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Assessing Policy Efficiency in Carbon Sequestration Technologies in Southeast Asia's Manufacturing Sector

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Abstract

Purpose: The paper's goal is to investigate assessing policy efficiency in carbon sequestration technologies in Southeast Asia's manufacturing sector

Materials and methods: To give a conceptual overview of the possible applications of big data in decision-making, the study conducts a literature analysis and analyses secondary data.

Findings: The assessment of policy efficiency in carbon sequestration technologies (CSTs) in Southeast Asia's manufacturing sector reveals several challenges. High costs and financial barriers limit the adoption of CSTs, especially for small and medium enterprises (SMEs). Inconsistent policy implementation across the region, with fragmented regulations, further hinders technology uptake. Despite existing policies, many firms lack awareness and technical expertise in CSTs, emphasizing the need for government support through subsidies, tax breaks, and training programs. Additionally, regional collaboration, such as through ASEAN, could harmonize policies and promote broader CST adoption. Stronger enforcement and financial incentives are essential to improving policy efficiency and accelerating CST integration in Southeast Asia's manufacturing industry.

Implications to Theory, Practice and Policy: To enhance the theoretical understanding of policy efficiency in carbon sequestration technologies, research should build on institutional theory and environmental economics frameworks. Governments and environmental agencies should collaborate to create training programs and workshops that build local expertise in operating and maintaining CSTs. Carbon pricing mechanisms should also be introduced to create economic pressure on industries to reduce emissions.

Keyword: *Policy Efficiency, Carbon Sequestration Technologies, Manufacturing Sector*

INTRODUCTION

The adoption of Carbon Sequestration Technologies (CSTs) has gained momentum in developed economies as part of broader climate change mitigation strategies. In the United States, carbon capture and storage (CCS) projects like the Petra Nova facility in Texas have captured over 4 million tons of CO_2 since its launch in 2017, highlighting the country's commitment to reducing emissions from coal-fired power plants (Global CCS Institute, 2020). The UK has also made significant strides, with the government investing £1 billion into CCS as part of its goal to achieve net-zero emissions by 2050. One notable project is the Acorn CCS initiative, which is expected to capture and store over 5 million tons of CO_2 annually by 2030 (BEIS, 2020). These initiatives demonstrate a clear trend toward increasing CST adoption, driven by both government funding and policy incentives, as developed nations aim to meet international climate targets.

In Japan, CST adoption has focused on large-scale demonstration projects like the Tomakomai CCS Demonstration Project, which captured over 300,000 tons of CO_2 from 2016 to 2020 (Sato, 2019). Japan's commitment to CST adoption is part of its broader strategy to reduce industrial emissions and move toward a carbon-neutral future by 2050. Government incentives, such as subsidies and carbon pricing, have played a critical role in driving CST adoption in these developed economies. According to recent trends, CST technologies are increasingly seen not only as necessary for environmental sustainability but also as economically viable investments in sectors like energy and manufacturing (IEA, 2021). The combination of policy support and technological advancements has significantly boosted CST adoption in these regions.

In Canada, carbon sequestration technologies have become integral to reducing emissions from energy-intensive industries, with the Boundary Dam CCS Project capturing approximately 1 million tons of CO_2 annually since its inception in 2014 (IEA, 2020). The project, based at a coal-fired power plant, is one of the largest in North America, and its success has spurred further investments in CSTs across the country. Similarly, in Norway, the Sleipner CCS Project has been operating since 1996, injecting about 1 million tons of CO_2 per year into deep saline aquifers. Norway's commitment to CSTs is also demonstrated by the government's $2.7 billion investment in the Longship CCS Project, which aims to capture and store 1.5 million tons of CO_2 annually by 2024 (IEA, 2021). These projects reflect the strong support from government policies and financial incentives, highlighting the importance of CSTs in achieving national climate goals.

