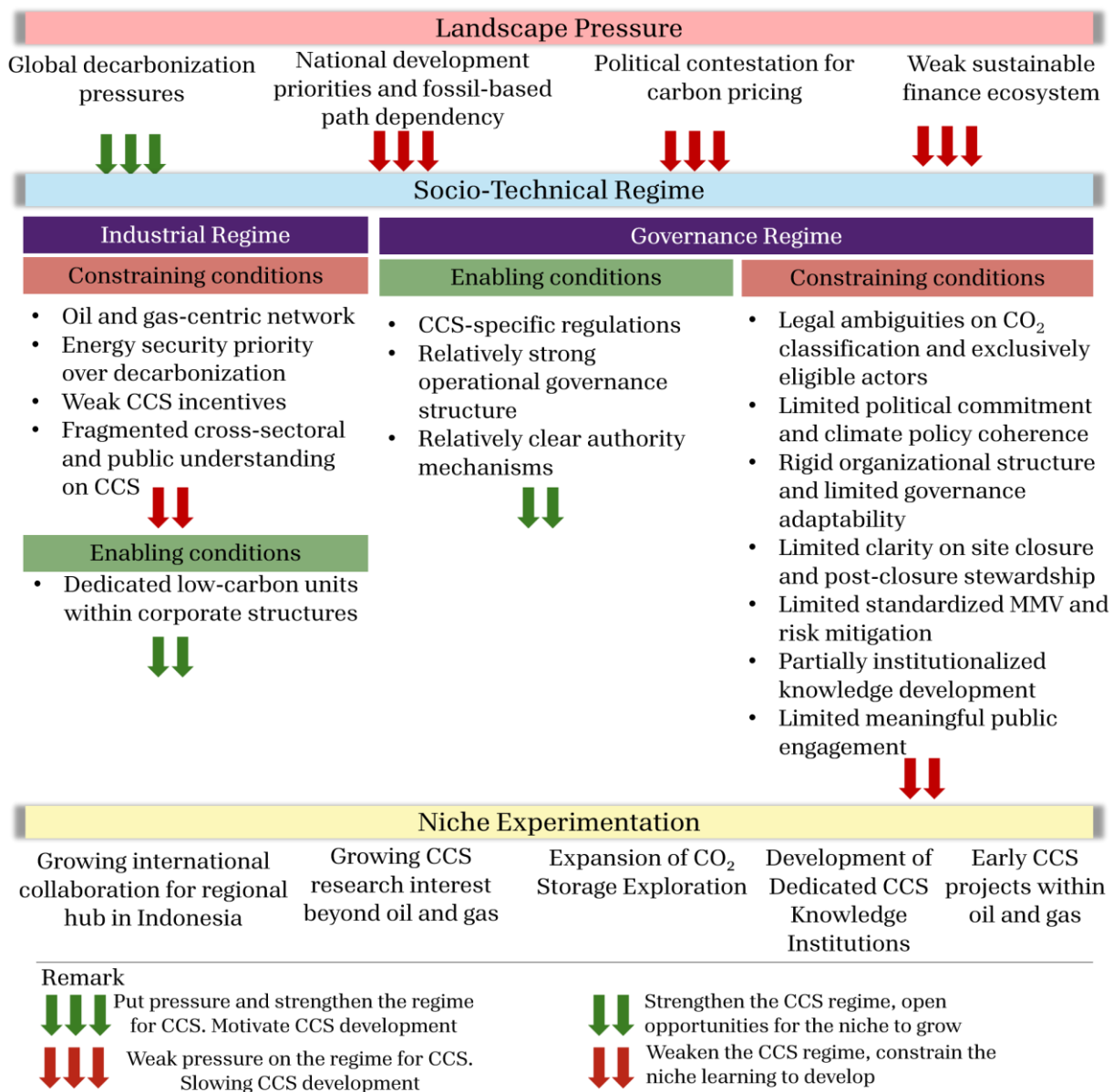


Figure 26. Governance readiness of Indonesia within the MLP framework

CCS in Indonesia: Barriers and Implementation Gaps

6.1 Socio-Technical Challenges

Table 8. Socio-technical challenges of CCS Implementation in Indonesia

No	Category	Challenges
1	CCS Governance and Regulatory Challenges	Weak legal foundation for CO ₂
2		Limited clarity on technical standards for MMV and Emergency Responses
3		Limited technical clarity on site-closure guidelines
4		Limited clarity on liability transfer after post-closure
5		Unclear cross-border mechanisms
6		Limited policy coherence for CCS and decarbonization pathway
7		Oil and gas-centric governance path dependency
8		Procedural rather than substantive public participation
9	CCS Innovation and Development Dynamics	High infrastructure and connectivity constraints
10		Limited knowledge and capacity in CCS implementation
11		Fragmented institutional understanding
12		CCS development concentrated in oil and gas
13		Limited knowledge diffusion beyond oil and gas
14	Decarbonization Commitment	Weak domestic decarbonization pressure
15		Limited disincentives for continuation of high-carbon activities
16		Conflicting priorities between fossil fuel expansion and decarbonization
17		Uneven low-carbon motivation
18	Economic Viability	Low economic incentives
19		Weak investment ecosystem
20		Capital-intensive pressure on CCS, highly dependent on external investment
21	Organizational and Institutional Culture	Inefficient Bureaucracy
22		Strong mechanistic governance
23		Risk-averse work culture, weak institutional adaptability
24	Political Dynamics	Inter-ministries coordination challenges
25		Fragmented political commitment
26		Political discontinuity on technology innovation due to the electoral cycle

The socio-technical analysis ([Chapter 4](#)) and governance readiness assessment ([Chapter 5](#)) reveal that the barriers to CCS implementation in Indonesia are not limited to technological or economic constraints alone. Instead, Indonesia's CCS is shaped by interconnected socio-technical challenges involving governance structures, political dynamics, market conditions, and organizational cultures. These interactions collectively explain why Indonesia's CCS is constrained for scaling as cross-sectoral climate mitigation.

[Table 8](#) synthesizes 26 socio-technical challenges identified across previous chapters, the analysis of socio-technical conditions and governance readiness. The categorization builds on the four themes discussed in [Chapter 3](#) (see [Table 6](#) and [section 3.4.1](#)), including CCS governance and regulatory challenges, CCS innovation and development dynamics, decarbonization commitment, and economic viability, with two additional themes emerging inductively from empirical findings: organizational and institutional culture, and political dynamics. Collectively, these six major themes capture principal challenges affecting CCS deployment in Indonesia.

Rather than treat these challenges as isolated issues, the remainder of this chapter analyses how they influence CCS deployment supporting climate mitigation. The identified challenges are mapped into CCS vision disruptors and short-term implementation barriers. Additionally, long-term barriers are also explored separately to capture potential future risks and uncertainties that could affect CCS deployment over time.

6.2 CCS Vision Disruptors

As discussed in [Section 3.2.4](#), disruptors are conditions that potentially paralyze the technology vision or distract short-term action that hinder the realization of long-term technology implementation ([Malekpour et al., 2017](#)). In Indonesia, CCS is envisioned as a long-term large-scale climate mitigation pathway within Indonesia's long-term climate change efforts ([LTS-LCCR, 2021](#)). The technology is expected to support carbon footprint reduction across energy and industrial sectors while supporting economic development ([Bloomberg, 2026](#); [MEMR, 2024a](#)). Building on the socio-technical challenges identified in [Section 6.1](#), twelve challenges were identified as vision disruptors (See [Table 25 \(Appendix D\)](#)). These disruptors interact, reinforce each other, and collectively constrain the transition of CCS from niche to broader socio-technical regime. [Figure 27](#) illustrates these interactions.

The first disruption mechanism concerns **fragmented governance direction**, which limits the ability of the existing regime to support CCS as a national climate mitigation. As shown in [Figure 27](#), fragmented institutional understanding across ministries and industrial actors contributes to fragmented political commitment to develop CCS as cross-sectoral decarbonization, resulting in inconsistent policy priorities and limited policy coherence. This is reflected in the current NDC and its weak integration into industrial decarbonization planning ([Kaneko & Kawanishi, 2016](#); [NDC, 2025](#)). From an MLP perspective, landscape pressure to decarbonize has not yet translated into a coherent CCS regime transformation, weakening the long-term institutional arrangements required to support the CCS vision.

The second disruptor observed is associated with **regime lock-in around the oil and gas sector**. As discussed in [Chapters 4 and 5](#), current CCS development, institutional learning, and regulatory design are still concentrated within oil and gas actors. This concentration accelerates niche learning in CCS by leveraging available technical expertise and infrastructure in the oil and gas sector ([Adisaputro & Saputra, 2017](#); [Ramadhan et al., 2024](#)), but at the same time reinforces oil-

and-gas governance path dependency and limits broader knowledge diffusion to other high emitters who have promising prospects as CCS adopters. Consequently, CCS niche developments are absorbed within the existing fossil fuel regime rather than challenge it. This further explains why Indonesia has progressed beyond initial experimentation but limited cross-sectoral diffusion.

As shown Figure 27, the third disruption mechanism relates to **weak domestic transition pressure for decarbonization**. Consequently, low-carbon initiatives are primarily driven by companies exposed to international markets or external climate regulations, while domestic industries remain weakly motivated (S. Setiawan et al., 2021; Sunanda et al., 2025). This uneven decarbonization pressure reinforces conflicting priorities between fossil-fuel expansion and decarbonization, reducing the possibility of widespread CCS adoption and weakening the long-term cross-sectoral CCS implementation beyond internationally oriented firms.

Other disruptors further reinforce these dynamics. Political discontinuity associated with electoral cycles introduces uncertainty over long-term policy commitment, making CCS highly dependent on the ongoing political leadership rather than stable institutional support. Additionally, public participation remains largely procedural, limiting opportunities for meaningful dialogues and social learning (Elliott & Setyowati, 2020). Although currently public acceptance is perceived as a weak determinant of project continuity, the current approach could risk future legitimacy as CCS projects expand and societal awareness of environmental and safety risks increases.

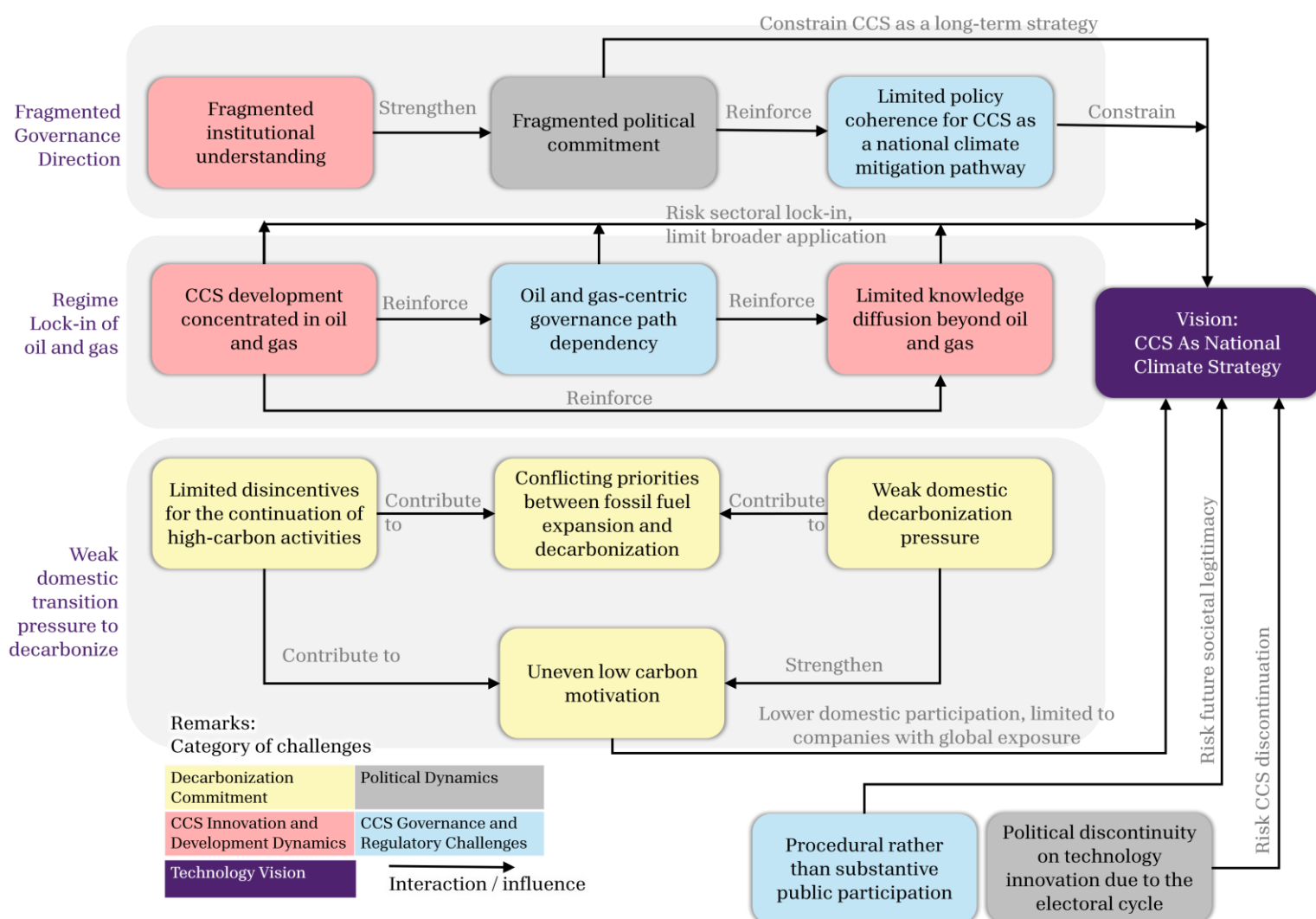


Figure 27. Vision disruptors interconnection and influence on Indonesia's CCS vision

Collectively, these disruptors constrain the transformation of niche experimentation into a broader decarbonization pathway. Together, they explain why CCS in Indonesia continues to evolve as an oil-and-gas business strategy rather than as Indonesia's national climate strategies.

6.3 CCS Short-term Barriers

As noted in [Section 3.2.4](#), short-term barriers refer to challenges that require immediate attention to enable CCS scaling beyond niche experimentation. From identified socio-technical challenges in [Section 6.1](#), fourteen challenges were identified as short-term barriers to CCS implementation ([Table 26](#) (see [Appendix D](#))). These barriers primarily affect the operational scaling of CCS projects. [Figure 28](#) shows how these barriers interact through four key reinforcing mechanisms that collectively constrain CCS broader diffusion in Indonesia.

The first mechanism is **operational governance uncertainty**. Although Indonesia has rapidly developed CCS-specific regulation frameworks, several operational governance mechanisms are underdefined. Key barriers include weak legal classification of CO₂, insufficiently specified technical standards used for MMV and contingency planning, limited technical criteria on site closures, weak cross-border mechanisms, and ambiguity on long-term liability transfer ([MEMR Regulation 16/2024, 2024](#); [PTK-070, 2023](#); [PR 14/2024, 2024](#)). These together increase the implementation uncertainty during project development and operation ([IEA, 2022](#); [Swennenhuis et al., 2024](#)). As a result, CCS development is constrained despite the availability of specific legal frameworks, mainly because the ambiguities increase the project regulatory risks.

As shown in [Figure 28](#), the second mechanism is related to **the weak economic ecosystem for CCS projects**. With existing insufficient carbon pricing and economic incentives, CCS projects continue to depend on the international carbon market ([Lestari, 2026](#); [MEMR Regulation 16/2024, 2024](#); [Wijaya et al., 2025](#)). This weak investment ecosystem further reinforces the reliance on external funding and international partnerships. As a result, CCS projects remain concentrated within a limited number of actors, those with stronger financial capacity and higher exposure to global markets, slowing broader CCS diffusion across domestic industries.

The third mechanism is associated with **limited cross-sectoral niche learning and infrastructure development**. Indonesia still faces limited knowledge and institutional capacity in CCS implementation experience and also lacks integrated CO₂ transport infrastructure. These conditions limit opportunities for cross-project learning and reduce the benefits of shared industrial infrastructure that could lower future costs for cross-sectoral CCS application ([ICCS, 2025a](#); [N. Liu, Liu, et al., 2025](#)). From an MLP perspective, niche development has not yet generated sufficient diffusion beyond early demonstration projects. Consequently, technological learning progresses incrementally, while opportunities to accelerate scaling through integrated infrastructure remain limited.

The last observed mechanism is **institutional inertia**, built from organizational culture and governance practices. A strong mechanistic governance structure contributes to lengthy bureaucratic processes, fragmented coordination, and a risk-averse institutional culture, particularly within government agencies and state-owned enterprises ([Apriliyanti & Kristiansen, 2019](#)). The perception of “state-loss” of failed projects within these organizations discourages decision-makers from supporting projects with uncertain commercial outcomes, while fragmented authorities slow cross-sectoral alignment unless supported by strong political

directive. Together, these conditions reduce governance adaptability, weakening Indonesia's ability to engage quickly to emerging CCS opportunities.

Overall, the short-term barriers show that Indonesia's immediate challenge is creating the governance, economic, institutional, and technological conditions necessary for niche expansions.

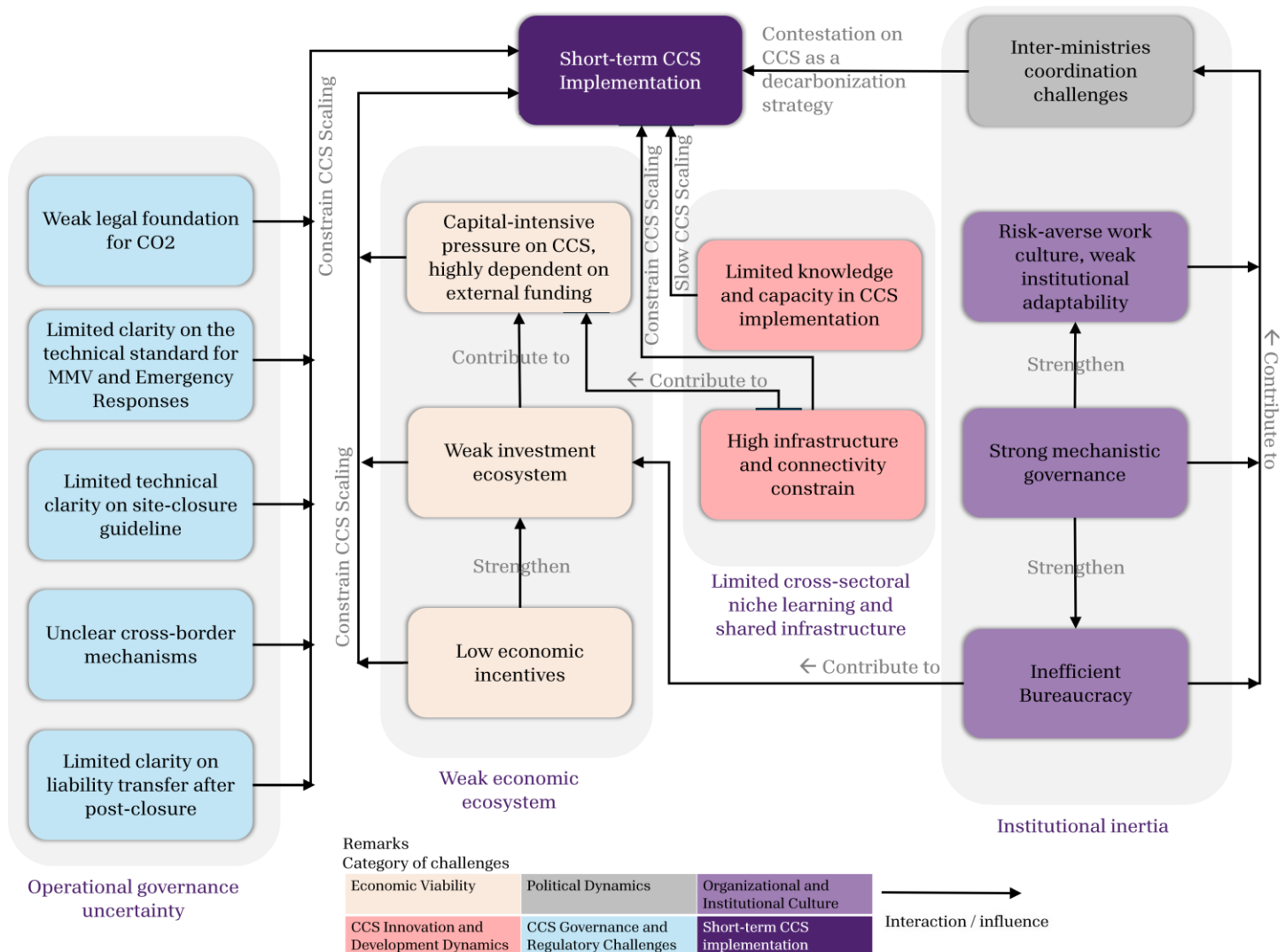


Figure 28. Short-term barriers interconnection and influence on Indonesia's CCS adoption

6.4 CCS Long-term Barriers

Following the framework discussed in Section 3.2.4, determining long-term barriers requires creativity to capture conditions that potentially affect the sustainability and credibility of CCS as a national decarbonization pathway. Unlike short-term barriers, these challenges are more uncertain in nature, emerging over long-time horizons as CCS becomes more deeply embedded within Indonesia's socio-technical regime. They concern whether CCS can remain politically, economically, and socially viable over multiple decades. Table 9 summarizes the identified long-term barriers and their implications for Indonesia's CCS deployment.

Several barriers are linked to **long-term governance continuity**. In nature, CCS requires multi-decade continuity in monitoring and liability management, while Indonesia's existing governance system is still vulnerable to political discontinuity and shifting national priorities every electoral cycle. This introduces risks of institutional fatigue, where governments may gradually deprioritize

costly long-term stewardship obligations on CCS, such as post-closure MMV. At the same time, intergenerational responsibility for CCS raises concerns regarding who will ultimately bear the long-term monitoring and environmental liabilities (Markusson et al., 2011b; Osazuwa-Peters & Hurlbert, 2020).

Long-term economic resilience of CCS currently remains uncertain. The existing CCS business model is currently dependent on regional carbon market growth and cross-border storage demand. This potentially strengthens the overdependence on international carbon markets, which expose CCS projects to future geopolitical tensions, regulatory changes, and carbon price volatility. Additionally, CCS competitiveness as a decarbonization pathway potentially weakens if low-carbon alternatives such as renewable energy, hydrogen, or energy storage become significantly cheaper and more scalable in the future (Grant et al., 2021).

