Toward a Transboundary Legal Framework: The Indonesia–Singapore Carbon Capture and Storage Agreement

Abstract

The escalating urgency of addressing climate change has prompted states to adopt innovative mitigation strategies, including Carbon Capture and Storage (CCS) technologies with transboundary applications. In February 2024, Indonesia and Singapore signed a Letter of Intent (LoI) to initiate bilateral cooperation on cross-border CCS, marking a significant development in regional carbon governance in Southeast Asia. This article analyzes the legal implications of this cooperation from the perspective of international law, with particular emphasis on the potential development of a binding bilateral agreement grounded in existing international legal frameworks. The central inquiry focuses on how the Indonesia–Singapore initiative contributes to the formulation of a transboundary legal framework for CCS and examines the relevant international legal principles and obligations that must be addressed. Employing a normative juridical methodology, this study draws on treaty law, state practice, and legal doctrine, while assessing pertinent international instruments such as the Paris Agreement, the United Nations Convention on the Law of the Sea (UNCLOS), and customary international law concerning transboundary environmental harm. The analysis indicates that, although the LoI is non-binding, it establishes a foundational platform for a legally enforceable bilateral treaty that may serve as a model for the region. Key legal challenges identified include jurisdictional clarity, liability allocation, environmental safeguards, and consistency with international climate obligations. The article concludes that the formulation of a robust bilateral agreement anchored in international legal norms is critical to ensuring legal certainty, environmental integrity, and reciprocal confidence in transboundary CCS implementation.

Keywords: Carbon Capture and Storage (CCS), Transboundary Environmental Governance, Indonesia–Singapore Agreement, International Environmental Law, Customary International Law

1. Introduction

The worsening impacts of climate change have compelled states to pursue increasingly innovative and collaborative mitigation strategies. One of the most promising developments in recent years is the advancement of Carbon Capture and Storage (CCS) technologies, which allow for the capture of carbon dioxide (CO) emissions from major industrial sources and their subsequent storage in deep geological formations. While traditionally implemented within national boundaries, the growing disparity between countries with high emissions and those with suitable storage sites has catalyzed interest in cross-border CCS arrangements (Mittler, 2023).

On 15 February 2024, Indonesia and Singapore signed a Letter of Intent (LoI) to explore bilateral cooperation on transboundary CCS, enabling Singapore to export captured CO_2 for geological storage in Indonesia (Antara News, 2024). This move signifies a strategic response to Singapore's limited geological storage capacity and Indonesia's potential to host large-scale CO_2 storage projects, especially in its depleted oil and gas fields. As Southeast Asia's first bilateral initiative on CCS, this agreement holds substantial implications for regional environmental governance and international legal development in the field of transboundary carbon management.

Although the LoI is non-binding in nature, it represents an important diplomatic and legal milestone. It lays the groundwork for the negotiation of a future binding bilateral treaty that could serve as a model for other ASEAN countries, many of which face similar asymmetries in emissions and geological capacity. As emphasized by Penningtons (2022), the establishment of a legally robust and harmonized CCS framework within Southeast Asia is increasingly urgent in light of global net-zero commitments and regional climate vulnerabilities.

Despite the importance of this cooperation, the legal architecture governing transboundary CCS remains underdeveloped at the international level. There is, to date, no comprehensive multilateral treaty that specifically addresses the legal dimensions of cross-border CCS. Instead, states must rely on a mosaic of international legal instruments and customary principles that only indirectly touch upon relevant aspects. These include the Paris Agreement, the United Nations Convention on the Law of the Sea (UNCLOS), and established principles of customary international environmental law, such as the prevention of transboundary harm and the obligation to conduct Environmental Impact Assessments (EIAs) for potentially hazardous activities.

The Paris Agreement, while central to global climate governance, does not explicitly regulate CCS or its transboundary applications. However, it implicitly encourages the use of CCS under its broader framework for mitigation actions, particularly in the context of nationally determined

contributions (NDCs) (UNFCCC, 2015). Under Article 6, the agreement also provides a legal basis for international cooperation through carbon markets, which could eventually support transboundary CCS financing and accountability mechanisms.

UNCLOS is another critical legal instrument that could guide the governance of cross-border CCS, especially where carbon is transported via maritime routes. Article 194 of UNCLOS obligates states to prevent, reduce, and control marine pollution, including pollution from land-based sources and vessels. Recent advisory opinions, such as the May 2024 decision of the International Tribunal for the Law of the Sea (ITLOS), have further clarified that greenhouse gases can constitute marine pollution under international law, thereby creating potential regulatory obligations for states engaging in CCS-related maritime transport (The Guardian, 2024). Additionally, customary international law imposes certain duties on states engaged in transboundary environmental activities. These include the principles of due diligence, the requirement to notify and consult potentially affected states, and the duty to prevent significant transboundary harm (Voigt, 2019). These principles, while well-established, often lack precise procedural guidelines when applied to novel technologies like CCS, especially in transboundary contexts.