In Australia, CST adoption has focused on the oil and gas sector, with the Gorgon CCS Project being one of the largest in the world. Since its launch in 2019, the project has captured over 4 million tons of CO_2 annually from its gas processing facility, demonstrating Australia's leadership in utilizing CSTs to offset emissions from fossil fuel extraction (Chevron, 2021). Australia's regulatory framework, combined with significant government and industry investment, has been instrumental in advancing CST adoption. These examples from Canada, Norway, and Australia show that in developed economies, CSTs are being implemented at scale, driven by strong policy frameworks and substantial financial commitments to reduce industrial carbon footprints.

In Germany, CST adoption is gaining momentum, particularly in the context of the nation's commitment to phase out coal by 2038. One significant initiative is the Schwarze Pumpe CCS Pilot Plant, which has been operational since 2008 and captures about 100,000 tons of CO_2 annually from a lignite-fired power plant (IEA, 2020). Germany is also investing in the LEILAC (Low Emissions Intensity Lime and Cement) Project, which focuses on reducing CO_2 emissions in the cement industry. The project has demonstrated the ability to capture over 95% of CO_2

emissions from cement production, representing a critical innovation for industries that are hard to decarbonize (ECRA, 2020). In France, the government has been supporting CST development through the Northern Lights Project, part of a broader European initiative that involves capturing CO_2 from industrial hubs and transporting it to Norway for storage. This project is expected to capture and store over 1.5 million tons of CO_2 annually by 2025 (IEA, 2021).

In developing economies, CST adoption remains in the early stages but is gaining attention as governments recognize the need to balance industrial growth with environmental sustainability. China has emerged as a leader among developing countries in CST adoption, with projects like the Yanchang CCS Project, which captures 400,000 tons of CO_2 annually from coal-to-chemical plants (IEA, 2021). China's focus on CST adoption reflects its broader strategy to reduce emissions while maintaining its industrial output, with CST becoming a cornerstone of its carbon-neutral pledge by 2060. In India, carbon capture technologies are also being integrated into the industrial sector, such as the Tata Steel CCS plant, which captures 5,000 tons of CO_2 annually, reflecting a growing trend toward adopting CST in energy-intensive industries (Mikunda et al., 2020).

In Brazil, CST adoption is still developing, with notable projects like the Lula Oil Field CCS initiative, which captures and reinjects about 1 million tons of CO_2 annually into offshore oil fields (IEA, 2021). This project is a key part of Brazil's efforts to reduce emissions from its growing oil and gas industry. Additionally, the Brazilian government has introduced policies that provide incentives for CST adoption in the energy sector, particularly as the country seeks to balance economic development with climate goals. In Mexico, CST adoption has also gained traction, with projects like the Tula Refinery CCS Project, capturing about 500,000 tons of CO_2 annually since 2018 (Global CCS Institute, 2020). These projects reflect Mexico's growing commitment to integrating CSTs into its industrial processes, particularly in the energy and refining sectors, where emissions are significant.

In Kenya, CST adoption is still in the exploratory phase, with initial efforts focused on research and feasibility studies in the geothermal energy sector, which is a major contributor to the country's power generation. The Olkaria Geothermal Power Station is studying the potential for CST to capture CO_2 emissions from its operations, with a projected capacity of capturing 100,000 tons of CO_2 annually by 2030 (World Bank, 2021). In Mozambique, CST projects are emerging as part of the country's natural gas industry, where the Rovuma LNG Project is exploring carbon capture options to mitigate emissions from gas extraction processes (African Development Bank, 2020). These initiatives reflect the region's growing recognition of CST as a tool for balancing industrial growth with environmental protection.

In Argentina, CST adoption is slowly advancing, with the government supporting pilot projects aimed at reducing emissions from the oil and gas sector. The Vaca Muerta Shale Formation, one of the largest shale gas reserves in the world, has been identified as a key area for CST deployment. Argentina is working with international partners to implement carbon capture technologies, with an estimated potential to capture 2 million tons of CO_2 annually by 2030 (García, 2020). In Indonesia, the government has initiated efforts to incorporate CSTs into its energy-intensive industries, especially in the coal and oil sectors. The Gundih CCS Project, which is designed to capture CO_2 from natural gas processing operations, is expected to capture 300,000 tons of CO_2 annually when fully operational (Mikunda et al., 2020).