Socio-technical legitimacy and transition direction are also part of **long-term legitimacy** concerns in CCS implementation. The concentration of CCS within oil and gas actors creates risks of long-term fossil fuel lock-in, where CCS functions to prolong the incumbent fossil fuel system rather than enabling broader cross-sectoral decarbonization. Additionally, the occurrence of major leakage or operational failure in one CCS project may significantly undermine public trust and weaken the legitimacy of other CCS projects (Terwel et al., 2009; Upham & Roberts, 2011). Finally, the weak participation from domestic industries potentially limits the development of a broader CCS ecosystem, constraining long-term adoption beyond incumbent actors.

Table 9. Long-term Barriers of CCS Implementation in Indonesia

No	Long-term Barrier	Category	Why it matters long-term
1	Oil and gas lock-in	Decarbonization Commitment	CCS may remain permanently tied to the oil and gas business
2	Major CCS leakage and accident	CCS Innovation and Development Dynamics	One incident may damage the legitimacy of all CCS projects nationally
3	Political discontinuity	Political Dynamics	CCS requires continuity across decades beyond the electoral cycle
4	Overdependence on international carbon market	Economic Viability	Foreign market changes could collapse CCS business model
5	Technology displacement by cheaper alternatives	CCS Innovation and Development Dynamics	Renewables, energy storage, hydrogen, or other options may become much cheaper in the future compared to CCS
6	Weak domestic industrial participation	Decarbonization Commitment	CCS ecosystem may fail to diffuse beyond incumbents
7	Cross-border geopolitical dispute	CCS Governance and Regulatory Challenges	Regional CCS operation may become politically sensitive
8	Long-term institutional fatigue	CCS Governance and Regulatory Challenges	Governments may gradually deprioritize costly CCS MMV
9	Intergenerational stewardship uncertainty	CCS Governance and Regulatory Challenges	Monitoring responsibilities will be transferred to future generations
10	Carbon market instability	Economic Viability	Volatile carbon market prices may weaken CCS profitability

Strategic Interventions in CCS Deployment Acceleration

Having identified the disruptors and barriers to CCS deployment (Chapter 6), this chapter proposes strategic interventions to accelerate CCS implementation in Indonesia. The proposed strategic interventions aim to address high-impact disruptors and barriers that influence across multiple dimensions of the CCS system, subsequently creating enabling conditions that could alleviate other interconnected challenges. The intervention design draws on the empirical findings of this study and is also informed by global CCS experiences and broader low-carbon technology transition literature. As noted in section 3.2.4, the interventions are organized into three areas: (1) enhancing CCS vision as a long-term climate mitigation, (2) addressing CCS short-term barriers at the national and corporate level, and (3) mitigating long-term threats of future CCS deployment.

7.1 Strategic Pathways to Enhance CCS Vision

Addressing the CCS vision disruptors (see [Section 6.2](#)) in Indonesia requires interventions that focus on strengthening socio-technical alignment across governance, industrial systems, and political commitment. [Table 10](#) summarizes the strategic interventions, including activities required to address CCS disruptors, and the following are the key strategies required to enhance Indonesia's CCS vision as a national decarbonization pathway.

1. Formalizing CCS Inter-ministerial working group within SATGAS TEH and Developing Dedicated CCS bodies within MEMR

Indonesia has developed the Energy Transition and Green Economy Task Force (SATGAS TEH), which currently highly focuses on coordinating foreign investment mobilization rather than as integrated decarbonization governance (see [Section 5.2.1](#)). Given that Satgas TEH already brings together ministries responsible for energy transition and decarbonization, formalizing a CCS inter-ministerial coordination within SATGAS TEH (upstream and downstream decarbonization bodies) could strengthen institutional understanding of CCS as a national climate strategy. Interview findings also highlight that most ministries already have dedicated teams for climate resilience development, which can be leveraged to discuss CCS and educate each ministry about CCS technological performance and its role in emission reductions. Additionally, MEMR as the central government in CCS and coordinator within SATGAS TEH, should develop a dedicated body for CCS similar to national energy target governance. This could accelerate CCS communication and education within government bodies. Strengthening understanding of CCS with these mechanisms may reduce fragmentation on political commitment ([Stirling, 2008](#)), improve policy coherence across ministries, and support broader CCS diffusion into other high-emitter sectors supervised by ministries such as MoI and MSOE.

2. Embedding CCS within RPJMN and NDC

Embedding CCS formally within Indonesia's RPJMN and future NDC submission becomes critical. Interview findings highlight that there are growing efforts to align NDC and CCS development as large-scale emission reduction strategies to strengthen institutional legitimacy for CCS implementation. Learning from Norway, where CCS is explicitly mentioned as NDC's strategies, such an approach increased industrial interests and participation in adopting CCS as their green transition pathway (Kronshage & Seljom, 2020). Currently, CCS support remains vulnerable to political discontinuity as it is not fully integrated within RPJMN for national development and NDC for decarbonization efforts. Integrating CCS into RPJMN and NDC should become a key priority to elevate CCS from sectoral experimentation into a nationally recognized decarbonization pathway, attracting high-emitter industries to learn more and adopt the technology. This eventually strengthens the political commitment to CCS.

3. Developing a National CCS Roadmap with Binding Milestones

To address the risk of political discontinuity every electoral cycle and extend cross-sectoral CCS adoption, developing a national CCS roadmap with binding milestones then becomes critical. MEMR used a similar approach for several national energy strategies, including national energy development (RUEN) and national electricity development (RUKN), to ensure consistent political commitment in changing political dynamics. Countries with stronger CCS governance, such as Canada, Australia, and Norway, also developed a clear roadmap of CCS development to improve investor confidence and industrial participation (CEM, 2024). The developed CCS roadmap should include milestone targets with clear target periods and extend CCS experimentation in other high emitters such as petrochemicals, steel, or cement. The roadmap should also emphasize phased transition targets such as pilot phase, cross-sectoral integration, and scaling. This approach aims to increase institutional legitimacy and non-oil and gas sector confidence to participate in CCS, allowing broader CCS application with lower political discontinuation risk.

4. Introducing Progressive Emission Reduction Obligations

Socio-technical analysis and interview findings show that low domestic decarbonization pressure strongly weakens Indonesia's green investment ecosystem. Therefore, the introduction of emission reduction obligations policy within industrial actors becomes critical to enable growing low-carbon project adoption, including CCS. Learning from Australia's safeguard mechanism, large emitters are mandated to have progressive emission reduction and prohibited from venting to the atmosphere (Gibb et al., 2024). Indonesia can adopt this policy to introduce industrial pressure beyond coal-fired power plants to innovate in low-carbon projects progressively to increase policy acceptance. The policy can start with large emitters (>100 kta-CO₂) and mandate them to develop decarbonisation business planning with clear phased emission reduction and also consider prohibition of venting to the atmosphere. This approach can strengthen domestic decarbonisation pressure, increasing attention on CCS as a strategic option for large emitters' decarbonisation, reducing reliance on the international market alone. As a result, high emitters with low global market exposure will be motivated to advance low-carbon projects for regulatory compliance objectives, increasing the market demand for CCS from other high emitters.

5. Prioritizing Integrated CCS Infrastructure Development within Industrial Areas

Current CCS implementation in Indonesia is geographically challenged and concentrated within oil-and-gas site areas, while Indonesia has 122 industrial areas across the country, introducing the potential of cluster-based CCS deployment to increase cross-sectoral participation (Daniswari, 2022; ICCSC, 2025a). To lower the cost and adoption barriers for domestic industrial actors,

integration of CCS infrastructure development should become a priority in developing CCS ecosystems, including shared pipeline networks, transport hubs, and storage-emitter integration. ICCSC, CoE-ITB, and MEMR could collaborate in identifying potential industrial areas near the identified storage sites for shared infrastructure development. In the long-term, this can reduce oil-and-gas path dependency and regional market reliance, strengthening the CCS vision as a national decarbonisation pathway.

7.2 Strategic Interventions for Short-Term CCS Acceleration

7.2.1 National-Level Strategic Interventions

To accelerate CCS implementation beyond current niche-learning experimentations, short-term barriers (see [Section 6.3](#)) should be addressed. There are strategic interventions required to strengthen existing CCS ecosystems, particularly in governance, financial, and technological performance, as summarized in [Table 11](#). The following are strategic interventions that should obtain immediate attention in addressing short-term barriers.

1. Strengthening CCS Governance Frameworks and Technical Guidelines with Clearer Mechanisms

Although Indonesia already has established one of the most advanced CCS-specific regulations among developing countries ([ICCSC, 2025b](#)), several key governance structures are underdefined (see [Table 26](#), [Appendix D](#)). First, provide clarity on CO₂ classification, whether it is under hazardous materials, commodity, or special substances, to allow cross-border transportation without legal consequences. Learning from the EU Directive and the UK, CO₂ is excluded from pollutants and hazardous materials to allow CCS activities ([IEA, 2022](#)). Second, technical standards for site closure, MMV, and risk management for CCS development should be clear to avoid inconsistent CCS operational governance across projects. There are several established international standards that could be considered, such as ISO Standards, IOGP in MMV, and EU Directives on site closure ([Dean & Ahead, 2024](#)). The regulation should make it explicit which authorities will be responsible for the asset upon asset transfer to the state. Additionally, current cross-border mechanisms still lack carbon accounting mechanisms and liability clarity across transboundary CCS operations. Addressing these governance issues will strengthen CCS ecosystems.

2. Develop a Progressive Carbon Pricing and Compliance Roadmap Activities

Limited economic incentives are the current bottleneck for low-carbon development in Indonesia, including CCS, and this is also voiced by all stakeholders during interviews. While Indonesia has established carbon pricing regulations, it does not strongly motivate industries to engage with low-carbon projects due to low carbon prices and limited implementation of regulations. Learning from the EU Emission Trading System (ETS), it was introduced to the market through four progressive phases and successfully increased carbon market participation and low-carbon innovations ([ICAP, 2026](#)). Indonesia can adopt a similar mechanism to introduce carbon pricing to attract market participation and low-carbon engagement. With a clear roadmap of carbon pricing, including clarity on sectoral scope and future pricing mechanisms, confidence in low-carbon technologies can increase, strengthening CCS's position in the domestic market. With the gradual increase of carbon pricing, the motivation for low-carbon innovation also increases, strengthening the sustainable investment ecosystem in Indonesia.

Table 10. Strategic Interventions to address CCS vision disruptors

No	Action	Activities	Objectives	Vision disruptors target
1	Formalize CCS Interministerial working group within SATGAS TEH and Dedicated CCS bodies within MEMR	1. CCS knowledge sharing to strengthen inter-ministries understanding 2. Harmonize the policy across ministries regarding decarbonization 3. Each ministry can introduce CCS to industries under their monitoring 4. Joint policy review mechanism 5. Shared CCS terminology/standards 6. Inter-ministerial technical task team. 7. Dedicated CCS body within MEMR for technology acceleration and effective coordination	1. Strengthen inter-ministries' knowledge development on CCS 2. Leverage Satgas TEH as a communication and coordination channel to discuss CCS within upstream and downstream decarbonization bodies 3. Dedicated CCS bodies within MEMR to strengthen coordination and accelerate policy development and adaptation	1. Fragmented Institutional understanding on CCS that will reduce fragmentation on political commitment 2. Fragmented political commitment 3. Limited policy Coherence 4. Limited understanding beyond oil and gas
2	Embed CCS within RPJMN and NDC	1. Formally include CCS as national decarbonization 2. Elevate CCS into a Presidential-Level Mandate: institutionalize CCS within long-term national development and climate planning. 3. Embed CCS inside SATGAS TEH with a Clear Mandate 4. Reframe CCS as a national decarbonization tool, not within oil and gas	Strengthen political commitment	1. Fragmented political commitment 2. Limited policy coherence
3	Introduce a National CCS Roadmap with Binding Milestones	1. Develop a clear roadmap that contains an industrial cluster deployment timeline, storage readiness milestones, cross-border milestones/target, MRV and liability timelines. Indonesia has other roadmaps such as Indonesia EMAS, Industrial development, RUEN / energy development. 2. Develop a shared CCS knowledge base/ Technical understanding, including technology performance for decarbonization, role per ministry. 3. Include non-oil and gas in the plan and put one non-oil-and-gas in a key acceleration project, where CCS in this sector is an example of non-oil-and-gas actors 4. Engage high-emitter industries, not limited to the oil and gas sector 5. Roadmap should include phased transition targets: pilot phase, cluster integration, and scaling	Reduce the risk of political discontinuation because the roadmap becomes an agreed/binding agreement within involved ministries. This also strengthens institutional understanding of CCS.	1. Political discontinuation due to electoral cycle 2. Fragmented knowledge understanding 3. Concentrated CCS applications in oil and gas

No	Action	Activities	Objectives	Vision disruptors target
4	Introduce Progressive Mandatory Emission Reduction Obligations	A “Safeguard Mechanism Indonesia” for facilities >100 ktCO₂/year. (starting with big emitters) 1. It mandates emissions reductions for large facilities and bans unlimited venting. 2. Create domestic pressure for incorporating low-carbon business development 3. CCS becomes a compliance tool, not a CSR project. 4. Non-O&G industries suddenly have a reason to adopt CCS	Increase domestic decarbonization pressure	1. Weak domestic decarbonization motivation 2. Uneven decarbonization 3. Concentrated CCS application within oil and gas 4. Limited disincentives in supporting high-carbon activities
5	Develop integrated infrastructure for CCS within industrial areas	1. Develop studies to identify shared CCS infrastructure within industrial areas. Indonesia has 122 industrial areas across the country. 2. Map potential integration between CCS projects and high-emitter areas 3. Prioritize investment in integrated facilities for CCS 4. Shared infrastructure reduces CCS cost uncertainty.	1. Increasing project attractiveness by lowering barriers for non-oil and gas to participate 2. Secure high emitters as the key point in the CCS business model, strengthening CCS in the domestic market 3. Expand the application of CCS beyond oil and gas, introducing the technology in other high-emitter businesses	1. Concentrated oil and gas application 2. Oil and gas governance path dependency 3. Limited knowledge beyond oil and gas
6	Strengthen Public Transparency and Participatory Governance for CCS	1. Develop centralized national CCS information platform 2. Require public disclosure of MMV, leakage incidents, and project performance 3. Introduce continuous stakeholder engagement throughout the project lifecycle 4. Develop an independent scientific review mechanism involving universities and research institutions 5. Strengthen local community capacity-building near CCS sites	1. Increase societal legitimacy and public trust 2. Reduce future social resistance risks 3. Improve accountability and transparency of CCS governance	1. Procedural public participation 2. Fragmented public understanding 3. Limited transparency and accessibility of CCS information 4. Weak societal legitimacy of CCS

3. Developing a National CCS Project Capital Support Fund

CCS adopters in Indonesia currently face investment challenges as CCS is capital intensive and receives limited international funding support due to its perceived high risks (Ramadhan et al., 2024; S. Setiawan et al., 2021). Given the weak green financing ecosystem in Indonesia, investment in CCS becomes more challenging. Therefore, developing a dedicated national CCS support fund becomes critical, supported through blended financing between government, climate finance, and international partnerships. This reduces early-stage investment risks and attracts more industrial players to engage with CCS. CCS experience from the UK provides insight, where the government provides the CCS Infrastructure Fund (CIF) with £1 billion to support early development of national CCS clusters, with target carbon abatement reaching 10MtCO₂/year by 2030 (IEA, 2025a). Priority should be directed toward integrated CCS hubs and shared infrastructure systems connecting industrial clusters with CCS infrastructure.

4. Strengthening CCS R&D, Institutional Learning, and Capacity Building Activities

As Indonesia has limited experience in CCS business operation, strengthening domestic technological and institutional capacity is equally essential. Rather than focusing solely on project-based consultancy, CoE-ITB could evolve into a national CCS knowledge centre responsible for coordinating R&D, capturing lessons learned, developing technical guidance, and facilitating cross-project learning. National interventions should also support targeted CCS R&D programs, institutionalized knowledge-sharing across CCS projects, technical training systems, and collaborative partnerships between industries, universities, and international institutions. These mechanisms can strengthen institutional learning while reducing fragmented understanding across stakeholders.

5. Improve Institutional Workflow and Adaptive Governance Mechanisms Activities

Improving institutional adaptability is equally important as improving regulations. The current CCS governance is affected by rigid institutional cultures, constraining CCS knowledge learning and coordination (Guttermann, 2025). Insight from the regional organization in the interview indicates that collaborating with Indonesia is complex and often takes a long time compared to neighbouring countries such as Malaysia, Thailand, and Singapore, with more straightforward processes. Therefore, simplifying inter-ministerial coordination procedures, clarifying institutional responsibilities, and introducing governance protection for strategic innovation decisions may improve institutional adaptability, increasing investment attractiveness. This also encourages actors to innovate and engage with new knowledge, reducing risk-averse mentality.

7.2.2 Corporate-Level Strategic Interventions

Beyond national-level strategies, accelerating CCS implementation also requires transformation at the corporate level. Chapter 5 analysis shows that Indonesia's current corporate low-carbon development remains uneven, where CCS adopters strengthen their internal knowledge capacity progressively while potential adopters perceive it as economically unattractive and an oil-and-gas-centric business. The findings also show differences between SOE and private enterprises in terms of work culture and innovation approach. Therefore, corporate-level transformation becomes important, as summarized in Table 12. The following are the corporate-level interventions required in accelerating CCS as a national decarbonization solution.

1. Strengthening Dedicated Low-Carbon Business Governance. Companies should develop a dedicated body within corporate management focusing on climate resilience and decarbonisation, exploring the business development options in green economic business which align with national

long-term development to sustain business competitiveness. This could strengthen long-term commitment to decarbonisation, and integrating decarbonisation KPIs into executive performance will further increase strategic commitment toward the low-carbon transition. This will benefit CCS as more companies will incorporate it into their low-carbon discussions.

2. Adopt ambidexterity and Open-innovation Culture. Companies should implement ambidexterity within organizational work culture, where employees are encouraged to spend time exploring innovation beyond routine operational activities (Van Assen, 2020). This improves experimentation and reduces scepticism toward new solutions such as CCS. Given Indonesia's limited experience in CCS, open innovation through collaboration with universities, research centres, and industrial partners can accelerate learning while reducing the burden of developing expertise internally (Newell et al., 2020).

3. Strengthen Cross-Sector Industrial Collaboration. Scaling CCS beyond oil-and-gas implementation requires stronger cross-sector collaboration. ICCSC should not limit membership to the oil-and-gas sector, developing a dedicated team to expand CCS engagement to other high-emitters. CoE-ITB could actively engage CCS actors for research partnerships and connect one project operator to others for strengthening knowledge diffusion. CCS adopters should also leverage the roles of ICCSC and CoE-ITB to accelerate collaboration between government and industries. Studies on shared infrastructure and CCS industrial clusters should also be prioritized to show potential future CCS operations and improve willingness from the non-oil and gas sector as the cost burden becomes lower.

4. Institutionalize Corporate Knowledge Development for Innovation. Major SOE such as Pertamina, PLN, and Pupuk Indonesia has numerous business portfolios operating across Indonesia (Guitarra, 2022), where the knowledge about the business is scattered and remains within each business unit. Drawing on the technology centre model used by multinational companies to connect each business unit for learning, institutionalizing knowledge creation, and advancing technological innovation (Fromhold-Eisebith, 2002). Such an approach can be adopted by Indonesia's major SOEs to accelerate institutional learning. This is also applicable for CCS, leveraging CoE-ITB while strengthening internal knowledge management processes.

5. Improve Institutional Workflow and Adaptive Business Approach. Companies, particularly SOEs, need to adopt a more adaptive and innovation-oriented work culture by reducing risk-averse behaviour through clearer institutional workflows, acceptable risk boundaries, and shared project responsibilities. Encouraging ambidexterity and showing management commitment to innovate will improve responsiveness to emerging technology such as CCS and reduce CCS development scepticism (Van Assen, 2020).

6. Improve Stakeholder Engagement and Social License Governance. Companies should also invest in long-term societal legitimacy by engaging with affected communities continuously, not only when completing procedural obligations. The approach should be beyond compensation-oriented, shifting toward participatory dialogue. When the communities have limited knowledge of the business, instead of exploiting the vulnerabilities, companies should continuously educate them. Strengthening community capacity, continuous dialogue, and transparent risk communication would strengthen long-term trust and social legitimacy rather than relying on short-term project acceptance (Elliott & Setyowati, 2020; Sara et al., 2015).