The Indonesia–Singapore initiative thus highlights a number of legal challenges that must be addressed to ensure the legitimacy and effectiveness of cross-border CCS. Key issues include jurisdictional clarity over stored carbon, liability for potential leakage or environmental harm, compliance mechanisms, and public participation in the decision-making process. In the absence of a specific international treaty on CCS, states must carefully negotiate bilateral or regional agreements that integrate existing legal norms while addressing the unique risks posed by cross-border carbon transport and storage(Ramadhan et al., 2024).

Legal scholars and international organizations have argued that transboundary CCS arrangements must be governed by legally binding treaties that provide clear standards for monitoring, verification, and enforcement (Maddahi, 2024). This is essential not only for ensuring environmental integrity and public trust but also for attracting the long-term investment necessary to scale up CCS infrastructure. In Southeast Asia, where legal harmonization remains a challenge, bilateral agreements such as the Indonesia–Singapore initiative may pave the way for a broader ASEAN framework for CCS governance.

The normative juridical method employed in this study aims to evaluate the Indonesia–Singapore LoI through the lens of treaty law, state practice, and legal doctrine. By examining both binding and non-binding international instruments, this approach reveals how existing legal norms can be localized and adapted to fit the emerging practice of transboundary CCS. The study draws from sources including the text of the Paris Agreement, interpretations of UNCLOS by judicial bodies, and legal commentary on the evolving nature of state responsibility in environmental matters.

While the current LoI is a soft-law instrument lacking enforceability, it nevertheless performs a critical function: it signals political will, outlines mutual expectations, and sets the procedural stage for formal treaty negotiations. As noted by legal observers, soft-law instruments often act as precursors to binding legal commitments, particularly in technical and politically sensitive areas like environmental protection and transboundary cooperation (Bodansky & Van Asselt, 2024).

In conclusion, the Indonesia–Singapore CCS cooperation presents a unique opportunity to develop a legally sound, environmentally responsible, and regionally replicable model for transboundary CCS. As countries around the world increasingly turn to CCS as part of their climate strategies, the creation of a bilateral legal framework rooted in international law could serve not only to enhance mutual confidence and environmental safeguards, but also to influence the evolution of global norms on carbon management.

In addition to its legal dimensions, the Indonesia–Singapore CCS cooperation carries broader socio-economic implications that merit closer examination. For Indonesia, the development of transboundary CCS infrastructure could stimulate regional investment, generate employment, and drive economic diversification, particularly in storage site areas such as depleted oil and gas fields. At the same time, it raises questions of social acceptance, environmental justice, and public accountability in host regions. For Singapore, the partnership offers a more cost-efficient pathway to meet its climate targets without compromising industrial growth. These factors underscore the necessity for a legal framework that not only ensures environmental integrity and compliance with international norms but also incorporates socioeconomic safeguards, equitable burden-sharing, and mechanisms for public accountability.

1.1. Literature Review

In recent years, the legal and policy discourse on Carbon Capture and Storage (CCS) has shifted significantly toward addressing the complexities and regulatory uncertainties surrounding transboundary CCS operations. Scholars increasingly recognize that the successful implementation of cross-border CCS projects depends not only on technological readiness and economic feasibility but also on the existence of clear and enforceable legal frameworks (Frattini et al., 2024). As CCS moves from a conceptual mitigation strategy to an operational reality, especially in regions with asymmetrical geological storage capacities, the legal architecture to govern such projects becomes ever more crucial.

Much of the existing literature highlights the fragmented nature of international law in relation to CCS governance. As Park, (2020) observes, there is currently no comprehensive multilateral treaty that explicitly regulates the transboundary transportation and geological storage of carbon dioxide. Instead, regulatory guidance must be inferred from a patchwork of existing legal instruments and customary norms. For example, the Paris Agreement, while heralded as a milestone in global climate governance, remains vague in its treatment of CCS. Although CCS is implicitly supported as part of the range of mitigation technologies under nationally determined contributions (NDCs), the Agreement lacks detailed guidance on the legal and procedural requirements for cross-border implementation (Adriansyah et al., 2023).

In this context, scholars have turned their attention to the potential applicability of other international regimes, most notably the United Nations Convention on the Law of the Sea (UNCLOS). Marsela (2024) note that while UNCLOS does not explicitly refer to CCS, its provisions on marine environmental protection, pollution prevention, and jurisdiction over activities in the seabed beyond national jurisdiction may be invoked to regulate maritime transport and offshore storage of CO_2. Particularly relevant are Articles 192 and 194, which require states to prevent marine pollution and protect the marine environment, a duty that could extend to activities associated with CO_2 leakage from sub-seabed storage sites.

Given the absence of binding multilateral instruments specific to CCS, bilateral and regional agreements are emerging as pragmatic legal tools. Hagemann et al (2011) argue that bilateral CCS treaties allow states to negotiate context-specific rules tailored to their geographical, political, and environmental realities. Their comparative study of CCS-related agreements in the Asia-Pacific region demonstrates that bilateral instruments offer greater legal certainty in addressing key issues such as jurisdictional control, liability allocation, long-term monitoring, and dispute resolution.

Moreover, they contend that such agreements may serve as experimental legal laboratories that inform the eventual development of broader multilateral frameworks.