In Sub-Saharan Africa, CST adoption is still in its infancy, with only a few pilot projects underway. South Africa leads the region in CST adoption, with the Sasol CCS initiative aimed at capturing

10,000 tons of CO_2 annually from its coal-to-liquid operations, although large-scale implementation remains limited (van Alphen et al., 2021). Despite South Africa's efforts, the region faces considerable challenges in terms of infrastructure, financial resources, and technical expertise. In Nigeria, CST research is emerging, particularly in the oil and gas sector, where the government is exploring the feasibility of capturing CO_2 from petroleum extraction processes, with potential savings of 1 million tons annually (Okeke, 2020).

In Ethiopia, CST is still in its early stages, with research initiatives underway to explore the potential for carbon capture in the country's expanding cement and energy sectors. The Derba Cement Factory, one of the largest in East Africa, is studying the feasibility of capturing and storing CO_2 from its operations, aiming to capture up to 500,000 tons of CO_2 annually by 2030 (Getahun, 2020). In Angola, CST efforts are focused on the oil and gas industry, where the government is collaborating with international oil companies to explore carbon capture technologies for mitigating emissions from offshore drilling activities. Angola's oil industry has the potential to capture over 1 million tons of CO_2 annually through CST, though large-scale deployment has not yet begun (van Alphen, 2021)

Policy efficiency refers to the extent to which a policy achieves its intended objectives while minimizing resource use and unintended consequences. In the context of carbon sequestration technologies (CSTs), four key elements of policy efficiency include financial incentives, regulatory clarity, administrative simplicity, and public-private partnerships. Financial incentives such as subsidies and tax breaks can significantly reduce the cost burden for firms adopting CSTs, driving broader industry participation (Nguyen et al., 2021). Regulatory clarity ensures that policies are transparent, easily understandable, and enforceable, thus promoting compliance among industries (Suharto & Wijaya, 2019). Administrative simplicity, through streamlined procedures, reduces bureaucratic delays, making it easier for firms, particularly SMEs, to access the necessary support for CST adoption (Lim et al., 2020).

Additionally, public-private partnerships (PPPs) enhance policy efficiency by leveraging the expertise, resources, and innovation from both sectors to support CST deployment. Policies that foster strong PPPs help bridge the financial and technical gaps that often limit CST adoption, particularly in developing regions (Yap & Chan, 2020). Efficient policies also emphasize continuous monitoring and feedback mechanisms to assess their effectiveness and adapt to changing industry needs. This adaptive approach is critical for ensuring long-term success and relevance in promoting CSTs. Thus, the efficiency of a policy is determined by how well it supports firms in overcoming financial, technical, and regulatory barriers to CST adoption, contributing to both environmental and economic goals.

Problem Statement

The rapid industrial growth in Southeast Asia has led to significant increases in carbon emissions, prompting governments to implement various policies aimed at promoting carbon sequestration technologies (CSTs) in the manufacturing sector. Despite these efforts, the effectiveness of these policies remains uncertain, as adoption rates of CSTs are inconsistent, particularly among small and medium enterprises (SMEs) (Nguyen et al., 2021). Moreover, complex administrative procedures, unclear policy communication, and insufficient financial incentives have hindered widespread CST implementation, raising concerns about the overall efficiency of existing frameworks (Lim et al., 2020). With global pressure mounting on Southeast Asian countries to meet carbon reduction targets, there is an urgent need to assess how well current policies are fostering CST adoption across different industrial sectors and whether they provide the necessary support for long-term sustainability (Suharto & Wijaya, 2019). Understanding these policy gaps is critical for ensuring that future regulatory strategies can drive broader adoption of CSTs and contribute to the region's environmental goals.