Table 11. National-Level strategic interventions to address short-term barriers

No	Action	Activities	Objectives	Short-term barrier target
1	Clarify and Strengthen CCS Governance Frameworks and Technical Guidelines	1. Formally define CO₂ legal classification, ownership, and transfer of liability across the CCS value chain. 2. Develop detailed technical standards for MMV, contingency planning, site closure, and long-term stewardship. 3. Clarify cross-border CCS governance, including carbon accounting standards, liability transfer points, and imported CO₂ treatment. 4. Develop sector-specific implementation guidelines beyond oil and gas industries. 5. Establish standardized technical criteria for leakage thresholds, emergency response, and post-closure transfer conditions.	Reduce regulatory ambiguity and improve governance certainty to strengthen investor confidence and operational consistency	1. Weak legal foundation for CO₂ 2. Limited MMV technical clarity 3. Weak contingency planning governance 4. Limited site closure clarity 5. Limited liability transfer clarity 6. Unclear cross-border mechanisms 7. Oil-and-gas governance path dependency
2	Develop a Progressive Carbon Pricing and Compliance Roadmap Activities	1. Expand carbon pricing gradually beyond coal-fired power generation into hard-to-abate sectors. 2. Establish phased emissions thresholds and compliance timelines similar to the EU ETS or Australia's Safeguard Mechanism. 3. Develop predictable carbon price trajectories and offset market development plans. 4. Clarify the role of CCS within future compliance obligations and industrial decarbonization pathways. 5. Introduce stronger disincentives for continued high-emission activities.	Increase long-term market certainty and create stronger domestic demand for CCS adoption.	1. Low economic incentives 2. Weak domestic decarbonization pressure 3. Limited disincentives for high-carbon activities 4. Weak investment ecosystem 5. Uneven low-carbon motivation
3	Establish a National CCS Project Capital Support Fund	1. Develop dedicated state-backed CCS infrastructure financing mechanisms. 2. Provide co-funding support for early-stage CCS demonstration and shared infrastructure projects. 3. Introduce risk-sharing instruments for high-capital CCS investments. 4. Prioritize integrated CCS hubs connecting industrial clusters and storage sites. 5. Mobilize blended finance involving MDBs, climate finance institutions, and private investors.	Reduce financial barriers and improve early-stage commercial viability of CCS projects	1. High capital intensity 2. Weak investment ecosystem 3. Dependence on international financing 4. Infrastructure connectivity constraints
4	Strengthen CCS R&D, Institutional Learning, and Capacity Building Activities	1. Establish targeted national CCS R&D funding schemes. 2. Strengthen collaboration between industry, universities, and international CCS institutions. 3. Develop national CCS training and certification programs. 4. Institutionalize cross-project knowledge-sharing mechanisms. 5. Expand CCS knowledge development beyond oil and gas sectors.	Improve domestic technical capability and reduce dependence on foreign expertise.	1. Limited knowledge and capacity 2. Fragmented institutional understanding 3. Limited knowledge diffusion 4. CCS concentration within oil and gas 5. Weak institutional adaptability
5	Improve Institutional Workflow and Adaptive Governance Mechanisms Activities	1. Simplify inter-ministerial coordination procedures for CCS permitting and approvals. 2. Develop clear institutional workflows and decision-making responsibilities. 3. Introduce governance protection mechanisms for strategic innovation decisions. 4. Clarify acceptable risk boundaries for public institutions and SOEs. 5. Strengthen adaptive governance mechanisms within CCS oversight institutions.	Improve governance efficiency and reduce institutional risk aversion toward CCS innovation.	1. Inefficient bureaucracy 2. Strong mechanistic governance 3. Risk-averse institutional culture 4. Inter-ministerial coordination challenges 5. Weak institutional adaptability

Table 12. Corporate-Level strategic interventions to address short-term barriers

No	Action	Activities	Objectives	Short-term barriers target
1	Develop Dedicated Low-Carbon Business Governance/Team	1. Establish dedicated low-carbon business units. 2. Integrate decarbonization KPIs into executive performance. 3. Separate Low-carbon and CCS governance from conventional business targets. 4. Strengthen internal knowledge and innovation capacity	Strengthen long-term organizational commitment toward decarbonization. Reduce organizational capacity and improve technological learning	1. Limited knowledge and capacity 2. Fragmented institutional understanding 3. Limited knowledge diffusion 4. CCS concentration within oil and gas
2	Adopt ambidexterity and open-innovation culture	1. Allocate time to move away from daily work and explore innovation ideas, outside the conventional business operation. This allows potential adopters becomes less sceptic to CCS as well as CCS adopters will welcome new ideas from the non-oil and gas sector 2. Welcome the open-innovation concept, meaning collaborating with other parties to build the capacity for business development instead of keeping all R&D effort within the company. 3. Build internal CCS technical capability. 4. Strengthen partnerships with research institutions and global CCS operators. 5. Increase participation in pilot projects and demonstration programs.	Reduce organizational capability gaps and improve technological learning, accelerate innovation and knowledge development	1. Limited knowledge and capacity 2. Fragmented institutional understanding 3. Limited knowledge diffusion 4. CCS concentration within oil and gas
3	Strengthen Cross-Sector Industrial Collaboration	1. For CCS adopters: engage actively with CoE-ITB and ICCSC for network building and institutional learning. Actively participate in the knowledge-sharing forum, including CCS Annual Forum. 2. For ICCSC: Extend the membership beyond oil and gas, build a dedicated team to focus on a broader knowledge diffusion program, engaging with potential CCS adopters 3. For CoE-ITB: not only receive requests from industries but actively show industries the capability of research and development within CoE-ITB, so the knowledge building can expand faster 4. Develop industrial CCS consortiums. 5. Encourage shared transport and storage infrastructure. 6. Facilitate partnerships between emitters and storage operators.	Expand CCS ecosystem beyond incumbent oil-and-gas actors.	1. Limited knowledge and capacity 2. Fragmented institutional understanding 3. Limited knowledge diffusion 4. CCS concentration within oil and gas
4	Institutionalize Corporate Knowledge Development for Innovation	For SOEs with major business units and many fields to operate across the country, institutionalize R&D as a technology centre. PERTAMINA, PLN, AND PUPUK INDONESIA have the capacity to do so as the three major SOEs. Learning from multinational companies, the technology centre is people with prior strong experiences in operations in the company's fields as well as those who strongly engage with research activities. This strengthens business troubleshooting as one field can be connected to another field through the technology centre, as well as the knowledge exchange process within corporate can be much easier. Additionally, having dedicated bodies to progress innovation will strengthen the business	Expand CCS ecosystem beyond incumbent oil-and-gas actors.	1. Limited knowledge and capacity 2. Fragmented institutional understanding 3. Limited knowledge diffusion 4. CCS concentration within oil and gas

No	Action	Activities	Objectives	Short-term barriers target
5	Improve Institutional Workflow and Adaptive Business Approach	1. Reduce the risk-averse work culture by developing clear institutional workflow, including what are acceptable risks. 2. Encourage innovation from leaders, so employees have high encouragement to do so. 3. Share risk and responsibilities in every company's project, thus people are willing to invest more of their time and improve their learning and experimentation	Strengthen innovation within corporate and reduce inefficiencies in workflow	1. Inefficient bureaucracy 2. Strong mechanistic governance 3. Risk-averse institutional culture
6	Improve Stakeholder Engagement and Social License Governance	1. Develop continuous community engagement mechanisms, not only when concerns occur. Strengthen the public affairs team program to engage with society, understanding their concern while educating them. 2. Improve transparency in project communication. 3. Shift from compensation-based engagement toward participatory dialogue.	Strengthen societal legitimacy and reduce future social conflict risks; build community trust	

7.3 Strategic Interventions for Long-Term CCS Implementation

Unlike short-term barriers that constrain current CCS deployment, long-term barriers concern the sustainability and resilience of CCS as a national decarbonization pathway under future political, economic, technological, and societal uncertainties. Rather than introducing entirely new interventions, long-term strategies focus on strengthening the adaptability of governance arrangements so that CCS remains effective as external conditions evolve. [Table 13](#) provides key interventions to deal with potential long-term risks in CCS technology applications.

First, **developing adaptive long-term CCS governance**. As CCS projects operate for decades beyond current political administration, governance structures need to be adaptive and institutionalized rather than the current leadership-driven approach ([N. Liu, Liu, et al., 2025](#)). While CCS projects are in operation, periodic governance review is required to evaluate the effectiveness of CCS regulations, MMV, liability arrangements, and cross-border mechanisms. Strategies with long-term impact such as CCS roadmap development, dedicated CCS body within MEMR, and national decarbonization alignment through RPJMN and NDC should be prioritized to reduce the risks of political discontinuity across electoral cycles.

Second, **building economically resilient and cross-sectoral CCS ecosystems**. Current CCS project concentration within the oil and gas sector and increasing dependency on regional markets threaten the sustain technology adoption. While this could accelerate early-stage CCS implementation, key stakeholders should consider the potential vulnerabilities to future market volatility, geopolitical shifts, and technological competition from alternative low-carbon technologies such as renewable energy, energy storage, and hydrogen. Therefore, strategies related to cross-sectoral expansion should be strengthened, including CCS cluster development with shared infrastructure, engaging non-oil-and-gas in CCS discussions, leverage current SATGAS TEH to introduce CCS across ministries. Additionally, ensuring economic competitiveness is an evergreen effort from CCS key stakeholders to maintain CCS competitiveness in the low-carbon market ([Karayannis et al., 2014](#); [Osazuwa-Peters & Hurlbert, 2020](#)).

Third, **strengthening long-term safety, risk anticipation, and public legitimacy**. Long-term CCS deployment will strongly depend on the ability to maintain public trust and operational safety ([Rasool & Moiz Hashmi, 2025](#)). One major leakage incident or operational failure in one CCS project may damage the legitimacy of CCS implementation nationally ([Markusson et al., 2012](#)). Therefore, Indonesia needs to progressively strengthen long-term safety governance and environmental monitoring systems. Strategies associated with enhancement of risk mitigation should also be prioritized, including clarity on technical criteria of MMV, risk mitigation, and site closure. Additionally, to avoid strong public distrust in the future, institutionalize public communication and risk communication beyond procedural checks in permitting systems.

Table 13. Strategic interventions for long-term barriers

No	Action	Activities	Long-term barrier target
1	Establish Adaptive and Continuous CCS Governance Review	1. Periodic review of CCS regulations and technical standards. 2. Continuous update of MMV, liability, and safety frameworks. 3. Scenario planning for future disruptions: carbon market collapse, CCS leakage, geopolitical conflict, technology displacement. 4. Create a long-term CCS governance evaluation body under MEMR/SATGAS TEH.	1. Political discontinuity 2. Institutional fatigue 3. Technology displacement 4. Cross-border geopolitical disputes 5. Carbon market instability
2	Diversify CCS Ecosystem Beyond Oil and Gas and International Markets Core Idea	1. Expand CCS participation into cement, steel, petrochemical, and power sectors. 2. Develop domestic carbon demand and domestic storage users. 3. Support integrated industrial CCS hubs. 4. Encourage domestic innovation ecosystems. 5. Maintain flexibility if alternative low-carbon technologies become more competitive.	1. Oil-and-gas lock-in 2. Weak domestic industrial participation 3. Overdependence on international carbon markets 4. Technology displacement
3	Strengthen Long-Term Stewardship and Public Trust Mechanisms Core Idea	1. Strengthen independent safety oversight. 2. Develop transparent public disclosure mechanisms. 3. Build national long-term environmental monitoring systems. 4. Create independent incident investigation mechanisms. 5. Institutionalize public communication and risk engagement.	1. Major CCS leakage and accidents 2. Weak social legitimacy 3. Long-term stewardship uncertainty 4. Institutional fatigue

8.1 Synthesis of Findings

This study shows that Indonesia has established strong pre-development ecosystems for CCS, supported by high geological storage potential, emerging CCS-specific regulations for cross-sectoral operations, dedicated research (CoE-ITB) and coordination (ICCSC) institutions, growing international collaboration for CCS studies and development, as well as increasing political interest in positioning Indonesia as a regional storage hub. Compared to many developing countries, Indonesia has developed a relatively advanced regulatory foundation for CCS, including permitting systems, cross-border mechanisms, carbon pricing regulations, and technical guidelines for operational, monitoring, and risk management ([Global CCS Institute, 2023](#); [ICCSC, 2025b](#)). These findings show that CCS in Indonesia is already beyond the conceptual phase but entering formal governance and industrial development planning.

Despite this progress, Indonesia's CCS transition remains constrained by weak socio-technical alignment, including limited institutional alignment, weak technical clarity on guidelines, fragmented institutional understanding, weak policy coherence, and limited integration into broader decarbonization strategies. As a result, CCS implementation is concentrated within the oil and gas sector, reflecting the adoption of existing oil-and-gas governance logic, expertise, and business interest. While this accelerates early introduction through oil and gas, it also limits broader participation from other high emitters and reinforces the dominance of incumbent actors.

The findings also highlight that Indonesia's current governance is dominated by strong hierarchical, centralized decision-making, in which political interests and leaders' mandates strongly influence institutional coordination and policy alignment. This has positioned CCS as vulnerable to the electoral cycle, shifting political interests, and ministries' priorities. Additionally, risk-aversion mentality, mechanistic governance culture, and concern over "state-loss" accountability further limit experimentation and innovation, particularly within government bodies and SOEs. These conditions together contribute to inefficient bureaucracy in Indonesia, reducing its investment attractiveness and international collaboration.

The study further shows that existing CCS implementations are highly reliant on regional carbon markets and cross-border mechanisms. This is highly driven by weak decarbonisation motivation from domestic industries due to limited disincentives in engaging with high-carbon activities, as well as growing international carbon markets from countries with higher willingness to pay for storage services. This international market reliance questions CCS effectiveness for national

decarbonisation efforts. The findings also reveal that current governance readiness remains uneven for long-term CCS applications. While the CCS operational governance structure is relatively strong, important elements such as long-term liability transfer, CO₂ classification, MMV, site closure, contingency plan, and cross-border are still underdefined. Public participation is similarly limited, with engagement often as a procedural check rather than substantive.

Overall, the research highlights that Indonesia's current CCS is largely situated in niche-level experimentation with a partially aligned socio-technical regime, constraining CCS scaling. Indonesia's CCS trajectory remains characterized by tensions between decarbonization and national energy production, between long-term decarbonization pathway and short-term political interest, and between ambitions as a leading regional hub and constrained institutional capacity for sustaining long-term CCS operation.

8.2 Socio-Technical Dynamics Shaping CCS Trajectories

This research shows that Indonesia's CCS transition reflects a regime-led socio-technical transition process. Unlike many socio-technical transitions where niche actors challenge incumbents, Indonesia's CCS development is primarily initiated and coordinated by incumbent regime oil and gas actors. As a result, CCS emerges not as a disruptive technology but as an adaptive strategy embedded within existing oil and gas businesses.

From a Multi-Level Perspective (MLP), landscape pressures influence Indonesia's low-carbon transition unevenly rather than creating broad systemic change. Low-carbon projects are largely driven by international market and climate developments such as low-carbon product requirements and mechanisms such as CBAM. Consequently, low-carbon developments are limited to companies with global market exposure, often motivated by sustaining the business rather than decarbonization. This is also evident in CCS deployment, where standalone CCS is increasingly linked to regional carbon market opportunities, while domestic demands remain weak, raising broader concern about its role in reducing national emission footprint. In the absence of strong industrial decarbonization mandates and low-carbon incentives, broader CCS adoption remains constrained.

At the regime level, CCS was introduced through oil and gas business frameworks aiming for accelerated implementation. While this has mobilized investment and technical expertise, it has also reinforced path dependency and limited participation from other carbon-intensive actors. Fragmented institutional understanding and weak policy coherence further constrain CCS integration into national decarbonization strategies. As a result, CCS is often perceived as an oil-and-gas business extension rather than a cross-sectoral decarbonization solution. There is also tension between decarbonization efforts and national energy security strategies, where CCS is framed for decarbonization but also boosts national energy production. These ambiguities further constrain political alignment for CCS as a national climate strategy, reflecting global debate regarding the risk of carbon lock-in through CCS adaptation rather than green transformation.

The findings also reveal that Indonesia's CCS is shaped by institutional and political culture. Strong hierarchical governance and dependence on political directives create vulnerabilities to shifting political interests and reinforce inefficient bureaucracy. These are enablers for a risk-averse mentality among government and SOE actors, limiting experimentation, innovation, and collaboration in emerging technologies.

Beyond technological and governance considerations, just transition is still limited and often overlooked in decision-making processes. Public engagement practice is often procedural rather than substantive consultation, while limited public understanding and socio-economic vulnerabilities reduce meaningful engagement. In Indonesia, social injustice practices are also evident in extractive companies where public participation and shared benefits are often perceived not important (Elliott & Setyowati, 2020). Combined with corruption practices in Indonesia, industrial actors often prioritize rent-seeking to secure political connections rather than addressing public concerns for business continuity (WHITE, 2006; L. Yusgiantoro et al., 2025).

Overall, Indonesia's trajectory reflects an adaptive regime response to reconcile with increasing decarbonization pressures within the existing fossil-fuel political economy ecosystem, rather than as a fully transformative sustainability transition.

8.3 Strategic Tension Between Decarbonization and Fossil Fuel Expansion

One of the key findings of the study is the existence of strategic tension between decarbonization ambitions and national energy security ambitions through fossil fuel expansion. CCS is promoted as a decarbonization strategy while expanding the fossil fuel economy. The introduction of CCS, yet its development is largely embedded within policies that continue to prioritize oil and gas production expansion and energy security. As a result, CCS becomes politically more attractive because it offers a solution to manage both decarbonization and fossil fuel production optimization. This is also reflected in current CCS projects where CCUS-EOR receives stronger political support compared to standalone CCS projects.

The study emphasizes that current CCS is concentrated within the oil and gas sector. Although CCS is positioned in long-term decarbonization, particularly from hard-to-abate sectors and coal-fired power plants, participation from these sectors remains limited. As Indonesia is one of the largest coal exporters in the global market (Workman, 2025), the involvement of coal-based power sectors in CCS should therefore be prioritized for effective CCS long-term strategy alignment. Additionally, the dominance of oil-and-gas actors has accelerated early CCS development by leveraging existing subsurface expertise, infrastructure, and investment network, but it also creates path dependency that constrains broader CCS application. This concentrated development is driven by geopolitical opportunity to secure regional investment immediately. Consequently, CCS governance risks becoming heavily investment-oriented, where attracting international markets may receive higher political support than strengthening domestic emission reduction pressure.

Importantly, the tension should not be interpreted solely as policy inconsistency or governance failure. For developing economies such as Indonesia, the challenges remain politically complex in balancing economic development, decarbonization, energy security, and socio-economic issues. In this context, CCS offers a pragmatic way to navigate these competing priorities, allowing emission reduction to coexist with continued utilization of fossil fuel resources.

Ultimately, this research reveals that Indonesia's CCS transition is shaped by political-economic negotiations regarding the future role within national development, where CCS is contested between decarbonization strategies and a mechanism to strengthen the fossil fuel regime. For long-term broader applications, CCS governance therefore should be adaptive and reduce reliance on single applications such as international market-driven or oil-and-gas-centric.

8.4 Feasibility and Risk of Proposed Strategic Interventions

The strategic interventions proposed in [Chapter 7](#) should not be interpreted as deterministic solutions that guarantee successful long-term CCS implementation in Indonesia. Instead, they reflect exploratory strategies developed based on socio-technical challenges and governance readiness gaps analysis throughout this study. The discussion in this section focuses on the relative feasibility, strategic importance, and potential influence of the intervention rather than their measurable effectiveness, as the proposed solutions are not tested using performance metrics of modelling.

Some proposed interventions have higher systemic impact because they address foundational barriers that subsequently influence multiple constraints. Interventions related to inter-ministerial coordination, policy coherence, institutional alignment, and domestic low-carbon motivation create broader enabling conditions for other interventions to be effective. For example, formalizing CCS coordination within current Satgas TEH, embedding CCS within national development planning and decarbonization strategies, and developing a dedicated CCS body within the main regulator may improve institutional understanding, reduce political commitment fragmentation, and increase long-term policy coherence. Subsequently, they may strengthen governance reforms, investment ecosystem, industrial participation, and cross-sectoral knowledge diffusion. In contrast, focusing solely on CCS regulation framework enhancement, such as clearer MMV standards, site closure, risk management, clarity on liability transfer, and CO₂ classification, is unlikely to significantly accelerate broader CCS implementation if domestic decarbonization pressure and economic incentives are still weak. Similarly, the intervention in developing a shared infrastructure CCS business model will be constrained by the perception of CCS as an oil and gas business extension rather than a national decarbonization strategy.

However, the feasibility of proposed interventions is vulnerable to Indonesia's political and institutional environments, including shifting political interest every electoral cycle, limited adaptive governance mechanisms with inefficient bureaucracy, and a strong mechanistic work culture with high reliance on executive mandate for decision-making and innovation.

The proposed interventions additionally have potential risks and unintended consequences. Strengthening CCS economic incentives without strong accountability mechanisms may reinforce fossil fuel lock-in, positioning CCS to function as a legitimizing pathway for continued fossil fuel expansion, limiting renewable energy and other low-carbon solutions adoption. Similarly, rapid acceleration of cross-border CCS operation without robust liability governance, public engagement, and domestic decarbonization pressure may increase long-term political risks and overdependence on external demand, weakening long-term domestic decarbonization resilience. In addition, as CCS is capital intensive and technology capabilities may not be evenly possessed across industrial actors, raising the concern regarding uneven transition benefits. This potentially reinforces that only incumbent actors with stronger political connections and financial capabilities will likely adopt CCS, limiting the broader CCS application as a national climate effort ([D. Reiner & Liang, 2009](#)).

Finally, the long-term effectiveness of proposed interventions depends not only on strengthening regulatory frameworks, but also on the broader ability of the CCS socio-technical ecosystem to sustain political commitment, institutional learning, domestic decarbonization, and societal legitimacy over time.

Conclusion

9.1 Conclusion to sub-research questions

The first sub-research question is discussed in Chapter 4 with the guiding question as follows

Sub-research question 1: “What actors are involved in Indonesia’s CCS development, and what roles and relationships characterize the current actor network of CCS implementation?”

The study indicates that Indonesia’s CCS ecosystem is largely centralized around the Ministry of Energy and Mineral Resources (MEMR) and dominated by oil and gas actors. Indonesia’s actor network is strengthened by the establishment of dedicated CCS knowledge actors and a coordination platform. While supporting actors such as research institutions, coordination platforms, international organizations, and other ministries contribute to knowledge development, policy coherence, and capacity building, the broader participation of non-oil and gas industries is still limited. Consequently, the existing CCS network is shaped by strong incumbent oil and gas influence, where technology experimentation, knowledge creation, and investment activities are largely concentrated within existing fossil fuel actor networks. This structure allows accelerated early-stage development but at the same time constrains broader diffusion of CCS across other high-emitting sectors.

The second sub-research question is discussed in Chapter 4 with the guiding question as follows:

Sub-research question 2: What socio-technical conditions shape the existing development phase of CCS in Indonesia?

Using the Multi-Level Perspective (MLP) framework, the study demonstrates that Indonesia’s CCS is situated in a niche-development phase supported by growing experimentation, institutional learning, international collaboration, and network formation. However, Indonesia’s CCS is not yet scaling a broader socio-technical transition toward large-scale decarbonization technology. Instead, CCS remains strongly embedded within the existing fossil fuel regime and is primarily driven by economic incentives, energy security priorities, and growing regional market opportunities. As a result, CCS technology in Indonesia functions more as a strategic extension of Indonesia’s current fossil fuel energy business under increasing global decarbonization pressure rather than as a fully integrated transformative decarbonization pathway.

The third sub-research question is discussed in Chapter 5 with the guiding question as follows:

Sub-research question 3: What governance conditions enable or constrain the development of CCS in Indonesia from demonstration level to large-scale implementation?

To answer this sub-research question, a governance readiness framework was synthesized from international CCS regulation frameworks and CCS governance studies. At the national level, Indonesia's current governance ecosystem shows relatively strong institutional efforts in developing CCS-specific regulatory frameworks for early-stage technology acceleration. However, overall governance readiness remains uneven and largely path-dependent on oil and gas business governance. The current governance ecosystem is largely motivated by attracting early investment, particularly for the regional carbon market, minimizing the burden on investors while critical concerns of long-term accountability, liability allocation, and cross-sector integration remain underdeveloped. As a result, current CCS implementation is limited to the oil and gas sector with weak cross-sectoral ecosystem integration. At the corporate level, CCS implementation is still perceived as an oil-and-gas extension, increasing barriers for other high emitters to adopt. Innovation in low-carbon projects within corporate business development strategies is still constrained by limited decarbonization incentives, hierarchical organizational cultures, and weak disincentives on continued engagement with high-carbon activities. Overall, Indonesia demonstrates stronger regulatory readiness than institutional readiness for large-scale CCS implementation.