A number of scholars have further emphasized the necessity of integrating foundational principles of international environmental law into these agreements. O'Riordan & Jordan (1995) stress the relevance of the precautionary principle, the polluter pays principle, and the principle of inter-state cooperation in minimizing environmental risks and promoting equitable responsibility-sharing. These principles not only reflect established state practice but also serve to legitimize CCS projects in the eyes of affected communities and civil society.

Finally, the establishment of robust monitoring, reporting, and verification (MRV) mechanisms is identified as a core requirement in the governance of transboundary CCS. Arfanuzzaman (2021) argue that transparent MRV systems are critical for building and maintaining trust between cooperating states and for ensuring compliance with environmental and safety standards. Their research highlights the role of independent oversight bodies and data-sharing protocols in enabling accountability across jurisdictions.

In sum, contemporary scholarship reveals a growing convergence around the idea that bilateral CCS agreements, while currently the most viable option, must be designed in alignment with overarching principles of international environmental law and adapted to the evolving landscape of climate governance. These agreements are not only legal instruments but also political tools for fostering cooperation and ensuring the environmental sustainability of carbon mitigation strategies in a globalized context.

1.2. Theoretical Framework

This study employs a multidisciplinary theoretical framework that synthesizes key concepts from international environmental law, state sovereignty, treaty law, and transboundary environmental governance to critically analyze the evolving legal structure of Carbon Capture and Storage (CCS) cooperation between Indonesia and Singapore. These theoretical lenses provide a comprehensive foundation to assess the normative implications and institutional challenges of implementing cross-border CCS projects in accordance with international legal standards.

1.2.1. Principles of International Environmental Law

At the core of this framework are foundational principles of international environmental law, which serve as normative benchmarks for designing environmentally sound and legally consistent CCS regimes. The *precautionary principle* is central to this analysis, requiring that states take

anticipatory action to prevent environmental degradation even in the absence of full scientific certainty (Tickner et al., 2007). In the context of CCS, this principle mandates the implementation of rigorous risk assessments and long-term monitoring, especially considering the uncertainties surrounding CO_2 leakage from geological formations. As CCS technologies are still evolving, the precautionary approach supports the use of robust safeguards before large-scale deployment.

Closely related is the *no-harm rule*, a customary norm obligating states to ensure that activities within their jurisdiction do not cause significant transboundary environmental damage (Boyle & Redgwell, 2021). This principle has been affirmed in international jurisprudence, including the *Trail Smelter* arbitration and the ICJ's *Pulp Mills* case, and is particularly relevant for transboundary CCS, where geological storage in one state could potentially impact neighboring states if not properly managed. The no-harm rule thus underpins the allocation of responsibility in the event of transboundary environmental harm.

The polluter pays principle further contributes to the theoretical foundation by asserting that those responsible for environmental damage must bear the financial costs of remediation and prevention. This principle is crucial for shaping liability regimes in CCS operations, especially when determining who bears the cost in case of CO_2leakage or storage failure across jurisdictions (Sadeleer, 2020). Incorporating this principle ensures economic accountability and promotes sustainable industrial practices.

1.2.2. Sovereignty and Jurisdiction in International Law

Sovereignty over natural resources and jurisdictional rights form the second pillar of the theoretical analysis. Under international law, particularly the United Nations Convention on the Law of the Sea (UNCLOS), coastal states enjoy sovereign rights over their Exclusive Economic Zones (EEZs) and continental shelves, including the right to explore and exploit natural resources (Gümplová, 2025). However, these rights are coupled with obligations to protect the marine environment. As Misbach et al (2022) highlights, the exercise of jurisdiction must be balanced with a duty of cooperation and environmental stewardship, especially when activities such as CCS involve shared marine spaces or could affect other states.

1.2.3. Treaty Law and International Cooperation Theory

The theory of international cooperation and treaty law provides another dimension for understanding how states formalize cross-border environmental efforts. Abbott & Snidal (2000) argue that states engage in treaty-making not merely to codify rules but also to manage

interdependence, reduce transaction costs, and establish institutional trust. This theoretical lens is useful for analyzing the 2024 Letter of Intent (LoI) between Indonesia and Singapore, which, although non-binding, reflects initial steps in formalizing mutual commitments and may evolve into a binding treaty that addresses jurisdictional, technical, and liability aspects of CCS. Bilateral arrangements can also function as experimental legal regimes that inform the architecture of future multilateral frameworks.

1.2.4. Transboundary Environmental Governance

Finally, the concept of transboundary environmental governance captures the need for institutional mechanisms that go beyond state-centric approaches. Keohane & Victor (2016) emphasize the importance of adaptive governance systems capable of managing environmental issues that transcend national borders and are characterized by scientific uncertainty and technological dynamism. This perspective is particularly relevant for CCS, a technology that not only involves physical infrastructure across territories but also requires harmonized standards for measurement, verification, and risk management. It encourages a shift from rigid treaty models to more flexible arrangements that can accommodate evolving knowledge and practices.