The fourth sub-research question is discussed in Chapters 6 and 7 with the guiding question as follows:

Sub-research question 4: What strategic interventions could accelerate the deployment of CCS in Indonesia at national-level and corporate-level?

Building on the previous three sub-research questions, socio-technical challenges were identified and subsequently mapped into technology vision disruptors, short-term barriers, and long-term barriers, adopting a diagnostic intervention framework by Malekpour et al (2017). The study illustrates that the principal barriers to CCS implementation are not primarily technological, but institutional, political, and organizational. Consequently, the most impactful interventions in accelerating CCS implementation are those that strengthen inter-ministerial coordination, improve policy coherence, increase domestic decarbonization pressure, expand CCS participation beyond oil and gas, and enhance organizational learning and innovation capacity. While improving regulatory clarity is important, large-scale CCS implementation as a national decarbonization strategy is less likely to occur without stronger domestic demand, broader industrial engagement, and adaptive governance mechanisms capable of sustaining long-term implementation. The proposed interventions therefore emphasize institutional transformation alongside technological deployment.

9.2 Conclusion to main research question

This study examines the socio-technical factors and governance structures that shape the implementation of CCS using the case of Indonesia, representing a developing country context with high potential for geological storage. The study was guided by the central question as follows:

“How can the deployment of Carbon Capture and Storage (CCS) be accelerated as a cross-sectoral national climate strategy in Indonesia?”

The findings highlight that accelerating CCS implementation in Indonesia is not primarily a technological challenge but an institutional and socio-technical challenge. While Indonesia is recognized as one of the most advanced CCS regulatory frameworks among developing countries and has high geological storage potential, large-scale CCS deployment is still constrained by fragmented institutional understanding and commitment, weak domestic decarbonization pressure, oil-and-gas-centric CCS implementation, and limited clarity on long-term governance. Therefore, CCS deployment can be accelerated by transforming CCS from a predominantly oil-and-gas-led investment opportunity into a nationally coordinated decarbonization strategy. This requires four interconnected conditions.

First, institutional alignment is required to establish a shared understanding of CCS across government bodies and strengthen political commitment and policy coherence between climate, industrial, and energy within national development strategies. Integrating CCS more explicitly within national development planning and decarbonization strategies would strengthen political commitment, reduce policy fragmentation, and reduce vulnerabilities to the electoral cycle.

Second, stronger domestic decarbonization demand is required to motivate low-carbon project investments, including CCS. The current CCS investment ecosystem is largely driven by the international market, creating vulnerabilities to geopolitical issues. Therefore, improving carbon pricing mechanisms, introducing progressive emission reduction obligations, strengthening incentives for industrial decarbonization, and increasing disincentives for high-carbon activities would strengthen CCS diffusion and reduce dependence on a single sector.

Third, CCS deployment needs to be introduced beyond the incumbent oil and gas sector for large-scale CCS deployment. While oil and gas actors have played a critical role in early-stage CCS implementation, large-scale decarbonization needs broader participation from other high emitters such as cement, steel, petrochemicals, and coal-fired power plants. Expanding industrial participation would strengthen CCS cross-sectoral diffusion and reduce dependence on a single sector. **Lastly**, long-term governance credibility must be strengthened. The clarity on liability transfer, standardized site closure, monitoring, and risk mitigation, as well as cross-border arrangements, would improve investor confidence and enhance the long-term sustainability of CCS deployment.

Overall, the acceleration of CCS in Indonesia depends on the ability to strengthen governance readiness, expand industrial participation, increase domestic decarbonization motivation, and sustain long-term political commitment. Without these conditions, CCS likely remains a niche technology concentrated within the oil and gas industry.

9.3 Research Contribution

This research contributes conceptually, empirically, and practically to the growing literature on CCS deployment and governance, particularly through evidence from Indonesia.

The primary contribution of this study is **the development of an integrated diagnostic framework** that combines socio-technical transition analysis, governance readiness assessment, and diagnostic intervention design. Existing CCS studies often focus on technological and economic feasibility aspects or on specific components of governance such as regulation, liability, or public acceptance. In contrast, this research examines how technological development, institutional arrangements, actor network interactions, political dynamics, and organizational culture collectively shape CCS implementation. The framework systematically links Multi-Level Perspective (MLP) analysis, governance readiness assessment, barrier diagnosis, and development of strategic interventions into a single analytical process. This approach not only identifies governance gaps, but also explains why barriers emerge, how they interact, and where interventions should be prioritized. Although the governance readiness assessment was developed specifically for CCS, the analytical logic is transferable to other emerging low-carbon technologies where institutional development and technology diffusion evolve simultaneously.

The study also contributes to socio-technical transition literature by demonstrating that **governance should be understood as embedded regime dynamics**. Integrating governance readiness within the MLP demonstrates how governance can simultaneously enable niche development while reinforcing existing regime structures, providing a richer understanding of why emerging climate technologies experience uneven transitions.

Empirically, the research provides **insights for Indonesia's CCS implementation** through identifying critical implementation gaps and proposing strategic interventions at both national and corporate levels. The analysis explains why relatively advanced regulatory development has not yet translated into broader cross-sectoral deployment. The existing technology adoption drivers, such as incumbent oil and gas actors and regional market opportunities, position CCS more as an industrial adaptation strategy rather than as a nationally embedded climate mitigation.

Practically, the study translates diagnostic findings into **a structured set for strategic interventions for decision-making** by distinguishing vision disruptors, short-term implementation barriers, and long-term sustainability barriers for CCS development. This temporal perspective enables interventions to be prioritised according to different stages of CCS transition, providing policymakers and industries with a prioritised pathway for strengthening governance readiness and supporting CCS development beyond regulatory reform alone.

This study **provides empirical evidence from Indonesia, a developing-country context**. Although grounded in Indonesia's case, the study suggests that successful CCS deployment depends not only on establishing CCS-specific regulations but also on alignment of institutional capacity, political alignment, policy coherence, and cross-sectoral participation. These insights may inform future comparative research on CCS governance in other developing economies, while recognizing that institutional contexts differ across countries.

9.4 Reflection

1. Governance and public legitimacy cannot be understood through regulation alone

One of the most challenging aspects of the interview process was discussing public participation as one of the governance issues. Compared to technical, business, and political discussions, public-related issues were noticeably more sensitive, and engaging public-affair stakeholders was particularly difficult. Reflecting on this experience, I believe this sensitivity is rooted in Indonesia's historical experiences with extractive industries, where environmental and societal costs have often been unevenly distributed, and public trust remains fragile. Several stakeholders were observed to be cautious when discussing how the companies interact with affected communities, highlighting the complexity and political nature of the issue. This experience reinforced my understanding that CCS deployment is not only about technical and economic challenges but also a social and political process influenced by historical experiences and power relations.

2. Organizational culture is as important as formal governance

Another important reflection concerns the influence of hierarchical and risk-averse institutional cultures. Throughout the interviews, government and SOE representatives were generally more cautious when discussing organizational weaknesses, political dynamics, or policy inconsistencies. This behaviour is often linked to broader governance conditions, where decision-making often depends on executive approval and public officials, and SOE actors can face legal consequences when their decisions are labelled “causing state-loss”. At the same time, public discourse shows that actors with strong political connections will be less likely to face legal consequences. Whether such perceptions are accurate or not, they contribute to a culture where avoiding risk is often safer than engaging with high-risk initiatives. Observing this dynamic during the interviews strengthened my understanding of why stakeholders repeatedly identified risk-averse organizational culture as a barrier to CCS development and broader technological experimentation.

3. Integrating socio-technical and governance perspectives provided a richer understanding of CCS

Conducting this research has changed how I understand technology transitions. Building on the learning experience at TU Delft about technology innovation and sustainable transition, I approached CCS primarily as a technology and governance challenge. However, integrating the Multi-Level Perspective with the governance readiness assessment I synthesized in this study revealed that technological development is shaped simultaneously by political priorities, institutional arrangements, organizational cultures, and actor interaction dynamics. Rather than evaluating the governance and socio-technical transitions separately, combining these perspectives provided a more comprehensive explanation of why implementation gaps emerge despite the relatively strong regulatory development. This experience also enriched my learning in qualitative research and strengthened my appreciation for such an approach to uncover institutional dynamics that are difficult to capture through quantitative or technical analysis alone.

9.5 Research Limitation

The findings should be interpreted within four main limitations related to the study scope.

1. Framework Scope: Limited techno-economic and broader industrial policy analysis

This study focuses on governance readiness and socio-technical transition rather than techno-economic or industrial policy analysis. Although economic viability emerged as one of the

governance concerns, the research did not evaluate project-level financial feasibility, macro-level economic effects, carbon price sensitivity, and financing mechanisms. The proposed approach also did not evaluate broader industrial policy instruments such as supply-chain development and industrial competitiveness. These factors remain important enablers of cross-sectoral CCS development.

2. Indonesia's case: a single developing country analysis

This research is based on Indonesia case. While Indonesia provides valuable insights from a developing-country context, the findings should not be interpreted as representing developing countries more broadly. Differences in political dynamics, institutional capacity, industrial structure, and governance arrangements may lead to different CCS transition pathways in other national contexts.

3. Empirical limitation: limited participation from supporting ministries and affected public

The empirical data from interviews in this study were primarily collected from central government institutions for CCS, industry stakeholders, and knowledge actors. Perspectives from supporting ministries and affected communities were limited. While societal legitimacy aspects were discussed through literature review and stakeholder interviews, direct engagement with the affected public was constrained by geographical limitations and the early stage of CCS development. Consequently, findings regarding public participation and inter-ministerial dynamics were mainly obtained with limited perspectives from both affected communities and supporting ministries.

4. Early-stage CCS evaluation: limited practical effectiveness

Indonesia's CCS industry remains in an early stage of development. Many governance issues identified in this study, such as long-term liability transfer, post-closure stewardship, cross-border cooperation, and long-term monitoring, are largely based on stakeholder expectations and governance literature rather than operational experiences. The practical effectiveness of existing governance structures can therefore only be fully assessed as CCS projects advance toward commercial-scale deployment.

9.6 Future Research Directions

This study identified several areas that require further assessment. **First**, future studies should apply the proposed framework in other national contexts, particularly developing countries, to evaluate whether similar socio-technical patterns emerge under different institutional and political settings. **Second**, future research should integrate the governance readiness evaluation with techno-economic analysis, including comparing scenarios with different project economic mechanisms such as different carbon pricing, financing mechanisms, storage-fee models, and investment risk assessment. Comparative modelling across these scenarios could provide clearer insights to achieve commercially viable CCS implementation. **Third**, future studies need to understand why non-oil-and-gas industries remain weakly engaged with CCS and compare CCS with alternative climate mitigation strategies across industrial sectors. This is to understand under which conditions CCS can be attractive for cross-sectoral climate mitigation. **Lastly**, as Indonesia progresses toward commercial CCS deployment, longitudinal studies should examine cross-border governance, long-term liability management, evolving public acceptance based on operational experience rather than stakeholder expectations, involving broader stakeholders for interviews.

- Abdullah, M. R. T. L., Siraj, S., & Ghazali, Z. (2021). An ISM Approach for Managing Critical Stakeholder Issues Regarding Carbon Capture and Storage (CCS) Deployment in Developing Asian Countries. *Sustainability*, 13(12), 6618. <https://doi.org/10.3390/su13126618>
- Adisaputro, D., & Saputra, B. (2017). Carbon Capture and Storage and Carbon Capture and Utilization: What Do They Offer to Indonesia? *Frontiers in Energy Research*, 5. <https://doi.org/10.3389/fenrg.2017.00006>
- Al Hakim, M. F., Tony, B., Chandra, S., Nugraha, F. Y., & Nandiwardhana, D. (2025). MAPPING THE POTENTIAL CO₂ SOURCE-SINKS FOR CARBON CAPTURE STORAGE FROM INDUSTRY IN INDONESIA. *Scientific Contributions Oil and Gas*, 48(1), 121–133. <https://doi.org/10.29017/scog.v48i1.1626>
- Alberta Department of Energy. (2023). *Quest CCS Project Annual Summary Report 2023*. <https://open.alberta.ca/dataset/356aeeda-134c-4779-971c-931573400ddf/resource/8a1b4350-9634-4e66-a983-8c16199fa2e7/download/quest-annual-summary-report-2022-alberta-department-of-energy.pdf>
- Alfada, A. (2019). The destructive effect of corruption on economic growth in Indonesia: A threshold model. *Heliyon*, 5(10). <https://doi.org/10.1016/j.heliyon.2019.e02649>
- Almendra, F., West, L., Zheng, L., & Forbes, S. (2011). *CCS Demonstration in Developing Countries: Priorities for a Financing Mechanism for Carbon Dioxide Capture and Storage*.
- Amelinda, A. T., & Soekarno, S. (2023). Financial Feasibility Study of Carbon Capture, Utilization, and Storage Project in West Java, Indonesia. *European Journal of Business and Management Research*, 8(3), 215–220. <https://doi.org/10.24018/ejbmr.2023.8.3.1969>
- Anindarini, G. (2021). *Partisipasi Publik dalam Penyusunan Amdal Pasca UU Cipta Kerja*. INDONESIA CENTER FOR ENVIRONMENTAL LAW.
- Anzola, D. A. V., & Baines, S. J. (2025, August 25). Risk-Based and Proportionate Measure, Monitoring and Verification (MMV) Plans That Meet Key Regulations. *SPE Asia Pacific CCUS Conference*. SPE Asia Pacific CCUS Conference. <https://doi.org/10.2118/225881-MS>
- Aprianto, D., Rudy Laksmono, Fitri Angelia Hartati Sinambela, & Sri Murtiana. (2024). Addressing Indonesia's Fossil Fuel Dependence: A Path Towards a Sustainable Future. *International Journal Of Humanities Education and Social Sciences (IJHESS)*, 4(3). <https://doi.org/10.55227/ijhess.v4i3.1200>
- Apriliyanti, I. D., & Kristiansen, S. O. (2019). The logics of political business in state-owned enterprises: The case of Indonesia. *International Journal of Emerging Markets*, 14(5), 709–730. <https://doi.org/10.1108/IJOEM-08-2018-0433>
- Araújo, I. L. de. (2021). *The Brazilian Carbon Capture and Storage (CCS) institutional framework: The new carbon market business in an energy transition economy*. [Tese, Universidade de São Paulo]. <https://doi.org/10.11606/T.106.2021.tde-18022022-222702>
- ASEAN Centre for Energy. (2025). *ASEAN CCS Updates 2025 Vol. 2*. ASEAN Centre for Energy. <https://aseanenergy.org/publications/asean-ccs-updates-2025-volume-2>
- Ashworth, P., Boughen, N., Mayhew, M., & Millar, F. (2010). From research to action: Now we have to move on CCS communication. *International Journal of Greenhouse Gas Control*, 4(2), 426–433. <https://doi.org/10.1016/j.ijggc.2009.10.012>
- Ayu, A. (2024, October 23). *BUMN vs Swasta: Siapa yang Lebih Efektif dalam Menerapkan Sistem Pengendalian Manajemen?* KOMPASIANA. <https://www.kompasiana.com/adindaayupr/6717df2934777c444b56dd82/bumn-vs-swasta-siapa-yang-lebih-efektif-dalam-menerapkan-sistem-pengendalian-manajemen>

- Bäckstrand, K., Meadowcroft, J., & Oppenheimer, M. (2011). The politics and policy of carbon capture and storage: Framing an emergent technology. *Global Environmental Change*, 21(2), 275–281. <https://doi.org/10.1016/j.gloenvcha.2011.03.008>
- BAPPENAS. (2025). *Strategi dan Penahapan Pembangunan Rendah Karbon dalam RPJPN 2025-2045*. Badan Perencanaan Nasional.
- Beck, U. (1992). From Industrial Society to the Risk Society: Questions of Survival, Social Structure and Ecological Enlightenment. *Theory, Culture & Society*, 9(1), 97–123. <https://doi.org/10.1177/026327692009001006>
- Bhattacharya, U., Hsu, P.-H., Tian, X., & Xu, Y. (2017). What Affects Innovation More: Policy or Policy Uncertainty? *Journal of Financial and Quantitative Analysis*, 52(5), 1869–1901. <https://doi.org/10.1017/S0022109017000540>
- Bloomberg. (2026). *15 Proyek Tangkap Karbon di RI, Industri Keluhkan Ongkosnya Mahal—Energi*. <https://www.bloombergentechnoz.com/detail-news/41235/15-proyek-tangkap-karbon-di-ri-industri-keluhkan-ongkosnya-mahal>
- Bokka, H. K., & Lau, H. C. (2023). Decarbonizing Borneo's power and industry sectors by carbon capture and storage. *Geoenergy Science and Engineering*, 226, 211796. <https://doi.org/10.1016/j.geoen.2023.211796>
- Braunreiter, L., & Bennett, S. J. (2017). The Neglected Importance of Corporate Perceptions and Positions for the Long-term Development of CCS. *Energy Procedia*, 114, 7197–7204. <https://doi.org/10.1016/j.egypro.2017.03.1825>
- Brunsting, S., Best-Waldhober, M. D., Feenstra, C. F. J. (Ynke), & Mikunda, T. (2011). Stakeholder participation practices and onshore CCS: Lessons from the dutch CCS case barendrecht. *Energy Procedia*, 4, 6376–6383. <https://doi.org/10.1016/j.egypro.2011.02.655>
- Carpenter, C. (2023). Well-Integrity Risk-Assessment Strategy Applied to CO2 Sequestration Project. *Journal of Petroleum Technology*, 75(01), 78–80. <https://doi.org/10.2118/0123-0078-JPT>
- CEM. (2024). *Global Developments with Carbon Capture, Use and Storage Deployment Programmes*. The 15th Clean Energy Ministerial Meeting, Foz Do Iguacu, Brazil. <https://www.cleanenergyministerial.org/content/uploads/2025/02/january-2025-global-overview-of-ccus-policies-and-programmes.pdf>
- Chau, S. (2024). *Norway has one of the world's highest carbon tax rates (1991-ongoing)*. SDG16 PLUS. <https://www.sdg16.plus/policies/carbon-tax-norway/>
- CoE-ITB. (2022). About CoE-ITB. *Indonesia Center of Excellence for CCS and CCUS ITB*. <https://ccus.itb.ac.id/about/>
- CoE-ITB. (2024). Projects. *Indonesia Center of Excellence for CCS and CCUS ITB*. <https://ccus.itb.ac.id/projects/>
- Daniswari, D. (2022, March 17). *Daftar 122 Kawasan Industri di Indonesia, dari Aceh hingga Maluku Utara*. KOMPAS.com. <https://regional.kompas.com/read/2022/03/17/135613178/daftar-122-kawasan-industri-di-indonesia-dari-aceh-hingga-maluku-utara>
- De Figueiredo, M. A. (2007). *The liability of carbon dioxide shortage* [Massachusetts Institute of Technology]. <http://hdl.handle.net/1721.1/38520>
- Dean, M., & Ahead, S. O. T. W. (2024, January 2). *Best Practices for Risk-Based Measurement, Monitoring, and Verification in CCUS Projects*. TheWayAhead. <https://jpt.spe.org/twa/best-practices-for-risk-based-measurement-monitoring-and-verification-in-ccus-projects>
- Draps, F., & Ibnuaji, N. (2025). *Indonesia CCS - New Regulation on Carbon Storage*. Ashurst. <https://www.ashurst.com/en/insights/indonesia-ccs-new-regulation-on-carbon-storage/>
- Dyarto, R., & Setyawan, D. (2021). Understanding the political challenges of introducing a carbon tax in Indonesia. *International Journal of Environmental Science and Technology*, 18(6), 1479–1488. <https://doi.org/10.1007/s13762-020-02925-4>
- EIA. (2025). *Country Analysis Brief: Indonesia*.

- Elliott, L., & Setyowati, A. B. (2020). TOWARD A SOCIALLY JUST TRANSITION TO LOW CARBON DEVELOPMENT: THE CASE OF INDONESIA. *Asian Affairs*, 51(4), 875–894.
<https://doi.org/10.1080/03068374.2020.1835000>
- Esvandi, D. (2026, April 28). *Kriminalisasi Kebijakan Bikin Pejabat Takut Berinovasi, Ekonomi RI Stagnan di 5 Persen*. *Tribunnews.com*.
<https://www.tribunnews.com/nasional/7822726/kriminalisasi-kebijakan-bikin-pejabat-takut-berinovasi-ekonomi-ri-stagnan-di-5-persen>
- ExxonMobil. (2026, May 5). *Growing Low Carbon Solutions | ExxonMobil Sustainability*. ExxonMobil. <https://corporate.exxonmobil.com/publications/advancing-climate-solutions/growing-low-carbon-solutions>
- Fromhold-Eisebith, M. (2002). Regional Cycles of Learning: Foreign Multinationals as Agents of Technological Upgrading in Less Developed Countries. *Environment and Planning A: Economy and Space*, 34(12), 2155–2173. <https://doi.org/10.1068/a3545>
- Fukuyama, F. (2013). What Is Governance? *Governance*, 26(3), 347–368.
<https://doi.org/10.1111/gove.12035>
- Gaurina-Medimurec, N., & Novak Mavar, K. (2020). Carbon Capture and Storage (CCS): Geological Sequestration of CO₂. In L. Almeida Frazão, A. Marcela Silva-Olaya, & J. Cota Silva (Eds.), *CO2 Sequestration*. IntechOpen. <https://doi.org/10.5772/intechopen.84428>
- Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, 31(8–9), 1257–1274.
[https://doi.org/10.1016/S0048-7333\(02\)00062-8](https://doi.org/10.1016/S0048-7333(02)00062-8)
- Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: Introducing the multi-level perspective into transport studies. *Journal of Transport Geography*, 24, 471–482.
<https://doi.org/10.1016/j.jtrangeo.2012.01.021>
- Geels, F. W. (2019). Socio-technical transitions to sustainability: A review of criticisms and elaborations of the Multi-Level Perspective. *Current Opinion in Environmental Sustainability*, 39, 187–201. <https://doi.org/10.1016/j.cosust.2019.06.009>
- Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, 36(3), 399–417. <https://doi.org/10.1016/j.respol.2007.01.003>
- Gibb, J., Forbes, A., & Simpson, L. (2024). Safeguard Mechanism reforms – how big and how much will it cost? *Australian Energy Producers Journal*, 64(2), S61–S64.
<https://doi.org/10.1071/EP23116>
- Global CCS Institute (with Havercroft, I., & Raji). (2023). *CCS Legal and Regulatory Indicator 2023*. Global CCS Institute.
- Global CCS Institute. (2025). *Global Status of CCS 2025*.
<https://www.globalccsinstitute.com/global-status-of-ccs/>
- Grant, N., Hawkes, A., Napp, T., & Gambhir, A. (2021). Cost reductions in renewables can substantially erode the value of carbon capture and storage in mitigation pathways. *One Earth*, 4(11), 1588–1601. <https://doi.org/10.1016/j.oneear.2021.10.024>
- Guitarra, P. (2022). *Tiga BUMN Raksasa RI Bangun Kluster Industri Hijau, Kaya Apa?* CNBC Indonesia. <https://www.cnbcindonesia.com/news/20220223171031-4-317752/tiga-bumn-raksasa-ri-bangun-kluster-industri-hijau-kaya-apa>
- Guterman, A. S. (2025). *Hierarchy Culture: Order Above All*. SSRN.
<https://doi.org/10.2139/ssrn.5592930>
- Ha-Duong, M., & Nguyen-Trinh, H. A. (2017). Two scenarios for carbon capture and storage in Vietnam. *Energy Policy*, 110, 559–569. <https://doi.org/10.1016/j.enpol.2017.08.040>
- Hanson, E., Nwakile, C., & Hammed, V. O. (2025). Carbon capture, utilization, and storage (CCUS) technologies: Evaluating the effectiveness of advanced CCUS solutions for reducing CO₂ emissions. *Results in Surfaces and Interfaces*, 18, 100381.
<https://doi.org/10.1016/j.rsurfi.2024.100381>
- Ibe, A. P., & Nwosi-Anele, A. S. (2024). Framework for Carbon-Capture and Storage (CCS) in Nigeria. *SPE Nigeria Annual International Conference and Exhibition*, D031S015R004.
<https://doi.org/10.2118/221616-MS>

- ICAP. (2026, March 10). *EU Emissions Trading System (EU ETS) | International Carbon Action Partnership*. <https://icapcarbonaction.com/en/ets/eu-emissions-trading-system-eu-ets>
- ICCSC. (2025a). *Strategic Initiatives dan Role dari ICCSC* [Video recording]. <https://www.youtube.com/watch?v=Q9EnTcrhf4g&t=329s>
- ICCSC. (2025b, April 30). *The 4th International & Indonesia CCS Forum 2026*. <https://iiccsforum.com/indonesia-positions-itself-as-the-leading-ccs-hub-in-asia-pacific/>
- ICEL. (2025). *Transisi Energi Berkeadilan Jadi Kunci Transformasi Ekonomi Indonesia*. Indonesian Center for Environmental Law. <https://icel-stg-dev-1.dev.dddtl.net/>
- IEA. (2020). *The role of CCUS in low-carbon power systems*.
- IEA. (2022). *Legal and Regulatory Frameworks for CCUS: An IEA CCUS Handbook*. OECD. <https://doi.org/10.1787/d52c3bda-en>
- IEA. (2023). Carbon Capture, Utilisation and Storage in Indonesia—Policy brief. *Carbon Capture*.
- IEA. (2025a). *Carbon Capture and Storage (CCS) Infrastructure Fund – Policies*. International Energy Agency. <https://www.iea.org/policies/11612-carbon-capture-and-storage-ccs-infrastructure-fund>
- IEA. (2025b). *World Energy Outlook 2025*.
- IESR. (2025). *Navigating Indonesia's Energy Transition at the Crossroads: A Pivotal Moment for Redefining the Future*.
- Ika, S. R., Yuliani, Okfitasari, A., & Widagdo, A. K. (2022). Factors influencing carbon emissions disclosures in high profile companies: Some Indonesian evidence. *IOP Conference Series: Earth and Environmental Science*, 1016(1), 012043. <https://doi.org/10.1088/1755-1315/1016/1/012043>
- Indonesia Corruption Watch. (2025). *61 Persen Anggota DPR 2024-2029 Merupakan Politisi Pebisnis* | ICW. <https://antikorupsi.org/id/61-persen-anggota-dpr-2024-2029-merupakan-politisi-pebisnis>
- IPCC. (2023). *IPCC, 2023: Climate Change 2023: Synthesis Report*. (First). Intergovernmental Panel on Climate Change (IPCC). <https://doi.org/10.59327/IPCC/AR6-9789291691647>
- Isaac, J. (2026). *Indonesia struggles to attract foreign investment despite rising inflows, economist says*. <https://indonesiabusinesspost.com/>. <https://indonesiabusinesspost.com/6652/markets-and-finance/indonesia-struggles-to-attract-foreign-investment-despite-rising-inflows-economist-says>
- ITA. (2024, April 18). *Indonesia Carbon Capture Storage*. International Trade Association. <https://www.trade.gov/market-intelligence/indonesia-carbon-capture-storage>
- JETP. (2025). *Just Energy Transition Partnership Indonesia Progress Report 2025*.
- Joe, I. (2025, October 9). *19 Carbon Capture and Storage (CCS) Projects Position Indonesia as a Regional Carbon Hub—Carbonnature.com*. <https://carbonnature.com/news/19-carbon-capture-and-storage-project/>
- JRC. (2025). *GHG emissions of all world countries: 2025* (M. Crippa, D. Guizzardi, F. Pagani, M. Banja, M. Muntean, E. Schaaf, R. Quadrelli, A. Risquez Martin, P. Taghavi-Moharamli, J. Köykkä, G. Grassi, J. Melo, M. Suárez-Moreno, F. Sedano, J. San-Miguel, G. Manca, E. Pisoni, F. Pekar, & European Commission, Eds.). Publications Office. <https://doi.org/10.2760/5917997>
- Kaarstad, O., Berger, B., & Berg, S. (2011). More than coal—Towards a broader role for CCS. *Energy Procedia*, 4, 2662–2668. <https://doi.org/10.1016/j.egypro.2011.02.166>
- Kaneko, S., & Kawanishi, M. (Eds.). (2016). *Climate Change Policies and Challenges in Indonesia*. Springer Japan. <https://doi.org/10.1007/978-4-431-55994-8>
- Karayannis, V., Charalampides, G., & Lakioti, E. (2014). Socio-economic Aspects of CCS Technologies. *Procedia Economics and Finance*, 14, 295–302. [https://doi.org/10.1016/S2212-5671\(14\)00716-3](https://doi.org/10.1016/S2212-5671(14)00716-3)
- Karki, A. (2026, January 9). *Indonesia's CCUS Strategy: Geopolitical Play integrated within Climate Policy* [Text]. USEA | United States Energy Association. <https://usea.org/article/indonesia%E2%80%99s-ccus-strategy-geopolitical-play-integrated-within-climate-policy>

- Keir, L., Watts, R., & Inwood, S. (2014). Environmental justice and citizen perceptions of a proposed electric transmission line. *Community Development*, 45(2), 108–121. <https://doi.org/10.1080/15575330.2014.887130>
- Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management*, 10(2), 175–198. <https://doi.org/10.1080/09537329808524310>
- Kern, F., Gaede, J., Meadowcroft, J., & Watson, J. (2016). The political economy of carbon capture and storage: An analysis of two demonstration projects. *Technological Forecasting and Social Change*, 102, 250–260. <https://doi.org/10.1016/j.techfore.2015.09.010>
- Ko, Y.-C., Zigan, K., & Liu, Y.-L. (2021). Carbon capture and storage in South Africa: A technological innovation system with a political economy focus. *Technological Forecasting and Social Change*, 166, 120633. <https://doi.org/10.1016/j.techfore.2021.120633>
- Koornneef, J., Ramírez, A., Turkenburg, W., & Faaij, A. (2012). The environmental impact and risk assessment of CO₂ capture, transport and storage – An evaluation of the knowledge base. *Progress in Energy and Combustion Science*, 38(1), 62–86. <https://doi.org/10.1016/j.pecs.2011.05.002>
- Kronshage, S., & Seljom, P. (2020). Country Report: Transition Pathways for Norway. *NDC Aspects*. <https://www.ndc-aspects.eu/sites/default/files/2024-11/D5.2%20-%20Norway%20country%20fiche.pdf>
- Kuckshinrichs, W., & Hake, J.-F. (Eds.). (2015). *Carbon Capture, Storage and Use: Technical, Economic, Environmental and Societal Perspectives*. Springer International Publishing. <https://doi.org/10.1007/978-3-319-11943-4>
- Kurniawan, R. D. (2026). *Regulasi CCS Rampung, Indonesia Siap Eksekusi Bisnis Karbon 577 Gigaton*. Warta Ekonomi. <https://wartaekonomi.co.id/read598637/regulasi-ccs-rampung-indonesia-siap-eksekusi-bisnis-karbon-577-gigaton>
- Kuswati, Y., Kusmayadi, D., & Hartati, T. (2023). The Role of Bureaucracy on the Effectiveness of Public Services. *International Journal of Social Science and Human Research*, 06(02). <https://doi.org/10.47191/ijsshr/v6-i2-37>
- Larkin, P., Leiss, W., & Krewski, D. (2019). Risk assessment and management frameworks for carbon capture and geological storage: A global perspective. *International Journal of Risk Assessment and Management*, 22(3/4), 254. <https://doi.org/10.1504/IJRAM.2019.103332>
- Leiss, W., & Larkin, P. (2019). Risk communication and public engagement in CCS projects: The foundations of public acceptability. *International Journal of Risk Assessment and Management*, 22(3/4), 384. <https://doi.org/10.1504/IJRAM.2019.103339>
- Lestari, G. (2026). *Perkuat Kemitraan Kawasan, Menteri Bahlil Teken Tiga Perjanjian dengan Korea*. ESDM (MEMR). <https://www.esdm.go.id/id/media-center/arsip-berita/perkuat-kemitraan-kawasan-menteri-bahlil-teken-tiga-perjanjian-dengan-korea>
- Liebman, A., Reynolds, A., Robertson, D., Nolan, S., Argyriou, M., & Sargent, B. (2019). *Green Finance in Indonesia: Barriers and Solutions*. 946796 Bytes. <https://doi.org/10.26180/8973821>
- Liu, H. (2011). *Strategy for promoting low-carbon technology transfer to developing countries The case of CCS*.
- Liu, N., Liu, D., Zhan, Y., Chen, Q., Qiao, Y., & Tan, R. (2025). From Innovation to Integration: The Evolving Role of Carbon Capture and Storage in Global Decarbonization. *cScience*, 1(1), e70008. <https://doi.org/10.1002/csc3.70008>
- Liu, N., Zhan, Y., Tan, R., Zhao, G., & Song, J. (2025). Unlocking Carbon Capture and Storage Potential: Policy Incentives, Economic Challenges, and Infrastructure Integration for CO₂ Transport. *CHAIN*, 2(3), 211–226. <https://doi.org/10.23919/CHAIN.2025.000015>
- LTS-LCCR. (2021). *Indonesia Long-Term Strategy for Low Carbon and Climate Resilience 2050 (Indonesia LTS-LCCR 2050)*.

- Ma, J., Li, L., Wang, H., Du, Y., Ma, J., Zhang, X., & Wang, Z. (2022). Carbon Capture and Storage: History and the Road Ahead. *Engineering*, 14, 33–43. <https://doi.org/10.1016/j.eng.2021.11.024>
- Malekpour, S., Brown, R. R., De Haan, F. J., & Wong, T. H. F. (2017). Preparing for disruptions: A diagnostic strategic planning intervention for sustainable development. *Cities*, 63, 58–69. <https://doi.org/10.1016/j.cities.2016.12.016>
- Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy*, 37(4), 596–615. <https://doi.org/10.1016/j.respol.2008.01.004>
- Markusson, N., Ishii, A., & Stephens, J. C. (2011a). The social and political complexities of learning in carbon capture and storage demonstration projects. *Global Environmental Change*, 21(2), 293–302. <https://doi.org/10.1016/j.gloenvcha.2011.01.010>
- Markusson, N., Ishii, A., & Stephens, J. C. (2011b). The social and political complexities of learning in carbon capture and storage demonstration projects. *Global Environmental Change*, 21(2), 293–302. <https://doi.org/10.1016/j.gloenvcha.2011.01.010>
- Markusson, N., Kern, F., Watson, J., Arapostathis, S., Chalmers, H., Ghaleigh, N., Heptonstall, P., Pearson, P., Rossati, D., & Russell, S. (2012). A socio-technical framework for assessing the viability of carbon capture and storage technology. *Technological Forecasting and Social Change*, 79(5), 903–918. <https://doi.org/10.1016/j.techfore.2011.12.001>
- Mascarenhas, K. L., Peyerl, D., Moretto, E. M., & Meneghini, J. R. (2019). Challenges for the Implementation of Carbon Capture and Storage (Ccs) in Brazil: A Socio-Technical Approach. *Polytechnica*, 2(1–2), 1–8. <https://doi.org/10.1007/s41050-019-00016-z>
- Mashari, D. P. S. (2025). Decarbonizing in the Upstream Oil and Gas Sector in Indonesia: Financing Challenges and Opportunities in Deploying CCS/CCUS Projects. *Indonesia Oil and Gas Review*, 1. <https://iogreview.com/iogr/article/view/21>
- Meadowcroft, J., & Langhelle, O. (2009). The Politics and Policy of Carbon Capture and Storage. In J. Meadowcroft & O. Langhelle (Eds.), *Caching the Carbon*. Edward Elgar Publishing. <https://doi.org/10.4337/9781849802222.00009>
- MEMR. (2024a). *Pemerintah Targetkan 15 Proyek CCS/CCUS Onstream Tahun 2030*. ESDM. <https://www.esdm.go.id/id/media-center/arsip-berita/pemerintah-targetkan-15-proyek-ccs-ccus-onstream-tahun-2030>
- MEMR. (2024b). *Perpres CCS/CCUS Resmi Disahkan, Atur Skema Penyelenggaraan, Alokasi Domestik Hingga Transportasi Karbon Lintas Negara*. Ministry of Energy and Mineral Resources (ESDM). <https://migas.esdm.go.id/post/Perpres-CCS-CCUS-Resmi-Disahkan-Atur-Skema-Penyelenggaraan-Alokasi-Domestik-Hingga-Transportasi-Karbon-Lintas-Negara>
- MEMR. (2025a). *Energy and Economic Statistic of Indonesia*. <https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2024.pdf>
- MEMR. (2025b). *Target Lifting Naik, Pemerintah Perkuat Kolaborasi dengan Badan Usaha Hulu Migas*. Ministry of Energy and Mineral Resources (ESDM). ESDM. <https://www.esdm.go.id/id/media-center/arsip-berita/target-lifting-naik-pemerintah-perkuat-kolaborasi-dengan-badan-usaha-hulu-migas>
- MEMR Regulation 16/2024. PENYELENGGARAAN KEGIATAN PENYIMPANAN KARBON, Republic of Indonesia (2024).
- Ministry of Finance. (2020). *Climate Finance Coordination to Achieve the NDC Target*. https://fiskal.kemenkeu.go.id/nda_gcf/en/koordinasi-pembiayaan-perubahan-iklim-untuk-pencapaian-target-ndc/
- Mulyasari, F., Harahap, A. K., Rio, A. O., Sule, R., & Kadir, W. G. A. (2021). Potentials of the public engagement strategy for public acceptance and social license to operate: Case study of Carbon Capture, Utilisation, and Storage Gundih Pilot Project in Indonesia. *International Journal of Greenhouse Gas Control*, 108, 103312. <https://doi.org/10.1016/j.ijggc.2021.103312>

- Naqvi, S. M. O., Raza, M. D., & Haider, S. H. (2025). Carbon-Neutral Concrete: A Review on Carbon Capture, Storage, and Utilization Technologies. *Journal of Advanced Concrete Technology*, 23(11), 531–545. <https://doi.org/10.3151/jact.23.531>
- NDC. (2025). *Indonesia Second NDC 2025*.
- Newell, S., Morton, J., Marabelli, M., & Galliers, R. (2020). *Managing digital innovation: A knowledge perspective*. Red Globe Press.
- Nugraha, F. A. (2024, November 15). *KLHK: Indonesia secara geografis berpotensi jadi pusat CCS*. Antara News. <https://www.antaranews.com/berita/4469953/klhk-indonesia-secara-geografis-berpotensi-jadi-pusat-ccs>
- Nugroho Dukut. (2026, April 3). *Perkuat Kemitraan Global dengan SK Group, ExxonMobil, dan POSCO, PHE Dorong Pengembangan CCS Lintas Negara dan Energi Rendah Karbon—PT. Pertamina Hulu Energi*. Pertamina Hulu Energi. <https://phe.pertamina.com/id/media/perkuat-kemitraan-global-dengan-sk-group-exxonmobil-dan-posco-phe-dorong-pengembangan-ccs-lintas-negara-dan-energi-rendah-karbon>
- Nurdifah, A. R. (2025). *Pupuk Indonesia Beli Gas Abadi Masela & Andaman untuk Pabrik Blue Amonia-Metanol*. Bisnis - EKONOMI. https://ekonomi.bisnis.com/read/20250522/257/1879124/pupuk-indonesia-beli-gas-abadi-masela-andaman-untuk-pabrik-blue-amonia-metanol#goog_rewarded
- OECD. (2024). *Pricing Greenhouse Gas Emissions*. OECD. https://www.oecd.org/en/publications/pricing-greenhouse-gas-emissions-2024_b44c74e6-en.html
- Osazuwa-Peters, M., & Hurlbert, M. (2020). Analyzing Regulatory Framework for Carbon Capture and Storage (CCS) Technology Development: A case study approach. *The Central European Review of Economics and Management*, 4(1), 107–148. <https://doi.org/10.29015/cerem.834>
- PEDOMAN TATA KERJA (PTK-070). PENYELENGGARAAN KEGIATAN PENYIMPANAN KARBON (2023).
- Pertamina. (2026). *PHE's CCS/CCUS On Going Study* [Internal document]. Stakeholder interview.
- Peters, G. P., Andrew, R. M., Canadell, J. G., Fuss, S., Jackson, R. B., Korsbakken, J. I., Quéré, C. L., & Nakicenovic, N. (2017). Key indicators to track current progress and future ambition of the Paris Agreement. *Nature Climate Change*, 7(2), 118–122.
- Pihkola, H., Tsupari, E., Kojo, M., Kujanpää, L., Nissilä, M., Sokka, L., & Behm, K. (2017). Integrated Sustainability Assessment of CCS – Identifying Non-technical Barriers and Drivers for CCS Implementation in Finland. *Energy Procedia*, 114, 7625–7637. <https://doi.org/10.1016/j.egypro.2017.03.1895>
- President Regulation 14/2024. PENYELENGGARAAN KEGIATAN PENANGKAPAN DAN PENYIMPANAN KARBON (2024).
- Putra, A. A., Juwari, & Handogo, R. (2018). Multi Region Carbon Capture and Storage Network in Indonesia Using Pinch Design Method. *Process Integration and Optimization for Sustainability*, 2(4), 321–341. <https://doi.org/10.1007/s41660-018-0050-5>
- Putra, N. (2025). *SKK Migas Tuntaskan Studi CCS di Proyek LNG Abadi Masela* | tempo.co. Tempo. <https://www.tempo.co/ekonomi/skk-migas-tuntaskan-studi-ccs-di-proyek-lng-abadi-masela-2083608>
- Putra, N. R., & Linda, R. (2022). IMPACT OF SOCIAL CHANGE ON SOCIETY FROM THE CRIME OF CORRUPTION. *Integritas : Jurnal Antikorupsi*, 8(1), 13–24. <https://doi.org/10.32697/integritas.v8i1.898>
- Putriyana, L., Daud, Y., Aziz, M., Hesty, N. W., & Nasruddin. (2023). Evaluation and ranking of the CO₂ storage potential in low to medium temperature geothermal fields in Indonesia. *Case Studies in Chemical and Environmental Engineering*, 8, 100406. <https://doi.org/10.1016/j.cscee.2023.100406>
- PwC. (2024). *Indonesia Carbon Market White Paper*. PwC Consulting. <https://www.pwc.com/id/en/publications/esg/indonesia-carbon-market-white-paper.pdf>