By integrating these theoretical approaches, this study critically evaluates the Indonesia–Singapore CCS cooperation as a case study for emerging transboundary environmental governance. The analysis illuminates how international legal norms, state sovereignty, and cooperative frameworks interact in the formation of a new regulatory landscape for climate mitigation technologies. Moreover, it underscores the necessity of constructing legally sound, environmentally responsible, and politically viable frameworks to support such cooperation in Southeast Asia and beyond.

2. Methodology

This research adopts a normative juridical methodology, which centers on the analysis of legal norms, principles, and instruments relevant to cross-border Carbon Capture and Storage (CCS), particularly within the context of international environmental law and transboundary governance. The normative juridical method is suitable for studies that aim to evaluate the content, coherence, and development of legal frameworks, as it focuses not on empirical data but on the structure and function of law itself (Soekanto & Sri Mamudji, 2011). This method allows for a comprehensive examination of the legal obligations and implications surrounding the Indonesia–Singapore CCS cooperation.

The primary legal materials utilized in this research include international treaties and conventions, such as the United Nations Convention on the Law of the Sea (UNCLOS) (Khoirunnisa, 2023), the Paris Agreement and other relevant international environmental agreements. These instruments provide the foundational legal context for understanding how states can regulate the storage and transportation of CO_2 across national boundaries. Additionally, the study examines bilateral instruments, particularly the 2024 Indonesia–Singapore Letter of Intent (LoI) on CCS cooperation, which, although non-binding, signals mutual intent and may evolve into a legally enforceable agreement. Such documents are essential for assessing how states begin to operationalize emerging international obligations and align with domestic policy priorities.

In addition to primary legal sources, the research incorporates secondary legal materials such as scholarly articles, commentaries, expert legal opinions, and reports from international organizations like the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA). These sources provide critical doctrinal perspectives and interpretations of international legal developments and trends in CCS governance. As argued by Frattini et al (2024), the integration of doctrinal and contextual legal analysis helps deepen the understanding of how legal principles evolve in response to emerging global challenges.

To conduct the legal analysis, this study applies legal interpretation techniques, including textual, contextual, and teleological interpretation. Textual interpretation focuses on the plain meaning of legal provisions, while contextual interpretation considers the broader legal environment in which these provisions operate. Teleological interpretation, on the other hand, emphasizes the purpose and objectives behind legal norms, particularly relevant in the environmental law context where legal texts must often be read in light of ecological goals and sustainability imperatives (Barak, 2005). These interpretative methods are employed to examine the congruence between the Indonesia–Singapore LoI and existing international law, as well as to explore its potential contribution to the development of a more cohesive legal framework for transboundary CCS activities.

The study also draws upon comparative legal analysis by examining how other jurisdictions have approached similar transboundary CCS arrangements, particularly in regions such as the European Union and North America. This comparative approach provides a broader understanding of best practices, common legal challenges, and innovative governance mechanisms that could inform Indonesia and Singapore's effort (Zweigert & Kotz, 1998).

Finally, the research includes an evaluation of legal gaps and implementation challenges, particularly in the absence of a specific multilateral regime governing transboundary CCS. Through this normative approach, the study aims not only to map current legal standards but also to propose normative pathways toward more coherent and enforceable international legal structures for CCS governance.

3. Result & Discussion

3.1. Legal and Institutional Context of CCS

3.1.1. The Technical and Policy Foundations of Carbon Capture and Storage

Carbon Capture and Storage (CCS) is a sophisticated technological process that captures carbon dioxide (CO_2) emissions at their source, primarily from industrial and power generation facilities before transporting it to secure geological formations for permanent storage (Hanson et al., 2025). These storage sites typically include depleted oil and gas reservoirs or deep saline aquifers, which offer the necessary geological stability to prevent leakage (International Energy Agency (IEA), 2023). The importance of CCS is underscored by its unique capacity to reduce emissions from sectors where alternatives like electrification or fuel switching remain limited, such as cement production, steel manufacturing, and petrochemical processing (Sandunika et al., 2023).

From a policy perspective, CCS is central to many national and international decarbonization strategies aiming to meet the Paris Agreement's target of limiting global warming to well below 2°C, ideally striving for 1.5°C (Rissman et al., 2020). The International Energy Agency (IEA) stresses that without large-scale deployment of CCS, achieving net-zero emissions by mid-century would be considerably more challenging and costl (Gabrielli et al., 2023). Yet, while the technical feasibility of CCS is advancing, its large-scale deployment faces significant challenges related to costs, public acceptance, and particularly the development of comprehensive legal and institutional frameworks that can govern both domestic and transboundary CCS activities safely and effectively (Rode et al., 2023).

3.1.2. Legal Gaps in International Regulation of Transboundary CCS

The international legal framework regulating transboundary CCS remains highly fragmented and incomplete, reflecting the novelty and complexity of this technology. No single treaty or convention comprehensively addresses the full CCS chain from capture, through transport, to long-

term subsurface storage (Hanson et al., 2025). Several key legal instruments and principles are relevant, yet gaps persist.

The Paris Agreement, while not explicitly mentioning CCS, offers some avenues for facilitating cross-border cooperation through Article 6, which promotes cooperative approaches including internationally transferred mitigation outcomes (ITMOs) (Hulu, 2023). This could be interpreted to accommodate cross-border CCS projects, particularly in linking emissions reductions across jurisdictions,. Article 4 further grants states discretion in determining their nationally determined contributions (NDCs), thereby allowing CCS integration according to national strategies (UNFCCC, 2015).

The United Nations Convention on the Law of the Sea (UNCLOS, 1982) is central for offshore CCS operations, particularly within Exclusive Economic Zones (EEZs) and continental shelves. UNCLOS mandates states to protect the marine environment (Art. 192) and prevent pollution from dumping and land-based sources (Arts. 194, 210). However, UNCLOS does not explicitly regulate CO_2 injection or storage beneath the seabed, leaving interpretative challenges concerning state responsibility and environmental safeguards (Hanson et al., 2025).

The 1996 London Protocol, an international treaty governing marine pollution, amended in 2009 to permit the export of CO_2 streams for sub-seabed storage, provides a partial regulatory framework (Garrett & McCoy, 2013). Nonetheless, this amendment has yet to enter into force due to insufficient ratification, creating legal uncertainty for international CCS transport and storage operations.

In the absence of comprehensive treaty law, customary international environmental law principles such as the no-harm rule, due diligence obligations, and state responsibility apply to transboundary CCS. These principles require states to prevent significant transboundary environmental damage and cooperate in managing shared environmental risks, providing a normative baseline (Boyle & Redgwell, 2021). However, their general nature limits their practical guidance for detailed regulatory needs.

3.1.3. The Institutional Landscape and Emerging Norms

Institutionally, CCS governance currently relies heavily on soft law mechanisms and sectoral initiatives rather than binding international regulations. Organizations such as the International Energy Agency (IEA) (2023) the Global CCS Institute, and United Nations bodies have developed technical guidelines, best practices, and voluntary standards to support project development and

environmental monitoring (Global CCS Institute, 2016). These efforts aim to fill regulatory gaps and promote transparency, accountability, and risk management, yet lack enforceability.

As transboundary CCS projects increasingly emerge, bilateral and regional agreements gain prominence as pragmatic tools to clarify legal responsibilities, coordinate regulatory frameworks, and foster cooperation (Sadkhan & Al-Mudhafar, 2024). The Indonesia–Singapore Letter of Intent (LoI) and forthcoming treaty negotiation illustrate this trend. Such bilateral frameworks can address specific operational, legal, and institutional complexities that general international law does not resolve, including liability, monitoring, and data sharing protocols. Moreover, they contribute to evolving regional norms that may eventually influence multilateral standards (Zivar et al., 2020).

This legal and institutional context highlights the need for a coherent, layered governance approach combining international law, bilateral agreements, and soft law to support the safe and effective deployment of CCS. The Indonesia–Singapore initiative, analyzed in the subsequent sections, embodies this emerging strategy by seeking to harmonize national laws and foster cross-border cooperation in a legally complex domain.

3.2. Analysis of the Indonesia–Singapore CCS Agreement

3.2.1 Legal Character and Status of the Letter of Intent (LoI)

The Letter of Intent (LoI) signed by Indonesia and Singapore on 15 February 2024 marks a significant political milestone, signaling both countries' commitment to exploring collaborative opportunities in cross-border Carbon Capture and Storage (CCS). As a non-binding document, the LoI does not create enforceable legal obligations under international law; rather, it functions as a soft law instrument reflecting mutual goodwill and a shared vision for future cooperation (Hanson et al., 2025). In this sense, the LoI is best understood as a precursor to a formal bilateral treaty, setting out broad principles and intentions while leaving room for detailed negotiations on substantive legal commitments.

The LoI outlines priority areas including the development of CO_2 transport infrastructure, regulatory harmonization, and joint efforts to build legal and technical frameworks that will underpin effective CCS operations. This approach aligns with the incremental negotiation strategy often observed in international environmental governance, where parties initially express political intent before committing to binding treaty obligations (Rajamani, 2016). This stepwise progression allows Indonesia and Singapore to test technical feasibility, align regulatory standards, and identify

possible legal challenges without prematurely locking themselves into rigid commitments. However, the transition from a soft law instrument like the LoI to a legally binding treaty requires precise legal drafting to avoid ambiguity, ensure clarity on rights and obligations, and incorporate dispute resolution mechanisms (Boyle & Redgwell, 2021).

3.2.2 Legal Issues Arising from Transboundary CCS Cooperation

The future bilateral treaty must comprehensively address several complex and interrelated legal challenges unique to transboundary CCS activities.

a. Jurisdiction and Sovereignty

The agreement must clearly define the spatial scope of jurisdictional authority over various phases of CCS operations. Singapore will likely hold regulatory jurisdiction over CO_2 capture facilities located within its territory, while Indonesia will exercise jurisdiction over the subseabed storage sites, often located within its exclusive economic zone (EEZ) or continental shelf under UNCLOS (United Nations Convention on the Law of the Sea) (Nations, 1982). Coordinating pipeline transit across maritime boundaries further complicates jurisdictional questions, necessitating clear demarcation of regulatory responsibilities for inspection, enforcement, and monitoring. Delimiting these roles helps avoid jurisdictional overlap or gaps that could undermine effective governance and environmental protection (Hanson et al., 2025).