- Rakhiemah, A. N., & Xu, Y. (2022). Economic viability of full-chain CCUS-EOR in Indonesia. *Resources, Conservation and Recycling*, 179, 106069. <https://doi.org/10.1016/j.resconrec.2021.106069>
- Ramadhan, R., Mon, M. T., Tangparitkul, S., Tansuchat, R., & Agustin, D. A. (2024). Carbon capture, utilization, and storage in Indonesia: An update on storage capacity, current status, economic viability, and policy. *Energy Geoscience*, 5(4), 100335. <https://doi.org/10.1016/j.engeos.2024.100335>
- Rasool, M. H., & Moiz Hashmi, S. A. (2025). Carbon capture and storage: An evidence-based review of its limitations and missed promises. *Petroleum Research*, S2096249525000973. <https://doi.org/10.1016/j.ptlrs.2025.09.005>
- Reiner, D., & Liang, X. (2009). Opportunities and hurdles in applying CCS Technologies in China—With a focus on industrial stakeholders. *Energy Procedia*, 1(1), 4827–4834. <https://doi.org/10.1016/j.egypro.2009.02.310>
- Reiner, D. M. (2016). Learning through a portfolio of carbon capture and storage demonstration projects. *Nature Energy*, 1(1), 15011. <https://doi.org/10.1038/nenergy.2015.11>
- Rencana Pembangunan Jangka Menengah Nasional (2025).
- Rijk, N. A. M., Hafkamp, W. A., Timmermans, A., & Geerlings, H. (2019). *Vying for vision: Climate and en energy policies between local ambitions national interests and international realities*. Erasmus University Rotterdam.
- Rimbono, R., Supriatna, J., Koestoer, R. H. S., & Hamzah, U. S. (2025). Bridging the Gap: Multi-Stakeholder Perspectives on the Role of Carbon Capture and Storage (CCS)/Carbon Capture Utilization and Storage (CCUS) in Achieving Indonesia's Net Zero Emissions. *Sustainability*, 17(13), 5935. <https://doi.org/10.3390/su17135935>
- Romasheva, N., & Ilinova, A. (2019). CCS Projects: How Regulatory Framework Influences Their Deployment. *Resources*, 8(4), 181. <https://doi.org/10.3390/resources8040181>
- Rotmans, J., Kemp, R., & van Asselt, M. (2001). More evolution than revolution: Transition management in public policy. *Foresight*, 3(1), 15–31. <https://doi.org/https://doi.org/10.1108/14636680110803003>
- Sara, J., Stikkelman, R. M., & Herder, P. M. (2015). Assessing relative importance and mutual influence of barriers for CCS deployment of the ROAD project using AHP and DEMATEL methods. *International Journal of Greenhouse Gas Control*, 41, 336–357. <https://doi.org/10.1016/j.ijggc.2015.07.008>
- Saxena, A., Prakash Gupta, J., Tiwary, J. K., Kumar, A., Sharma, S., Pandey, G., Biswas, S., & Raghav Chaturvedi, K. (2024). Innovative Pathways in Carbon Capture: Advancements and Strategic Approaches for Effective Carbon Capture, Utilization, and Storage. *Sustainability*, 16(22), 10132. <https://doi.org/10.3390/su162210132>
- Setiawan, A. D., & Cuppen, E. (2013). Stakeholder perspectives on carbon capture and storage in Indonesia. *Energy Policy*, 61, 1188–1199. <https://doi.org/10.1016/j.enpol.2013.06.057>
- Setiawan, S., Ismalina, P., Nurhidajat, R., Tjahjaprijadi, C., & Munandar, Y. (2021). GREEN FINANCE IN INDONESIA'S LOW CARBON SUSTAINABLE DEVELOPMENT. *International Journal of Energy Economics and Policy*, 11(5), 191–203. <https://doi.org/10.32479/ijeep.11447>
- Shah, K. U., Raghoo, P., & Blechinger, P. (2024). Is there a case for a coal moratorium in Indonesia? Power sector optimization modeling of low-carbon strategies. *Renewable and Sustainable Energy Transition*, 5, 100074. <https://doi.org/10.1016/j.rset.2023.100074>
- Shin, B.-J., Mun, J.-H., Devkota, S., Kim, S.-M., Kang, T.-H., Mazari, S. A., Cho, K., Kim, S. H., Chun, D.-H., Kim, K.-M., Yoon, H. C., & Moon, J.-H. (2023). Comparative assessment and multi-objective optimization for the gray and blue ammonia synthesis processes: Energy, Economic and Environmental (3E) analysis. *International Journal of Hydrogen Energy*, 48(90), 35123–35138. <https://doi.org/10.1016/j.ijhydene.2023.05.205>
- Shirmohammadi, R., Aslani, A., & Ghasempour, R. (2020). Challenges of carbon capture technologies deployment in developing countries. *Sustainable Energy Technologies and Assessments*, 42, 100837. <https://doi.org/10.1016/j.seta.2020.100837>

- Sihite, E. (2023). *KLHK Ingatkan Bahaya di Balik Jorjoran Investasi Gudang Karbon—Energi*. <https://www.bloombergentechnoz.com/detail-news/15964/klhk-ingatkan-bahaya-di-balik-jorjoran-investasi-gudang-karbon>
- Sitinjak, C., Ebbenezzer, S., & Ober, J. (2023). Exploring Public Attitudes and Acceptance of CCUS Technologies in JABODETABEK: A Cross-Sectional Study. *Energies*, 16(10), 4026. <https://doi.org/10.3390/en16104026>
- Soehaimi, A., Padmawidjaja, T., Subagio, S., Mandi, I., Tohari, A., Suharsono, S., Menier, D., Mathew, M., Ramkumar, M., & Novico, F. (2025). Assessing Geological and Seismic Hazards of Malili-Matano Region, East Luwu Regency, Sulawesi: A preliminary study for CCS and Strategic Infrastructure Planning. *Environmental Challenges*, 19, 101177. <https://doi.org/10.1016/j.envc.2025.101177>
- Song, Y., Jun, S., Na, Y., Kim, K., Jang, Y., & Wang, J. (2023). Geomechanical challenges during geological CO₂ storage: A review. *Chemical Engineering Journal*, 456, 140968. <https://doi.org/10.1016/j.cej.2022.140968>
- Sovacool, B. K., Geels, F. W., Andersen, A. D., Grubb, M., Jordan, A. J., Kern, F., Kivimaa, P., Lockwood, M., Markard, J., Meadowcroft, J., Meckling, J., Moore, B., Raven, R., Rogge, K. S., Rosenbloom, D., Schmidt, T. S., Schot, J., Sharp, D., Stephenson, J., ... Yang, K. (2025). The acceleration of low-carbon transitions: Insights, concepts, challenges, and new directions for research. *Energy Research & Social Science*, 121, 103948. <https://doi.org/10.1016/j.erss.2025.103948>
- Stirling, A. (2008). “Opening Up” and “Closing Down”: Power, Participation, and Pluralism in the Social Appraisal of Technology. *Science, Technology, & Human Values*, 33(2), 262–294. <https://doi.org/10.1177/0162243907311265>
- Suchman, M. C. (1995). Managing Legitimacy: Strategic and Institutional Approaches. *The Academy of Management Review*, 20(3), 571. <https://doi.org/10.2307/258788>
- Sunanda, W., Setyonegoro, M. I. B., Hadi, S. P., & Sarjiya. (2025). Advancing the carbon pricing framework in Indonesia: A systematic review of policies, challenges, and global lessons. *Results in Engineering*, 28, 107155. <https://doi.org/10.1016/j.rineng.2025.107155>
- Swennenhuis, F., De Gooyert, V., & De Coninck, H. C. (2024). Socio-technical dynamics of carbon dioxide capture and storage: A systems view on enablers and barriers at North Sea Port. *International Journal of Greenhouse Gas Control*, 137, 104201. <https://doi.org/10.1016/j.ijggc.2024.104201>
- Terwel, B. W., Harinck, F., Ellemers, N., Daamen, D. D. L., & Best-Waldhofer, M. D. (2009). Trust as predictor of public acceptance of CCS. *Energy Procedia*, 1(1), 4613–4616. <https://doi.org/10.1016/j.egypro.2009.02.282>
- Turner, M., Prasojo, E., & Sumarwono, R. (2022). The challenge of reforming big bureaucracy in Indonesia. *Policy Studies*, 43(2), 333–351. <https://doi.org/10.1080/01442872.2019.1708301>
- Upham, P., & Roberts, T. (2011). Public perceptions of CCS: Emergent themes in pan-European focus groups and implications for communications. *International Journal of Greenhouse Gas Control*, 5(5), 1359–1367. <https://doi.org/10.1016/j.ijggc.2011.06.005>
- Van Alphen, K., Hekkert, M. P., & Turkenburg, W. C. (2010). Accelerating the deployment of carbon capture and storage technologies by strengthening the innovation system. *International Journal of Greenhouse Gas Control*, 4(2), 396–409. <https://doi.org/10.1016/j.ijggc.2009.09.019>
- Van Assen, M. F. (2020). Empowering leadership and contextual ambidexterity – The mediating role of committed leadership for continuous improvement. *European Management Journal*, 38(3), 435–449. <https://doi.org/10.1016/j.emj.2019.12.002>
- Voelker, C., Permana, A., Sachs, T., & Tiong, R. (2008). Political risk perception in Indonesian power projects. *Journal of Financial Management of Property and Construction*, 13(1), 18–34. <https://doi.org/10.1108/13664380810882057>
- Wagire, A. A., Joshi, R., Rathore, A. P. S., & Jain, R. (2021). Development of maturity model for assessing the implementation of Industry 4.0: Learning from theory and practice.

- Production Planning & Control*, 32(8), 603–622.
<https://doi.org/10.1080/09537287.2020.1744763>
- Wahyudi, N. A. (2024, February 15). *Aturan Main CCS Terbit, RI Buka Kerja Sama “Impor” CO2 dengan Singapura*. *Bisnis.com*.
<https://hijau.bisnis.com/read/20240215/651/1741354/aturan-main-ccs-terbit-ri-buka-kerja-sama-impor-co2-dengan-singapura>
- Wainstein, M. E., & Bumpus, A. G. (2016). Business models as drivers of the low carbon power system transition: A multi-level perspective. *Journal of Cleaner Production*, 126, 572–585.
<https://doi.org/10.1016/j.jclepro.2016.02.095>
- WALHI. (2024, July 30). *Hentikan Promosi dan Implementasi Carbon Capture Storage: Teknologi Gagal yang Dipakai untuk Memperpanjang Hidup Industri Bahan Bakar Fosil*. WALHI.
<http://www.walhi.or.id/hentikan-promosi-dan-implementasi-carbon-capture-storage-teknologi-gagal-yang-dipakai-untuk-memperpanjang-hidup-industri-bahan-bakar-fosil>
- Wang, N. (2020). *What Went Wrong? Learning From Three Decades of Carbon Capture and Sequestration (CCS) Pilot and Demonstration Projects* (SSRN Scholarly Paper No. 3720763). Social Science Research Network. <https://doi.org/10.2139/ssrn.3720763>
- Wettestad, J., Inderberg, T. H. J., & Gulbrandsen, L. H. (2024). Exploring paths and innovation in Norwegian carbon capture and storage policy. *Environmental Policy and Governance*, 34(2), 125–136. <https://doi.org/10.1002/eet.2068>
- WHITE, A. (2006). The Paradox of Corruption as Antithesis to Economic Development: Does Corruption Undermine Economic Development in Indonesia and China, and Why Are the Experiences Different in Each Country? *Asian-Pacific Law and Policy Journal*, 8(1), 1–34.
- Wijaya, D. W., Yustanti, D. E., Khoirunnisa, K., & Jubaidi, D. (2025). *Toward a Transboundary Legal Framework the Indonesia–Singapore Carbon Capture and Storage Agreement*. SSRN. <https://doi.org/10.2139/ssrn.5362597>
- Wilson, E. J., Klass, A. B., & Bergan, S. (2009). Assessing a Liability Regime for Carbon Capture and Storage. *Energy Procedia*, 1(1), 4575–4582.
<https://doi.org/10.1016/j.egypro.2009.02.277>
- Workman, D. (2025). *Coal Exports by Country 2025*. <https://www.worldstopexports.com/coal-exports-country/>
- Wu, X., Ramesh, M., & Howlett, M. (2015). Policy capacity: A conceptual framework for understanding policy competences and capabilities. *Policy and Society*, 34(3–4), 165–171.
<https://doi.org/10.1016/j.polsoc.2015.09.001>
- Yang, L., Zhang, X., & McAlinden, K. J. (2016). The effect of trust on people’s acceptance of CCS (carbon capture and storage) technologies: Evidence from a survey in the People’s Republic of China. *Energy*, 96, 69–79. <https://doi.org/10.1016/j.energy.2015.12.044>
- Yang, X., Heidug, W., & Cooke, D. (2019). An adaptive policy-based framework for China’s Carbon Capture and Storage development. *Frontiers of Engineering Management*, 6(1), 78–86.
<https://doi.org/10.1007/s42524-019-0003-x>
- Yuniar, M., Pardede, R., Fathoni, S., Indra, C., Tjahjono, T., Saputri, O., & Qinthara, N. (2025). *Ekonomi dan Keuangan Hijau—Konsep dan Implementasi di Indonesia*. Bank Indonesia Institute.
- Yusgiantoro, L. A., & Bagus, T. (2023). *Important Factors to Deploy Carbon Capture Storage / Carbon Capture Utilization Storage (CCS/CCUS) in Indonesia by Using an Interpretive Structural Model*.
- Yusgiantoro, L., Prabowo, T. B., & Kristanto, D. (2025). The Structural Factors in Advancing CCS/CCUS Technology in Indonesia: A Comprehensive Analysis. *Scientific Contributions Oil and Gas*, 48(2), 233–242. <https://doi.org/10.29017/scog.v48i2.1780>
- Yustika, M. (2025). *Two years after launch, Indonesia’s carbon market struggles to find momentum*. <https://ieefa.org/resources/two-years-after-launch-indonesias-carbon-market-struggles-find-momentum>

- Zhang, H. (2021). Regulations for carbon capture, utilization and storage: Comparative analysis of development in Europe, China and the Middle East. *Resources, Conservation and Recycling*, 173, 105722. <https://doi.org/10.1016/j.resconrec.2021.105722>
- Zuch, M., & Ladenburg, J. (2023). Navigating the information pathway to carbon capture and storage acceptance: Patterns and insights from a literature review. *Energy Research & Social Science*, 105, 103283. <https://doi.org/10.1016/j.erss.2023.103283>

Appendix A: Carbon Capture Storage

A.1 CCS System and Value Chain

CCS comprises a set of interdependent components that collectively form a system where the overall technology performance depends on how the components work together as an integrated system. As illustrated in Figure 29, CCS as a climate mitigation strategy consists of three main components including carbon capture, transport, and storage. While commonly described as a CCS value chain, these components are highly interconnected and rely on coordinated development across infrastructure, institutions, and stakeholders, building a complex CCS system.

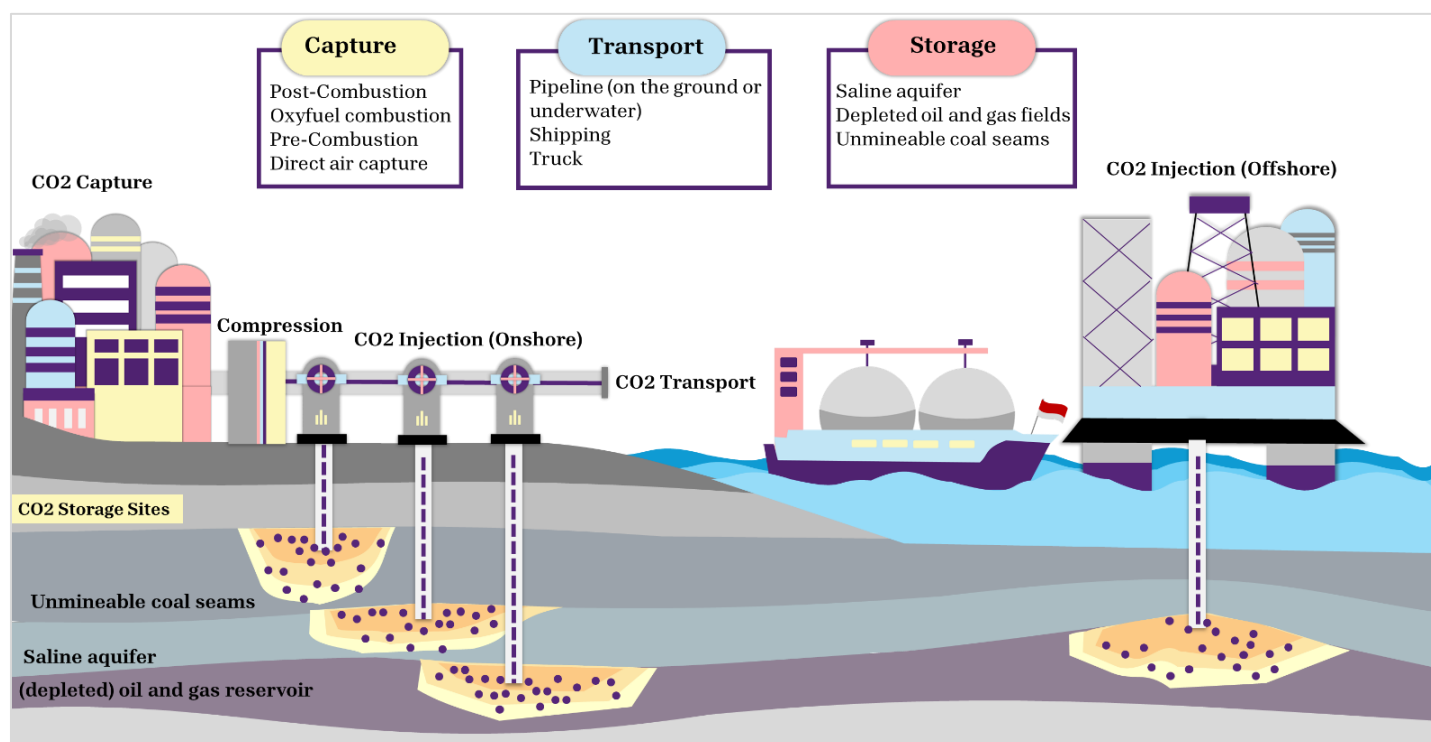


Figure 29. CCS Value Chain Illustration and key technological options on each chain

Carbon capture involves the separation of CO₂ from industrial processes or coal-fired power generation. The main technological options, such as pre-combustion, post-combustion, and oxyfuel combustion, differ in cost, effectiveness, energy requirements, and sectoral suitability. Pre-

combustion capture separates CO₂ during fuel processing before it is used, producing a hydrogen-rich stream that can be used for energy or industrial processes. While this process is efficient and produces high-purity CO₂, it typically requires high capital costs. Post-combustion capture CO₂ from flue gas after the fuel is used and is widely considered the most retrofitting existing facilities, although it is energy intensive (Kuckshinrichs & Hake, 2015). Oxyfuel combustion uses pure oxygen instead of air for fuel combustion, then separates CO₂ through condensation of water vapor. This approach requires additional energy for oxygen production and is sensitive to impurities (Hanson et al., 2025). Emerging approaches, such as direct air capture (DAC), remove CO₂ directly from the atmosphere, though they remain at an early stage of development (Naqvi et al., 2025). Importantly, the viability of the capture system depends on the availability of downstream facilities, including transport and storage, highlighting its dependence on the broader CCS system.

CO₂ transport system connects emission sources to storage sites through several options including pipeline, shipping, or truck. The most viable option is transporting CO₂ in high densities, which requires compression prior to transport as well as meeting the storage site's pressure (Kuckshinrichs & Hake, 2015). Carbon transport systems are associated with potential risk exposure, particularly when the installations are located near population areas. Accidental carbon leakage raises safety concerns as it could significantly affect human health, as shown in Table 14. Therefore, strictly ensuring CO₂ stream composition is critical to ensure system integrity and minimize corrosion, leakage, or system failures. Table 15 outlines recommendations for gas content in transport pipelines that should be met before CO₂ gas is transported. Additionally, the economic viability of the transport system depends on the CO₂ volume, transport distance, and infrastructure utilization.

Table 14. Health effects of increased CO₂ concentration

Concentration	Health effect
0.05%	Natural concentration in air (safe)
0.5%	Maximum allowable concentration for daily exposure of 8h/day
4%	Concentration in healed breath, immediately dangerous to health
5%	Headache, dizziness, unconsciousness
8%	Unconsciousness, death after 30-60 min
>17%	Unconsciousness, death after 1 min

Source: (Kuckshinrichs & Hake, 2015)

Table 15. Recommended quality of CO₂ stream in CCS pipeline transport

Gas	Limit	Reason
H ₂ O	500 ppm	Technical: below the solubility limit of H ₂ O in CO ₂
H ₂ S	200 ppm	Health- and safety-related aspect
CO	2000 ppm	Health- and safety-related aspect
O ₂	Aquifer <4 vol.%	recommended limit to prevent corrosion
CH ₄	Aquifer <4 vol.% ;	recommended limit
Ar	<4 vol.%	recommended limit
H ₂	<4 vol.%	Further reduction of hydrogen is desired
SO _x	100 ppm	Health- and safety-related aspect
NO _x	100 ppm	Health- and safety-related aspect
CO ₂	>95.5 vol.%	Main component for storage sites

Source: (Kuckshinrichs & Hake, 2015)

CO₂ storage activities involve the long-term carbon injection into geological storage sites including saline aquifers, depleted oil and gas fields, and unmineable coal seams. Saline aquifers have favourable geological characteristics with a large capacity for storing carbon despite their subsurface behaviour uncertainties requiring high monitoring activities. Depleted oil and gas fields, as they have been previously used for oil and gas extraction, have a wealth of documented geological data, although its storing capacity is lower compared to saline aquifers ([Hanson et al., 2025](#)). Another potential option is unmineable coal seams with lower capacity and limited geological suitability. Carbon storage activities require rigorous site characterization with a well-developed monitoring, measurement, and verification (MMV) plan. The operation also introduces long-term liability challenges to ensure MMV after site closure.

Beyond technological components, CCS implementation involves multiple actors where the interactions are structured through regulatory frameworks, financial mechanisms, and arrangements that allocate risks and liabilities. CCS implementation also introduces strong interdependencies in investment. Capture investments depend on access to transport and storage, while the transport system depends on sufficient gas supply and storage development depends on regulatory approval, liability governance, and financial mechanisms. Delays or uncertainties in one component could constrain the entire CCS value chain development. Managing these interaction dynamics between technology and actors contributes to CCS system complexities.

Finally, understanding CCS systems emphasizes that its implementation does not solely depend on technological maturity, but on the effectiveness of alignment between regulation, financial mechanisms, infrastructure development, and stakeholders' coordination.