b. State Responsibility and Liability

A robust liability regime is essential to allocate responsibility for any environmental harm resulting from CCS activities, such as CO_2 leakage or contamination of marine ecosystems. The treaty must address questions of liability attribution whether it rests on the emitting entity, the transporter, or the host state responsible for storage and determine if liability will be strict or fault-based. Strict liability may incentivize higher safety standards but could deter investment due to increased risk exposure, while fault-based liability might complicate claims and enforcement (Rode et al., 2023). The framework should also define mechanisms for compensation, remediation, and dispute resolution to uphold the no-harm principle central to international environmental law (Boyle & Redgwell, 2021).

c. Environmental Protection Standards

Harmonizing environmental safeguards is critical for legitimacy and compliance. The treaty should mandate joint environmental impact assessments (EIAs), setting unified criteria for site

selection, injection protocols, monitoring of storage integrity, and long-term stewardship. Public participation mechanisms and transparency will also enhance stakeholder trust and align with emerging norms under the Paris Agreement and UNCLOS obligations related to marine environmental protection (Rajamani, 2016).

e. Data Sharing, Transparency, and Verification

Effective CCS governance depends on transparent and reliable monitoring, reporting, and verification (MRV) systems. The treaty should require regular data exchange on CO_2 volumes captured, transported, and stored, supported by independent third-party verification to ensure compliance and build confidence. These measures align with the cooperative spirit of the Paris Agreement's Article 6, which encourages international collaboration and transparency in mitigation efforts (UNFCCC, 2015).

f. Compatibility with International Legal Commitments

The treaty's design must harmonize with existing international obligations, especially UNCLOS provisions regulating marine environments and sub-seabed activities, and the Paris Agreement's climate mitigation framework. Addressing these legal intersections ensures the bilateral agreement complements rather than conflicts with multilateral regimes (Boyle & Redgwell, 2021).

3.2.3 The Role of the Bilateral Treaty as a Normative Model

Beyond facilitating concrete cooperation between Indonesia and Singapore, the bilateral treaty holds broader normative significance. Given the absence of a comprehensive multilateral regime specifically tailored to transboundary CCS, bilateral frameworks like this can fill critical governance gaps by creating detailed, context-specific rules that address technical, legal, and institutional challenges (Hanson et al., 2025).

This treaty could serve as a pioneering model in Southeast Asia, where neighboring states with complementary capacities, such as limited storage potential in Singapore and substantial geological storage in Indonesia may replicate such cooperation. By advancing legal clarity, environmental safeguards, and institutional coordination, this bilateral agreement could influence regional standards and inform the development of future multilateral arrangements (Rode et al., 2023).

However, while bilateralism provides important immediate solutions, it is not a substitute for multilateral norm development. Instead, it functions as an essential building block or "bridge" that helps harmonize national regulations and facilitates eventual creation of more comprehensive regional or global CCS governance frameworks (Rajamani, 2016).

3.2.4. Socioeconomic Dimensions of the Indonesia–Singapore CCS Cooperation

While legal and environmental safeguards are essential components of a transboundary Carbon Capture and Storage (CCS) agreement, socioeconomic considerations are equally vital to ensure the political feasibility, long-term sustainability, and social legitimacy of such cooperation. These considerations extend beyond abstract legal norms and engage directly with the lived realities of affected populations, national development priorities, and regional disparities in capacity and vulnerability. A comprehensive CCS governance framework must, therefore, be responsive not only to international legal obligations but also to the broader social and economic implications of implementation on both sides of the partnership.

In the case of Indonesia, potential carbon storage sites such as depleted hydrocarbon fields, saline aquifers, or offshore geological formations are often located in provinces that experience significant economic disparities compared to urban centers like Jakarta or Surabaya. These sites may be situated near coastal or rural communities that are economically marginalized, lack adequate infrastructure, or have limited access to essential services such as healthcare, education, and clean water. The establishment of CCS infrastructure in such areas offers important economic opportunities, including job creation in construction, monitoring, logistics, and long-term site stewardship. Local economies may also benefit from ancillary developments such as roads, ports, or research facilities that accompany CCS projects. Moreover, if properly structured, carbon storage projects could generate revenue streams for local governments through licensing, land lease agreements, or benefit-sharing schemes, thereby contributing to regional development.

However, these benefits are not guaranteed and may be offset by a range of socioeconomic risks if not addressed through robust policy and legal safeguards. Communities in proximity to storage sites may harbor concerns about the long-term safety of subsurface carbon storage, potential environmental degradation, or disruptions to traditional land and marine resource use. These concerns may be exacerbated by legacies of extractive development in Indonesia, where local populations have often been excluded from decision-making processes and have borne disproportionate environmental costs. The potential for local resistance—manifested in protests,

litigation, or political opposition—poses a serious challenge to the social license to operate for transboundary CCS projects. Accordingly, the bilateral agreement must incorporate inclusive procedures for public consultation, grievance redress mechanisms, and community consent to mitigate conflict and build local trust.

From Singapore's perspective, the decision to outsource carbon storage aligns with its national constraints: limited landmass, lack of suitable geological formations for long-term CO_2 storage, and high population density. Transboundary cooperation offers Singapore a cost-effective and technically feasible pathway to meet its nationally determined contributions (NDCs) under the Paris Agreement while maintaining its economic competitiveness and industrial base. However, this economic rationality must be tempered with a sense of distributive justice. Given the uneven distribution of environmental and social risks across jurisdictions, Singapore should be expected to assume a fair share of the financial and institutional burden associated with project implementation.

This could involve providing financial assistance for the development of infrastructure in Indonesia, supporting social development initiatives in affected communities, and investing in joint capacity-building programs aimed at strengthening local regulatory institutions. Additionally, Singapore could contribute to the funding of long-term environmental monitoring and remediation funds to ensure continued oversight beyond the operational lifespan of CCS facilities. Such measures would not only reflect the principle of equitable burden-sharing but also enhance regional solidarity and cooperative climate governance in Southeast Asia.

Crucially, both states must ensure that affected communities are not passive recipients of policy decisions but active participants in governance. This entails the integration of procedural rights such as access to information, prior consultation, and participatory planning into the design and implementation of CCS projects. Public engagement mechanisms, including stakeholder forums, participatory mapping, and local monitoring committees, can facilitate transparency, accountability, and community buy-in. In addition, socio-cultural assessments should complement environmental impact assessments to identify and mitigate potential disruptions to local livelihoods, customs, and identity.

In sum, a well-designed bilateral CCS treaty must go beyond technocratic and legalistic considerations to encompass a holistic socioeconomic framework. By institutionalizing community participation, financial equity, and inclusive development, such a treaty can promote

public legitimacy, reduce implementation risks, and foster mutual confidence between states. The Indonesia–Singapore initiative thus has the potential not only to serve as a legal prototype but also as a model of ethically grounded and socially inclusive climate cooperation for the wider ASEAN region.

3.3. Toward a Transboundary Legal Framework

3.3.1. The Need for a Comprehensive Bilateral Treaty

The Letter of Intent (LoI) between Indonesia and Singapore represents a foundational step toward cross-border carbon capture and storage (CCS) cooperation, yet it simultaneously highlights the imperative for a detailed and legally binding bilateral treaty. While the LoI sets forth a framework for collaboration, its non-binding nature lacks the enforceability and precision necessary to govern the complex technical, environmental, and legal challenges inherent to transboundary CCS operations (Rajamani, 2016). A comprehensive treaty would provide legal certainty to stakeholders, including governments, private investors, and local communities, by delineating responsibilities, regulatory standards, and mechanisms to manage risks associated with CO_2transport and storage.

Such a treaty must harmonize technical standards to ensure safe and efficient operations across jurisdictions, especially in areas like pipeline construction, injection protocols, and monitoring systems. Harmonization would reduce transaction costs and prevent regulatory conflicts that could delay project implementation (Rode et al., 2023). Moreover, the treaty should explicitly allocate liabilities, addressing who bears responsibility for potential CO_2 leakage or environmental harm a critical concern given the long-term nature of storage and monitoring. It should also establish clear dispute resolution mechanisms, potentially through arbitration or specialized tribunals, to manage disagreements swiftly and fairly.

Additionally, recognizing the dynamic nature of CCS technology and evolving international norms, the treaty should incorporate adaptive governance provisions. These could include periodic reviews, flexible amendment clauses, and provisions for incorporating scientific advances, thereby maintaining relevance and robustness over time (Boyle & Redgwell, 2021).

3.3.2. Relevant International Legal Principles

In shaping this bilateral treaty, several core international environmental law principles provide essential guidance. First, the precautionary principle requires states to adopt preventive measures in the face of scientific uncertainty, which is pertinent to CCS given risks of leakage and

unknown long-term impacts of subsurface storage (Hanson et al., 2025). This principle underpins the need for stringent site selection criteria, monitoring protocols, and emergency response plans.

Second, the polluter pays principle allocates financial responsibility to the party causing emissions or damage, reinforcing accountability and incentivizing risk reduction. Applying this principle in the CCS context ensures that emitters or operators bear remediation costs, preventing undue burdens on host states or third parties (Rajamani, 2016).

Third, the no-harm rule and due diligence obligations mandate that states prevent activities within their jurisdiction from causing significant transboundary environmental harm. This principle necessitates rigorous cooperation and information exchange, ensuring both states actively manage and mitigate CCS risks (Boyle & Redgwell, 2021).

Finally, procedural principles such as access to information, public participation, and transparency highlighted in the Aarhus Convention and echoed in the Paris Agreement—are vital for legitimacy and stakeholder trust. Including these mechanisms promotes inclusivity, accountability, and compliance in CCS governance (UNFCCC, 2015).

3.3.3. Model for Regional Legal Cooperation

The Indonesia–Singapore bilateral treaty has the potential to serve as a normative pilot for regional CCS governance in Southeast Asia, a region characterized by diverse energy portfolios and proximate geological storage options. By setting standards and demonstrating effective cooperation, this treaty can catalyze multilateral or regional frameworks, harmonizing laws and policies to facilitate broader transboundary CCS projects (Rode et al., 2023). Such regional cooperation could streamline permitting processes, unify environmental standards, and enhance capacity-building among states with varying technical and regulatory expertise.