A2. Framework and Research Approach

Table 16. Governance readiness operationalization

Dimensions	Description
Authorization and Access	
Existence of CCS-specific regulatory framework	Presence of dedicated CCS regulatory regime covering capture, transport, and storage liability. This also includes the site assessment before the project is developed to provide reliable potential storage and operational data
Authorization and Storage Rights Clarity	Existence and specific CCS regulations that define permitting pathways, operational requirements, and long-term responsibilities. This covers each CCS chain: capture, transport, and storage. The availability of guidelines on CCS project standards to follow
Clarity on CO ₂ classification and ownership	Provide clear classification of CO ₂ , whether captured CO ₂ is excluded as hazardous waste or a pollutant. Concentration of CO ₂ in the regulation should consider the potential impurities in the CCS chain. The ownership of CO ₂ should be clearly defined as it moves across the CCS chain; it is particularly important for non-integrated projects
Eligibility rules for actors	Regulatory provision defining which state actors are permitted to develop, operate, or invest in CCS (state enterprises, private firms, foreign partners)
State Capacity and Coordination	
Inter-agency coordination mechanism	Existence and effectiveness of formal mechanisms for coordination among agencies with CCS-relevant authority (e.g inter-ministries task forces, joint permitting mechanism, MoU)
Policy Integration and Strategic Coherence	Alignment of CCS-relevant policies across energy, industrial, environmental, and climate actions, absence of contradictory requirements or incentives
Institutional Capacity and Adaptability	Strong enforcement of the technology as a key priority in climate mitigation options. No fragmentation of support within government bodies and key stakeholders. Adaptive governance mechanism for CCS during the long-term operations.
Alignment with National Decarbonization	Explicit inclusion of CCS in national energy and climate plans with dedicated targets, scenarios, and budget allocation
Risk and Liability Governance	
Liability Allocation of Long-Term Stewardship	Existence of clear guidelines defining under what conditions the long-term stored CO ₂ liability can be transferred from operator to states, including criteria of liability transfer eligibility.
Operational Liability and Financial Assurances	Provide clear guidelines on what is under operator obligation during exploration and operation, including risk assessment. The availability of financial benefits obtained by the operator in developing the projects. A clear regulatory framework to ensure the operators are financially secured before and during CCS operation
Measurement, Monitoring, and Verification (MMV) Governance	Mandate standards on MMV with the objectives of comparing the condition with baseline, detecting CO ₂ migration, detecting potential leakage, quantifying the volume of CO ₂ associated with significant leakage and unintended migration
Contingency Planning for Carbon Leakage and Failure	Measures for the mitigation, identification and accounting of actual or potential leakages of CO ₂ , including sanctions or provisions relating to leakage, remediation and/or liability, to be borne by an operator or proponent throughout the operational phase of the project, under law
Knowledge Sharing and Public Participation	
Transparency and Accessibility of CCS Information	Public availability of project information, environmental assessment, regulatory decisions, and monitoring data.
Stakeholder Engagement Governance	Formal consultation processes, documented stakeholder engagement, inclusion of local communities (storage sites) in decision milestones, and incorporating project feedback. This includes the presence of a public education program about the CCS technology and associated risks
Knowledge Governance and Institutional Learning	Existence of repositories for project learning and evaluation, cross-project reviews, mechanism for updating guidance on lesson learned
Public Participation in Project Development	Formal roles for NGOs in advisory bodies, documented NGO inputs and how they were addressed, measures of civil society representation in governance

Source: Author synthesis mainly based on (IEA, 2022) complemented by (Ashworth et al., 2010; Markusson et al., 2011b; Osazuwa-Peters & Hurlbert, 2020; Rijk et al., 2019; Wilson et al., 2009; Wu et al., 2015; Zhang, 2021) and related governance literatures

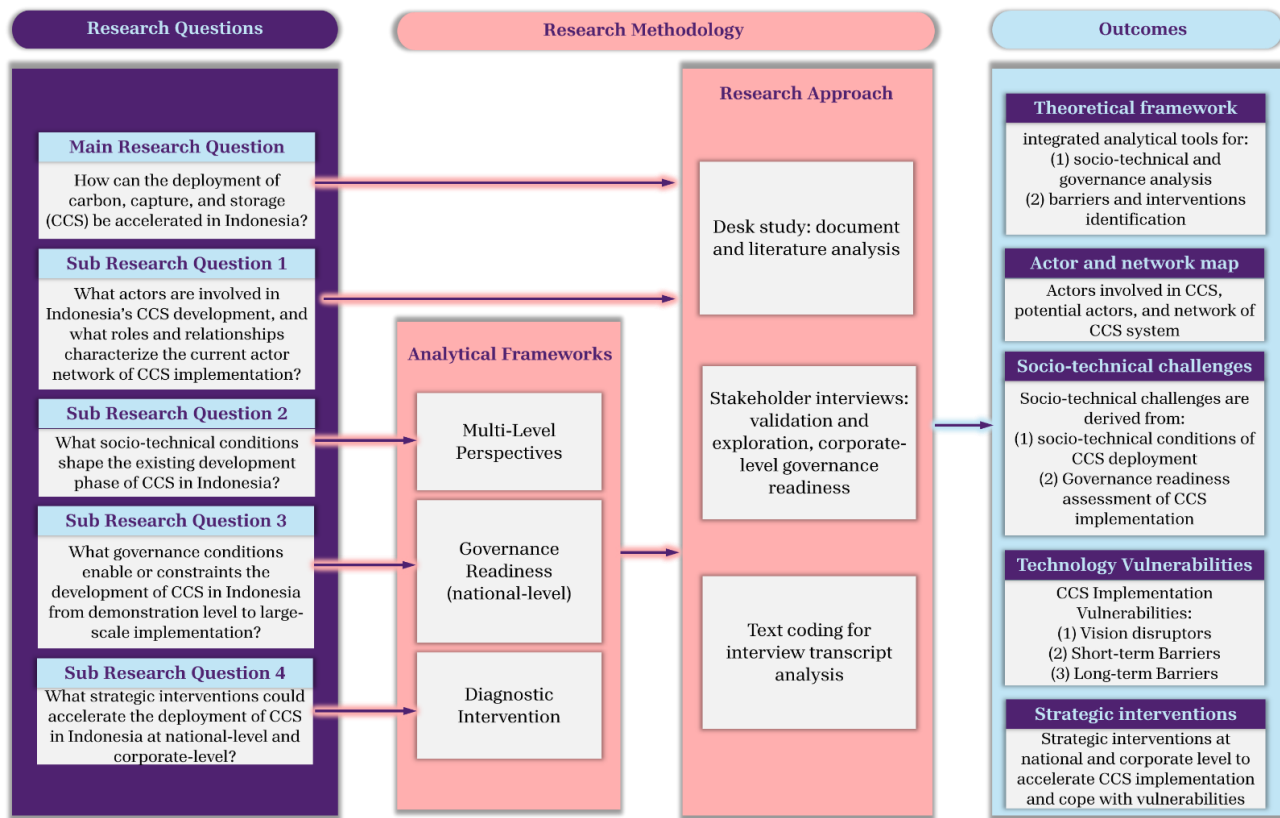


Figure 30. Research design for the study

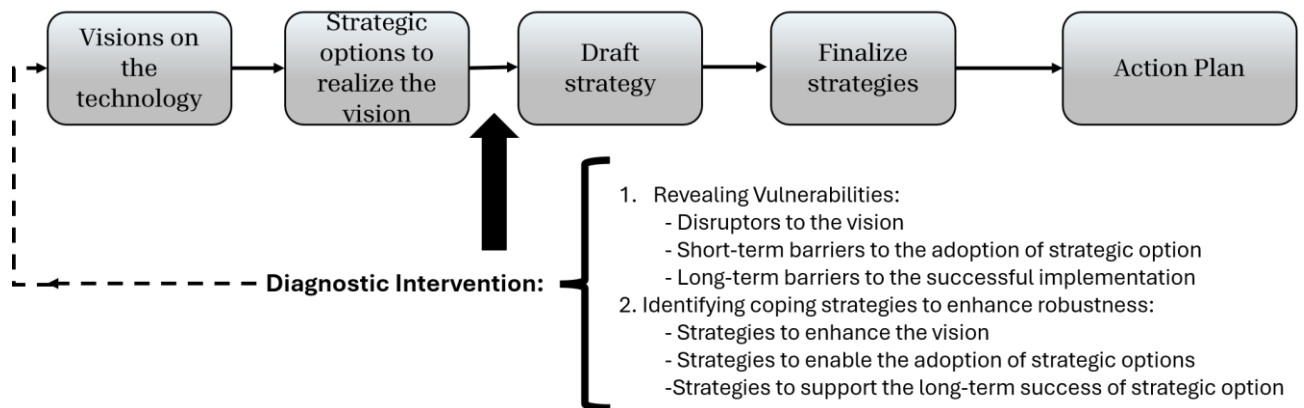


Figure 31. An overview of the diagnostic intervention and its link to the strategic planning process

Source: (Malekpour et al., 2017)

Appendix B: Socio-Technical Analysis

B1. Actors of CCS in Indonesia

Table 17. Actors associated with CCS implementation in Indonesia

No	Category	Actors	Role in CCS Implementation in Indonesia
1	Government	Ministry of Energy and Mineral Resources (MEMR)	Main regulator for CCS Implementation as well as oil and gas operations through the Directorate General of Oil and Gas
		Ministry of Environment and Forestry (MEF)	Regulator for carbon pricing mechanism and defining CO ₂
		Ministry of Finance (MF)	Supporting CCS in the carbon pricing mechanism, fiscal incentives, and climate change funding
		National Development Planning Agency (NDPA)	Integrating CCS deployment into national development plans such as RPJMN and the energy transition roadmap
		Coordinating Ministry for Food Affairs (CMFA)	As a steering committee for carbon pricing implementation, including evaluating, reviewing, and approving carbon abatement initiatives for carbon credits.
		Ministry of Investment and Downstream Industry (MIDI)	Coordinating investment at national level, including low carbon project investments
2	Oil and Gas Governance Bodies	SKK Migas	Special task force from MEMR for upstream oil and gas business activities, including CCS
3	Oil and Gas Industries	State-owned: PERTAMINA	Key CCS Developer in Indonesia within upstream business
		Private: ExxonMobil, BP, REPSOL, INPEX	Involved in CCS resource exploration and development at several points
4	CCS technology support	SLB: technology provider Breicip Franlab: advisory Bumi Armada, Nebula Energy, K-line: transport	Providing technological support and advisory for CCS implementation, contributing to system infrastructure.
5	Research and Knowledge Institution	Centre of Excellence for CCS/CCUS	National research centre dedicated to CCS/CCUS knowledge development and as a platform for research collaboration in CCS/CCUS
		Bandung Institute of Technology (ITB)	Nationally leading technological university to lead CCS/CCUS research centre
		LEMIGAS	Oil and gas research and studies including geological storage studies
6	Coordinating Network	Indonesia CCS Centre (ICCS)	Non-government initiative for national coordination platform aiming for policy advocacy, public reach, and stakeholder coordination

No	Category	Actors	Role in CCS Implementation in Indonesia
7	International organization	Asian Development Bank (ADB), World Bank, IFC, Japan Credit Mechanism (JCM)	Provide funding support for boost economic growth and improve clean energy access across Indonesia, under Indonesia Productive and Sustainable Investment Development Policy Loan
		ASEAN Energy	Intergovernmental coordination for regional energy and CCS collaboration
8	NGO/Think Tanks	NGO: WALHI, Greenpeace	Influencing public perception, social monitoring for CCS
9	Local Communities	Affected communities	Social awareness about CCS, including risks, operation, and benefits, could influence the social license for CCS operators

B1. Socio-Technical Analysis

Table 18. Multi-level perspective analysis for CCS implementation in Indonesia

Landscape level		
No	Conditions	Implications
1	Global Climate Governance and Decarbonization Pressure	Creating market opportunities through foreign low-carbon demand, including carbon storage and regional market competition for low-carbon push the acceleration of low-carbon solutions. The global pressure affects the domestic market not directly, but from the foreign market.
2	National Development Priorities and Fossil-Based Economy Path Dependency	Positions CCS as a strategic technological option within green economic transition priority while maintaining fossil-based energy reliability, creating policy support for CCS-related investments and projects. This shows political legitimacy and investment signalling, particularly when projects align with the national development plan.
3	Weak Sustainable Finance and Investment Ecosystem	Limited access to green finance, high perceived investment risks for green projects, and lack of financial standardization for low-carbon development constrain large-scale investment required for CCS implementation
4	Political-Economic Contestation in Decarbonization Policy	Fragmented support toward carbon pricing policy influences slow implementation of the policy, weakening economic incentives for CCS adoption. The contestation introduces uncertainty, constraining the development of a credible investment environment.
Regime level		
1	Production-Oriented Energy Regime and CCS Development	CCS gains strong support when they align with the national production priorities, as energy security is the main government priority. This positions CCS as a complementary technology for the existing energy sector instead of a climate mitigation strategy.
2	Weak Carbon Pricing and Economic Incentive Structure	Weak economic incentives shape the main objective for CCS as capitalizing on the regional carbon market, limiting the broader domestic application. The effectiveness of CCS to reduce national carbon footprint is limited with the current incentive structure.
4	Fragmented Societal and Institutional Understanding of CCS	Fragmented understanding of CCS creates broader coordination challenges in introducing CCS as a national decarbonization strategy.

5	Regulatory Institutionalization for CCS Development	This creates a foundation for business players to invest in CCS technology and not limited to oil and gas. While this reduces investment uncertainty, broader application of CCS is still limited and often linked to capitalization of regional markets rather than climate mitigation
Niche level		
No	Conditions	Implications
1	Expansion of CO ₂ Storage Exploration Activities	Strengthen the technical capacity, institutional learning, and infrastructure planning for the CCS system. This creates a foundation to attract investors with stronger institutional legitimacy for actively performing CCS storage exploration activities.
2	Early CCS Project Implementation within the Oil and Gas Sector	Reducing technical uncertainty and strengthening industrial confidence, creating initial learning processes starting from the oil and gas sector to broader implementation. This potentially increases the willingness of non-oil-and-gas industries to participate in CCS as the system matures over time.
3	International Collaboration and Regional Storage Hub Development	Strengthening cross-border governance mechanisms, technical coordination, and regional business models for CCS. This creates a foundation to improve foreign investor confidence in CCS collaboration with Indonesia
4	Increasing Research Cross-Sectoral Interest Beyond the Oil and Gas Sector	The growing interest from other carbon-intensive sectors opens opportunities for broader CCS implementation, strengthening niche development and moving toward regime.
5	Development of Dedicated Knowledge and Coordination Networks	This provides a foundation for knowledge development and coordination for accelerating CCS implementation. Although the current condition is still dominated by the oil-and-gas sector, an institutionalized knowledge ecosystem further strengthens the CCS ecosystem in Indonesia, increasing industries and foreign investors' confidence.

Appendix C: Indonesia's CCS Governance Structure

C.1 Authorization Mechanisms

Table 19. WIPK offering mechanisms to business entities⁶

Aspects	Auction	Limited Selection
Requirements	The preparation is based on a. Initial risk assessment b. Technical evaluation of data processing results, including oil and gas exploration and exploitation activities Based on the risk assessment and technical evaluation, a proposal is developed and submitted to MEMR, ensuring that the designated WIPK aligns with regulatory frameworks	The proposer must submit a designated WIPK proposal to MEMR which includes: a. Proposed area boundaries b. Initial risk assessment c. Evaluation of impacts to safety, health, and environment d. Comprehensive technical evaluation e. Work plan and available budget for exploration f. Administrative documents g. Experience and investment value related to oil and gas, mining, geothermal, and CCS
Participations	Business entities Shortlist business entities by MEMR	Companies who propose limited selection Short list business entities by MEMR

⁶ Business entities refer to Indonesian business entities and foreign entities with a permanent establishment presence in Indonesia.

MEMR Short list refers to business entities approved by MEMR that have met qualifications to participate in WIPK offering through limited selection

CCS Permit types

Exploration Permit

As shown in [Table 19](#), an exploration permit will be offered through auction and limited selection process; it is valid for 6 years and can be extended for a maximum of 4 years. Companies that want to participate must submit a technical assessment for the potential sites, which must provide data availability of sites, regional geology information, exploration concept, strategic location for storage sites, potential storage capacity, operation process concept, and amount of targeted stored-CO₂.

The inclusion of prior experience in oil and gas, mining, or geothermal sector reinforces the institutional preference for established actors, potentially limiting the early-stage participation from emerging CCS-focused firms.

Transportation Permit

There are three types of transportation permit for CCS activities

- a. Pipeline transportation (not underwater): carbon transportation permit granted by MEMR upon the approval of an environmental impact assessment
- b. Underwater pipeline transportation: carbon transportation permit granted by MEMR and the Ministry of Maritime Affairs and Fisheries (MMAF)
- c. Ship, Truck, or other method of transportation: carbon transportation permit granted by the Ministry of Transportation (MOT) upon approval from the Ministry of Environment and Forestry (MEF)

Carbon Transportation Permits are valid for up to 20 years and 10 years for transportation by trucks, ships, and/or other methods. Permits can be extended for a maximum of 10 years for each extension.

President Regulation 14/2024 also allows cross-border carbon transportation if there is a bilateral agreement between the countries involved. The framework emphasizes that in the event of a leak during transportation within the territory of Indonesia (including Indonesian waters), such a leak must not add to Indonesia's greenhouse gas inventory.

Carbon storage permit

An exploration permit can be converted to a carbon storage permit once the plan of CCS development and operation is approved by MEMR. The storage permit is valid for 30 years and can be extended for a maximum of 20 years. The permit holder of carbon storage is responsible for CCS project development, operation, and post-closure. Under PR 14/2024, there are two potential schemes of CCS business operation, either within PSC or WIPK mechanisms, as provided by Table 20. PSC mechanism allows existing oil and gas permit holders to include CCS activities within existing PSC work permits if ZTI of carbon storage is identified in the work areas of oil and gas. Unlike current oil and gas permits, a CCS permit within the WIPK scheme cannot be transferred to any companies. This may enhance regulatory control for CCS but also reduce market flexibility and investment attractiveness.

Exploration permit mechanism

The evaluation criteria for the limited selection process will be based on the following aspects:

- a. Early risk assessment
- b. Technical assessment from submitted study for Injection Target Zone (ZTI, *Zona Target Injeksi*)
- c. Technical capabilities related to oil and gas, mining, geothermal, and CCS business
- d. Financial capabilities in carrying out the ZTI exploration and CCS operation
- e. Technical capabilities in managing hazardous and toxic materials
- f. Compliance with laws and regulations in Indonesia

Table 20. Differences between PSC and WIPK scheme in CCS Permit System

Source: synthesized from PR 12/2024

Criteria	PSC Scheme	WIPK Scheme
Applicants	PSC Permit Holder (Existing oil and gas actors)	Any business entities as long as meeting auction requirements (including PSC permit holders)
CCS Area	PSC Work Area (Area of existing oil and gas operation)	Any suitable area as determined by MEMR (not limited to oil and gas work areas)
Licensing	Pursuant to PSC	WIPK exploration permit, carbon transportation permit, storage permit
CCS Activities	Conducted as complementary to oil and gas operation	CCS as main business
Transfer	Participating interest in PSC can be transferred to other interested business actors upon notification and approval by SKK Migas and MEMR	WIPK permits cannot be transferred

C.2 CCS Operational Framework

Table 21. CCS operator obligation and financial incentives schemes

Source: Author documentation synthesized from (MEMR 16/2025, PTK-070)

Aspect	Description
Exploration	Obligations: - Provide a plan of development and budget for site operations. The plan must include a technical assessment of the site, including geology, geophysics, reservoir profile, seismic reprocessing data, conceptual risk mitigation. - Provide technical assessment that includes estimation of storage capacity, depth and thickness of injection zone, integrity and hydraulic conductivity of injection zone, and dynamic modelling for CO₂ distribution - Perform exploration according to the MEMR-approved plan - Regularly report exploration activities including credible exploration data - Provide environmental and social impact assessment
Carbon Operation	Obligations: - Provide a work plan for pre-operation, operation, post-closure, MRV, and risk mitigation - Perform the operation process according to the MEMR-approved plan - Comply with the regulations regarding procurement, construction, commissioning, injection, MRV, and site closure - Regularly report to authorities every 6 months and on incidental events - Pay royalty to the government for the storage sites and provide insurance for post-closure activities - Provide data obtained during CCS operation and be responsible for all tools used to provide high-accuracy measurement data - Guarantee occupational safety and health, and provide an emergency response system for carbon leakage and associated risks with CCS
Carbon transportation	Obligations: - Ensure safety and risk mitigation - Operate according to the approved plan including transportation mode, maximum capacity of transported CO₂, and quality assurance for CO₂ transportation - Responsible for any leakage that occurs during CO₂ transportation
Financial	- Provide a carbon storage operational guarantee of at least USD 1.5 million or 10% of the injection well budget. - Contribute to post-closure annually from storage-fee revenues through the operator's approved work plan and budget

MMV Mechanism

Table 22. MMV governance in Indonesia's CCS frameworks

Source: Author documentation synthesized from (MEMR 16/2025, PTK-070)

Aspect	Description
Monitoring requirements	Obligations: a. Monitoring results must be reported to MEMR and MEF; stored carbon must be registered to SRN-PPI to track NDC efforts b. Monitoring must be performed during exploration, operation, and 10-years post-closure c. Monitoring can adopt direct or indirect methods to identify leakage, groundwater contamination, Integrity of buffer zone layers, impermeable zone layers, and geological traps. d. Update the modelling used to observe storage site performance regularly, including geology modelling, reservoir modelling, and geo-mechanical modelling e. Monitoring must be able to compare environment condition with the pre-CCS operation f. The method used must be able to detect CO₂ leakage and unexpected movement g. Operators perform hydrogeology study to assess potential of interaction between groundwater and injected CO₂
Reporting	Obligations: a. Reporting must be performed every 6 months and when there is an incidental event b. Reporting must also include amount of captured, transported, and stored CO₂ c. Performance review must consider calculated emission baseline d. Monitoring results must include activity data, size, location, and CCS implementation period e. Managerial system must be described, including responsible personnel and data-monitoring systems for CCS activities.
Verification	There will be verification of the quality of data reported

Risk Mitigation Mechanisms

Table 23. Indonesia's CCS risk mitigation obligations

Source: Author documentation synthesized from (MEMR 16/2025, PTK-070)

Aspect	Description
Risk Mitigation	a. Integrate risk management across all CCS project phases. b. Minimize risks to the environment, operational safety, and asset integrity. c. Identify and mitigate risks across reservoirs, injection facilities, and all well types. d. Conduct periodic risk management updates with transparent documentation. e. Evaluate the integrity of all wells used or intersecting CCS operations. f. Assess casing condition, cement bond logs, and leakage potential, and report findings to SKK Migas.

C.3 CCS Site Closure Guideline

Table 24. Indonesia site Closure guidelines

Source: synthesized from (MEMR 16/2024, PTK-070)

Aspect	Description
Site closure driver	CCS can be closed if meet the criteria below a. Stored CO₂ already meets the maximum capacity of the storage site b. No more CO₂ injected to the site c. Permit expires and is not extended d. Emergency conditions e. Force majeure
Operator obligations	Obligations: a. Operators must provide a site closure plan that includes information on reservoirs, equipment, installations, facilities, and wells that are being closed for CCS activities, budget of closure, mitigation plan on potential environmental degradation, risk exposure to humans, and facilities failure b. Coordinate with relevant authorities for the site closure, including MEMR, MEF, MMAF (for offshore), etc c. Store and manage all CCS closure documents and ensure key closure data remains available for future use. d. Prepare plans for post-closure management and long-term monitoring and define responsibilities and mechanisms for post-closure issues. e. Conduct a final evaluation of the entire closure process. f. Document evaluation results and recommendations for future learning.