Moreover, integrating the bilateral treaty with established international regimes, most notably the United Nations Convention on the Law of the Sea (UNCLOS) and climate change frameworks—can bolster legal coherence. Coordination with UNCLOS is especially critical for jurisdictional clarity in offshore storage within Exclusive Economic Zones (EEZs) or continental shelves, reconciling sovereign rights with environmental protection obligationsb (Hanson et al., 2025).

3.3.4. Challenges and Future Directions

Despite the clear benefits, several challenges remain in developing a robust transboundary CCS legal framework. First, reconciling differing national legal systems, institutional capacities,

and regulatory cultures requires significant negotiation and compromise. Countries may vary in their environmental standards, enforcement capabilities, and risk tolerance, complicating harmonization efforts (Boyle & Redgwell, 2021).

Second, addressing long-term liability poses a particular challenge given the extended timeframe over which stored CO_2 must be monitored and secured, potentially beyond the operational lifespan of projects or even the existence of private operators. Establishing financial mechanisms or state-backed guarantees for ongoing stewardship will be necessary (Rode et al., 2023).

Third, effective enforcement and dispute resolution mechanisms are essential to uphold treaty commitments and manage conflicts efficiently. Without these, legal uncertainty and mistrust could undermine cooperative efforts.

Future research and policy efforts should focus on clarifying these issues, developing adaptive governance models, and enhancing multilateral dialogues to build a comprehensive, durable legal regime for transboundary CCS one that balances innovation with precaution and cooperation with sovereignty (Rajamani, 2016).

4. Research Limitations

This study is primarily based on doctrinal legal research, focusing on the analysis of international treaties, soft law instruments, and national regulations relevant to Carbon Capture and Storage (CCS). As such, it does not include empirical data or fieldwork concerning the technical or operational aspects of cross-border CCS implementation between Indonesia and Singapore. The research relies on publicly available documents and academic literature, which may limit access to the most recent or confidential developments in bilateral negotiations.

Additionally, since the Indonesia–Singapore CCS agreement is still at the Letter of Intent (LoI) stage, legal interpretations remain speculative and subject to change based on the eventual content of a formal treaty. The study also does not extensively address the political economy or geopolitical dynamics that may influence treaty formation and implementation.

Lastly, while the analysis references general international legal principles and selected comparative experiences, it does not provide a full comparative legal study of other transboundary CCS agreements due to scope limitations. Future research may benefit from incorporating

stakeholder interviews, comparative regional studies, and technical assessments to offer a more comprehensive understanding of cross-border CCS governance.

5. Conclusion

The Letter of Intent (LoI) signed between Indonesia and Singapore on 15 February 2024 represents a landmark initiative in the advancement of transboundary Carbon Capture and Storage (CCS) governance in Southeast Asia. Although the LoI is not legally binding, it functions as a political commitment and a strategic foundation for future bilateral negotiations. Its emphasis on collaboration in CO_2 transport, regulatory coordination, and technical feasibility assessments indicates a proactive, phased approach toward a formalized legal framework.

This paper has shown that the eventual development of a binding bilateral treaty is not merely desirable but necessary to resolve outstanding legal uncertainties inherent in transboundary CCS operations. These include issues of jurisdiction, long-term liability, environmental risk management, and alignment with broader international legal regimes such as the United Nations Convention on the Law of the Sea (UNCLOS) and the Paris Agreement. Embedding principles of international environmental law such as the precautionary principle, the polluter pays principle, and the no-harm rule—will be crucial to ensuring the treaty's legal robustness and ecological legitimacy.

Furthermore, the Indonesia–Singapore initiative has the potential to evolve into a normative model for regional CCS governance. If successful, it could guide similar cooperative frameworks in ASEAN, promoting legal coherence and supporting global carbon mitigation efforts. In sum, a carefully negotiated, principle-based bilateral treaty offers a critical pathway for not only achieving climate targets but also reinforcing international legal development and intergovernmental trust.

Credit authorship contribution statement

Didit Wijayanto Wijaya: Supervision, Validation, Visualization. **Dyah Ersita Yustanti**: Project administration, Investigation. **Khoirunnisa Khoirunnisa**: Resources, Data curation, Formal analysis, Data analysis. **Didi Jubaidi**: Conceptualization, Methodology, Literature review, Writing – original draft.

Data Availability Statement

The data used in this study were obtained from publicly available sources such as the Open Access Library, DOAJ (Directory of Open Access Journals) and Google Scholar, as indicated in

the Data section of the article.

Funding Statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest associated with this publication. No financial, personal, or professional relationships with individuals or organizations have influenced or could potentially influence the work presented in this manuscript.

Declaration of the Use of AI

No AI technology was used in the creation or writing of this article.

Acknowledgements

The authors would like to thank all those who have provided technical support and valuable input during this research process.

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Toward a Transboundary Legal Framework:
The Indonesia–Singapore Carbon Capture and Storage Agreement

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