Appendix D: Barriers

Table 25. Vision Disruptors of CCS Implementation in Indonesia

No	Vision Disruptor	Category	Why it disrupts the CCS Vision
1	Fragmented institutional understanding	CCS Innovation and Development Dynamics	Different actors hold conflicting understandings of CCS objectives and governance
2	CCS development concentrated in oil and gas	CCS Innovation and Development Dynamics	Reinforce perception that CCS is an oil-and-gas extension rather than a national decarbonization strategy
3	Limited knowledge diffusion beyond oil and gas	CCS Innovation and Development Dynamics	Limits broader socio-technical transition of CCS, beyond oil and gas
4	Limited policy coherence for CCS and decarbonization pathway	CCS Governance and Regulatory Challenges	CCS has limited role across industrial and climate strategy
5	Oil and gas-centric governance path dependency	CCS Governance and Regulatory Challenges	Locks governance and participation within the incumbent oil and gas sector
6	Procedural rather than substantive public participation	CCS Governance and Regulatory Challenges	Weak societal legitimacy for long-term CCS implementation
7	Weak domestic decarbonization pressure	Decarbonization Commitment	Reduce urgency for companies to adopt CCS
8	Limited disincentives for continuation of high-carbon activities	Decarbonization Commitment	Weaken low-carbon technology transition including CCS
9	Conflicting priorities between fossil fuel expansion and decarbonization	Decarbonization Commitment	Creates contradictory policy direction
10	Uneven low-carbon motivation	Decarbonization Commitment	Actors engage on low-carbon projects only when exposed to global market pressure
11	Fragmented political commitment	Political Dynamics	CCS support depends heavily on specific leaders or administrations
12	Political discontinuity on technology innovation due to the electoral cycle	Political Dynamics	CCS implementation constrained and relied on political directive every electoral cycle

Table 26. Short-term Barriers of CCS Implementation in Indonesia

No	Short-term Barrier	Category	Why it is a short-term barrier
1	High infrastructure and connectivity constraints	CCS Innovation and Development Dynamics	Limited integration of pipeline and transport slows the deployment, and low security of the emitter as CO ₂ supply for CCS
2	Limited knowledge and capacity in CCS implementation	CCS Innovation and Development Dynamics	Indonesia still highly depends on external expertise for large-scale CCS deployment
3	Weak legal foundation for CO ₂	CCS Governance and Regulatory Challenges	Unclear CO ₂ classification complicates governance and investment
4	Limited clarity on technical standards for MMV and Emergency Responses	CCS Governance and Regulatory Challenges	Uneven contingency planning and MMV across CCS projects
5	Limited technical clarity on site-closure guidelines	CCS Governance and Regulatory Challenges	Uneven technical assessment in site closure across the projects
6	Limited clarity on liability transfer after post-closure	CCS Governance and Regulatory Challenges	Risk can be transferred to the state and affected people without clarity on mitigation
7	Unclear cross-border mechanisms	CCS Governance and Regulatory Challenges	Slow the regional CCS operation and constrain regional collaboration
8	Low economic incentives	Economic Viability	CCS remains economically unattractive domestically
9	Weak investment ecosystem	Economic Viability	CCS investment remains weak
10	Capital-intensive pressure on CCS, highly dependent on external funding	Economic Viability	Projects rely heavily on foreign capital and support
11	Inefficient Bureaucracy	Organizational and Institutional Culture	Slows permitting and coordination
12	Strong mechanistic governance	Organizational and Institutional Culture	Reduces flexibility and responsiveness to changes
13	Risk-averse work culture, weak institutional adaptability	Organizational and Institutional Culture	Limits experimentation and innovation, including in CCS
14	Inter-ministries coordination challenges	Political Dynamics	Multi-sector governance remains limited

Appendix E: Interview Analysis

Final Code Book

Table 27. Final code book for interview analysis with total frequency

No	Code	Description	Totals
1	Political interest alignment	Alignment on a technology as a national decarbonization pathway	64
2	Decarbonization alignment challenge	Alignment on CCS as national decarbonization strategy	61
3	Investment Ecosystem Concern	Availability of financing, investment incentives, risk-sharing mechanisms, and market conditions supporting CCS deployment	55
4	Economic viability concern	This refers to the economic performance of CCS implementation, the level of economic benefit received by the operators from business perspectives	52
5	Limited political commitment	Government backing to implement CCS as the climate mitigation strategy, including policies and incentives	44
6	Cross-sector collaboration	Collaboration between different stakeholders from different sectors	35
7	Coordination challenges	Collaboration with parties that have a good reputation to implement the CCS, also to gain public trust for implementing this high-risk technology	33
8	Global market influence	Influence of international carbon markets, CCS trends, and global investment dynamics on domestic CCS development	33
9	Knowledge Exchange	Sharing of CCS knowledge, experiences, lessons learned, and best practices among stakeholders	27
10	Industries commitment	The ability of industries to make timely decisions regarding CCS projects, following through long-term stability of CCS implementation	26
11	Specific regulation support	Regulatory and policy frameworks that are developed in particular to govern CCS across its value chain; capture, transport, and storage	26
12	Growing adoption interest	Increasing attention and willingness among stakeholders to explore and implement CCS projects	25

No	Code	Description	Totals
13	Inefficient bureaucracy	Administrative complexity and lengthy approval processes that delay CCS development and implementation	24
14	Governance enhancement	Improvement of regulatory frameworks, institutional coordination, and oversight mechanisms for CCS implementation	23
15	Institutional learning	Learning from experiences within the national CCS system as well as adopting experiences from other institutions to strengthen CCS policy, knowledge, and decision-making	23
16	CCS broader adoption	Application of CCS that is not limited to a certain sector, involving many high emitters	22
17	Public Vulnerabilities	Potential social, economic, environmental, or health impacts of CCS that may disproportionately affect communities	22
18	Knowledge development	Generation of scientific, technical, regulatory, and operational knowledge related to CCS	21
19	Innovation concern	Challenges related to developing, scaling, and deploying innovative CCS technologies and solutions	20
20	International CCS Collaboration	Cooperation between countries on CCS development, knowledge sharing, infrastructure, and project implementation	20
21	Production over decarbonization	Prioritization of industrial production or fossil fuel output over emission reduction objectives	20
22	Public engagement concern	Concern related to involvement of the public in CCS decision-making and implementation	20
23	Leadership mandate approach	Direction and support from political or organizational leaders to advance CCS policies and projects	19
24	Limited Public Knowledge	The level of understanding of the role of CCS in decarbonization strategies	19
25	Oil and gas domination	Strong influence of the oil and gas sector in shaping CCS development, priorities, and decision-making	18
26	Policy coherence concern	Inconsistencies or misalignment among policies, regulations, and strategies affecting CCS deployment	18
27	Specific sector acceleration	Use specific sector to introduce CCS technology in the existing market	18
28	Organization capacity	Ability of organizations to provide sufficient resources, expertise, and management support for CCS activities	17
29	Risk-aversion tendency	Reluctance among stakeholders to engage in CCS due to uncertainty, perceived risks, or potential liabilities	17
30	Shifting political interest	Changes in political priorities or government agendas that affect long-term CCS support and stability	17
31	Technological challenges	Technical barriers and operational difficulties associated with CCS deployment across the value chain	17
32	Capital-intensive investment	CCS implementation requires high capital cost for its complete value chain, capture, transport, and storage	16
33	Dedicated CCS Institutions	Institutions dedicated to CCS, including national research institutions and coordination platform	16
34	Fragmented governance	Uneven governance mechanisms across stakeholders	16

No	Code	Description	Totals
35	Business profit opportunity	CCS creates business profit through lower operational cost by reducing carbon tax payment or obtaining profit from storage fee or other mechanism	15
36	CCS project assessment	Refers to CCS feasibility study including technical, economic evaluation, and risk mitigation review	15
37	Capacity building	Increasing capabilities of the institution bodies including training, workshops, research	12
38	Cross-border governance concern	Refers to concern associated with transboundary CCS operation involving at least two countries	11
39	Limited stakeholder knowledge	The level of technology understanding of CCS is uneven across stakeholders, or even some stakeholders show limited understanding	11
40	Early-stage development	Initial phase of development, demonstration phase	10
41	Stakeholder engagement	Active involvement of relevant stakeholders throughout CCS planning, decision-making, and implementation processes	10
42	Technological Readiness	Maturity and deployment status of CCS technologies for commercial-scale implementation	9
43	CO2 classification clarity	Legal definition of CO2, whether it is as a waste, hazardous materials, special substance, or commodity	8
44	Higher consumer cost	The cost of implementing CCS is passed down to the customers	8
45	International support	Financial, technical, or policy assistance provided by international organizations, partners, or foreign governments	8
46	Long-term liability concern	Refers to the long-term commitment and risk associated with CCS, creating specific challenges in regulatory development and business planning	8
47	Post-closure stewardship	Long-term monitoring, maintenance, and management responsibilities after storage site closure	8
48	Misleading CCS Framing	Presentation of CCS in ways that create misconceptions about its purpose, effectiveness, or role in decarbonization	6
49	MMV governance concern	Challenges in governing monitoring, measurement, and verification (MMV) systems to ensure transparency and accountability	6
50	Limited trust in government	Public trust regarding the capability of the government with regard to climate mitigation	5
51	Carbon storage exploration	Activities related to storage site exploration, including geological observation, modelling, and testing on the potential storage sites	4
52	Regional market competition	Competition among regions or countries to attract CCS investments, projects, and carbon storage opportunities	4
53	Risk planning governance	Governance mechanisms for identifying, assessing, managing, and communicating CCS-related risks	4
54	Variety of mitigation pathways	Availability of multiple climate mitigation options alongside CCS to achieve emission reduction goals	3
55	Limited site-closure guideline	Lack of clear procedures, standardized guidance, and regulatory requirements for the closure and decommissioning of CCS storage sites	2
56	Carbon leakage risk	Unintended increased emissions in one region due to emission reduction in another region. Also, the potential leak of carbon from the transport and storage activity, especially when it is located in the high populated area	1
57	Seismic activity risk	CCS risk that potentially induces seismic activity, raising public concern, especially those who live in active seismic areas	1

Code Group and Stakeholder Group

Table 28. Code grouping for the text-analysis

Code group	Code	Code group	Code
Governance and Institutional Readiness	CO2 classification clarity	Political and Strategic Commitment	Decarbonization alignment challenge
	Coordination challenges		Governance enhancement
	Cross-border governance concern		Growing adoption interest
	Cross-sector collaboration		Industries commitment
	Decarbonization alignment challenge		International CCS Collaboration
	Dedicated CCS Institutions		Limited political commitment
	Fragmented governance		Policy coherence concern
	Governance enhancement		Political interest alignment
	Inefficient bureaucracy		Shifting political interest
	Innovation concern		Specific sector acceleration
	Leadership mandate approach	CCS Development Pathways and Dynamic	Carbon storage exploration
	Limited site-closure guideline		CCS broader adoption
	Long-term liability concern		CCS project assessment
	MMV governance concern		Cross-border governance concern
	Policy coherence concern		Cross-sector collaboration
	Political interest alignment		Dedicated CCS institutions
	Risk planning governance		Early-stage development
	Risk-aversion tendency		Growing adoption interest
	Specific regulation support		International CCS collaboration
	Stakeholder engagement		International support
Socio-Technical Risks and Challenges	Carbon leakage risk	Stakeholder Knowledge and Capacity	Oil and gas domination
	CO2 classification clarity		Public engagement concern
	Innovation concern		Specific sector acceleration
	Limited Public Knowledge		Variety of mitigation pathways
	Limited site-closure guideline		Capacity building
	Limited stakeholder knowledge		Global market influence
	Limited trust in government		Institutional learning
	Long-term liability concern		Knowledge development
	Misleading CCS framing		Knowledge exchange
	Oil and gas domination		Limited public knowledge
	Post-closure stewardship	Economic and Market Viability	Limited stakeholder knowledge
	Production over decarbonization		Organization capacity
	Public engagement concern		Business profit opportunity
	Public vulnerabilities		Capital-intensive investment
	Regional market competition		Economic viability concern
	Seismic activity risk		Higher consumer cost
	Specific sector acceleration		Investment ecosystem concern
	Technological challenges		Regional market competition
	Technological readiness		

Table 29. Stakeholder grouping for text-analysis

Stakeholder group	Stakeholder interview
Government/Public Governance	S1-G
	S8-IO
CCS Adopters	S3-OGP
	S4-OGP
	S5-OGS
Potential CCS Adopters	S6-NOGP
	S7-NOGS
Knowledge Actors	S2-R
	S9-NTT

Text-coding mapping

Table 30. Text-coding matrix between code groups and stakeholder groups

	CCS Adopters	Government / Public Governance	Knowledge Actor	Potential CCS Adopters	Totals
CCS Development Pathways and Dynamics	60	25	48	42	175
Economic and Market Viability	41	17	22	29	109
Governance and Institutional Readiness	101	51	54	65	271
Political and Strategic Commitment	78	50	36	58	222
Socio-Technical Risks and Challenges	73	23	36	39	171
Stakeholder Knowledge and Capacity	47	16	36	30	129
Totals	400	182	232	263	1077

Overview

Governance and Institutional Readiness dominate all stakeholder groups, indicating that governance issues are central across the CCS ecosystem. This strengthens the findings where most stakeholders perceive CCS is not merely a technological challenge. Instead, concerns revolve around the institutional environment needed to enable implementation. Interview findings indicate CCS adopters are more concerned with implementation certainty than with technological feasibility, as they have confidence in the capacity building around CCS technology. Their perspectives suggest that institutional and governance conditions represent the primary barriers to scaling CCS deployment. Government stakeholders tend to frame CCS readiness predominantly as governance and policy challenges, highlighting the concerns around institutional arrangements and political commitments. Knowledge actors emphasize their concerns around broader socio-technical transition, focusing on long-term development pathways, institutional learning, and capacity-building requirements. Potential CCS adopters remain cautious about CCS technology as a decarbonization pathway, and CCS is assessed primarily through concerns about governance certainty, strategic commitment, and positioning future CCS adoption depending on governance credibility.

Appendix F: Interview Protocol

Interview objectives:

1. Validating and exploring findings regarding socio-technical conditions and governance readiness that shape Indonesia's CCS implementation
 - a. Answering research question 2 on socio-technical conditions
 - b. Answering research question 3 on governance readiness
2. Explore stakeholders' perspectives on CCS technology in Indonesia
3. Understanding dynamics of CCS technology within national and corporate levels
4. Understanding barriers and challenges through stakeholders' lens (for sub-research question 4 on strategic interventions)
5. Understanding stakeholder points of view for key priorities to be considered for CCS acceleration (for sub research question 4 on strategic interventions)

Interview Questions

The interview will be conducted either in English or Bahasa Indonesia, depending on the interviewee's preferred language level

Introduction questions

1. Can you briefly describe yourself and how your work relates to low-carbon development or CCS initiatives in Indonesia?
2. Before we begin, do you have any questions for me?

Understanding the general perception of CCS implementation

3. What are your perspectives about CCS in Indonesia, especially its market development and decarbonization strategies?
 - a. What is your view on the current situation in Indonesia where CCS is positioned as a complementary technology for the oil and gas sector, rather than as a national decarbonization strategy?
 - b. Several studies mention that CCS is a reasonable option for countries with high reliance on carbon-intensive economies, including Indonesia. What do you think about this? Is CCS considered reasonable for Indonesia to meet their NDC?

4. In your view, how does the government
5. How do you think the government and industrial actors in Indonesia see CCS technology?

Understanding the socio-technical aspects of CCS in Indonesia

Actor and Network

6. These are the actors identified in Indonesia's CCS system (show the list of actors and power and interest grid). Is there any important actor that may be missing here?

Landscape Pressure

7. Landscape pressure refers to conditions that influence technology development in general; in this context is low-carbon technologies including CCS, for climate mitigation.

These are conditions that influence CCS development in Indonesia from studying existing studies, institution documents, and regulation documents:

- a. Global climate change pressure
- b. National development plan (RPJPN and RPJMN) for green economy
- c. International funding support for low-carbon development
- d. Weak sustainable finance ecosystem
- e. Political contestation on carbon policy
- f. Social injustices practices in extractive industries
- g. High corruption practices in Indonesia

(show it in slide)

Can you rank from the most influential to the least influential? Is there any other condition that may also influence the development of low carbon technology in Indonesia?

Regime Level

8. With the same previous approach, now let's discuss the current dominating situations in Indonesia's CCS ecosystem. These are the dominant practices of CCS implementation dynamics in Indonesia.
 - a. National oil and gas production target as policy priority
 - b. Limited economic incentives in carbon pricing policy
 - c. CCUS-EOR is currently favoured over CCS alone, considering the business model for CCS is currently considered weak in Indonesia
 - d. Availability of specific regulation for CCS, creating a strong foundation for CCS implementation
 - e. Limited public awareness about CCS and how it can be used for decarbonization
 - f. Competition with renewable energy technologies in International Climate Finance

Before we discuss further, could you rank these situations from the best to reflect the current CCS system in Indonesia to those that reflect less?

9. Indonesia has set a target of producing 1 million barrels of oil per day and 12 BSCFD of gas by 2030 to strengthen energy security. How do you think this policy direction influences the development and role of CCS in Indonesia?

10. Now, Indonesia has three scenarios that allow industries to advance their sustainability and decarbonization plan
 - a. Carbon tax with IDR 30,000/t-CO₂ (USD 2/t-CO₂)
 - b) Carbon trading mechanism through IDX Carbon (IDR 96,000 for Indonesia Technology Based Solution Authorized (IDTBSA) – Non renewable sector)
 - c) Result-based payment (RBP), reward for companies who perform decarbonization using green credit

How do the existing carbon pricing mechanisms in Indonesia affect the incentives for industries to invest in CCS?
11. In Indonesia, CCUS linked with Enhanced Oil Recovery (EOR) is often considered more economically viable than standalone CCS. From your perspective, what factors explain this preference?
12. Indonesia has recently introduced several regulations to support CCS development. How do these regulations shape the opportunities and challenges for implementing CCS projects in Indonesia?
13. Public awareness and understanding of CCS in Indonesia are still relatively limited. In your view, how does this affect the acceptance and development of CCS projects?
14. In Indonesia's climate mitigation strategy, how does CCS compete with renewable energy technologies in terms of policy support, investment, and international climate finance?
15. Is there anything in your mind that should also be considered as current dominant CCS practices in Indonesia that we have not discussed?

Niche Level

16. Several CCS pilot projects and CO₂ storage exploration activities have recently started in Indonesia, particularly within the oil and gas sector. From your perspective, how important are these early initiatives for advancing CCS development in Indonesia?
17. What conditions would be required to develop CCS beyond pilot projects but to wider commercial deployment in Indonesia?
18. Since 2017, Indonesia has had dedicated research institutions such as the Centre of Excellence for CCS/CCUS led by ITB and other initiatives. How do you see this advancing CCS knowledge and technology development? How do industry players collaborate with the institution for CCS project development?
19. There is increasing discussion about Indonesia becoming a regional CO₂ storage hub, supported by coordination networks such as the Indonesia CCS Centre. How do you see Indonesia's potential to play this regional role? And how national platform such as Indonesia CCS accelerate CCS initiatives?
20. What are the main challenges that emerging CCS initiatives currently face when trying to move from niche experimentation into mainstream deployment in Indonesia?

Authorization and Access

21. The latest regulation issued, MEMR 16/2024, allows different types of business sectors to take part in CCS development as long as they meet technical and financial requirements. How do you see the participation of different sectors in CCS development?
- Probe:
- A. Are CCS projects mainly led by oil and gas companies?
 - B. Do non-oil and gas sectors face barriers?
22. Indonesia has introduced several regulations specifically governing CCS implementation (show in the slide the list of regulations), they also cover the potential CO₂ transport and cross-border storage. From your view, how do existing regulations influence the willingness of companies to play a part in CCS?
- Probe:
- A. Does this improve business players' confidence?
 - B. Are these regulations still insufficient to motivate business players to develop CCS?
23. The classification of CO₂ in regulation is also considered important, whether they are defined as waste or commodity. How important is this legal definition of CO₂ for accelerating CCS projects in Indonesia?

State Capacity and Coordination

24. From your perspective, how would you describe the level of government commitment and capacity to support CCS implementation?
- Probe:
- A. Are they committed to implementing CCS as a decarbonization strategy?
 - B. How about the institutional capacity in supporting CCS?
25. How would you describe the collaboration among stakeholders such as government, industry, and research institutions in CCS development?
- Probe:
- A. How is the current inter-ministerial coordination for CCS?
 - B. How do industries collaborate with research institutions and government to deploy CCS?
 - C. Do you observe support priorities among stakeholders?

Risk and Liability Governance

26. Based on your understanding, how are risks and responsibilities currently distributed among actors involved in CCS projects in Indonesia?
27. In current regulations, long-term responsibility will be under companies until 10 years after site closure, and it will be transferred to the state. How do you think this arrangement influences CCS development?
- Probe:
- A. Who will be responsible when it is still under state still unclear. Do you think this will weaken the CCS project attractiveness? Or do you think this will put additional pressure on state-owned companies?

28. CCS projects involve risk assessment, including technical, environmental, and financial risks. From your perspective, what kind of risk management arrangements are necessary to support CCS?

Knowledge Development and Public Participation

29. From your perspective, how well-developed knowledge ecosystem for CCS in Indonesia? This includes research capacity and knowledge exchange among CCS stakeholders in Indonesia, such as government, industry, and research institutes.
30. How would you describe the current level of public participation and awareness of CCS in Indonesia?

Probe:

- A. The mandate of public participation is still limited; do you think this will significantly affect Indonesia's CCS?

Barriers and Recommendations

31. What are the main barriers to CCS implementation in Indonesia that may not have been discussed? Do you have anything in mind?
32. What key interventions or improvement needed to accelerate CCS in Indonesia for the short term and long-term?
33. What role do you see your organization will contribute to future CCS in Indonesia? Are there any important issues that we have not discussed but should be highlighted?

Appendix G: Artificial Intelligent (AI) Reflection

In this research, AI (ChatGPT) was used mainly to strengthen academic writing by providing insights into potential ways to develop the story, and it was not used to directly what AI provides. AI was not used to find relevant academic papers directly; however, AI was used to discuss potential keywords to identify relevant papers or articles. AI was also used to find media coverage about issues related to the technology, in addition to the manual search on a search engine. Grammarly AI was also used to provide insights into effective academic writing. Copilot by Microsoft was also used to find troubleshooting related to issues faced while using the Microsoft Office software in developing the report, such as MS Word and PowerPoint. Finally, Elicit was used to find relevant papers that discuss similar arguments from the researcher's analysis. Collectively, these AI tools were used as supplementary but did not replace the researcher's analytical judgement or independent research. There is no direct use of AI for citations or performing analysis, as it may have low relevance to the topic discussed. The usage of AI is declared here to maintain research transparency regarding research integrity and methodology for this thesis writing.