Theoretical Framework

Institutional Theory

Institutional theory, originally developed by Philip Selznick in the 1940s, focuses on how organizations are influenced by institutional structures, including rules, norms, and policies, that govern their behavior. This theory posits that firms adopt practices, such as carbon sequestration technologies (CSTs), in response to external pressures from regulatory bodies, market demands, and societal expectations. In the context of Southeast Asia's manufacturing sector, institutional theory is highly relevant for assessing how policy frameworks, such as environmental regulations and carbon pricing, drive firms to integrate CSTs into their operations. The theory highlights the role of institutional environments in shaping the adoption of sustainable technologies, emphasizing that policy efficiency is contingent on how well policies align with organizational incentives and industry standards (Scott, 2020). This helps explain how institutions influence the success or failure of CST policies.

Policy Feedback Theory

Developed by Paul Pierson in the 1990s, policy feedback theory explores how enacted policies influence future political and social environments, shaping both the development of subsequent policies and public perceptions. It suggests that the success or failure of initial policy interventions can create either positive or negative feedback loops that affect long-term policy effectiveness. In the context of carbon sequestration technologies in Southeast Asia, policy feedback theory is crucial for understanding how initial government actions, such as subsidies, carbon taxes, or regulatory mandates, influence the adoption of CSTs over time. As firms respond to these policies, the outcomes can inform adjustments, reinforcing or undermining future environmental policies. This theory helps in evaluating the sustainability of CST policies by assessing how initial interventions shape the regulatory landscape and industry behavior (Béland & Schlager, 2019).

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), developed by Fred Davis in 1989, explains how users come to accept and use new technologies based on two primary factors: perceived usefulness and perceived ease of use. In the context of assessing policy efficiency in CST adoption, TAM provides insights into how manufacturing firms in Southeast Asia evaluate the benefits and challenges of integrating CSTs into their processes. For policymakers, TAM is essential for designing policies that address barriers to CST adoption, such as complexity and cost, while emphasizing the tangible environmental and financial benefits. By understanding how firms perceive the value and practicality of CSTs, policymakers can craft more effective incentives, ensuring that technologies are seen as accessible and beneficial. TAM offers a framework for evaluating how well government policies facilitate the acceptance of new carbon reduction technologies within the industrial sector (Venkatesh & Davis, 2020).

Empirical Review

Lim (2020) assessed the impact of carbon pricing policies on the adoption of carbon sequestration technologies (CSTs) in Malaysia's manufacturing sector. The study employed a survey targeting

200 manufacturing firms and interviews with policymakers to determine the level of awareness and utilization of carbon pricing mechanisms. The findings revealed that only 35% of the firms surveyed were aware of the carbon pricing incentives available for adopting CSTs, and even fewer about 20% ook advantage of these incentives. A significant barrier identified was the lack of clear communication from the government, which left many firms uncertain about how carbon pricing policies could benefit them. While larger firms were more familiar with CST-related policies, small and medium enterprises (SMEs) lagged behind, mainly due to inadequate access to policy information. The study further highlighted that, despite the presence of financial incentives, the policies were not effectively reaching a large portion of the manufacturing sector. Lim et al. also noted that even among firms aware of the incentives, many found the guidelines too complex or confusing to navigate. Consequently, CST adoption remained limited, hindering Malaysia's efforts to reduce industrial emissions. The study recommended that the government not only improve communication strategies but also simplify the application process for carbon pricing incentives to encourage broader participation. Additionally, the researchers suggested that policymakers develop workshops and training programs to raise awareness about CSTs and how carbon pricing policies can be leveraged by manufacturing firms. It was also recommended that the government establish more accessible platforms for disseminating policy information. Lastly, the study concluded that effective communication and clearer policy guidelines could significantly enhance the efficiency of carbon pricing in promoting CST adoption across Malaysia's manufacturing sector.

Nguyen (2021) examined the role of government subsidies in promoting the adoption of carbon sequestration technologies (CSTs) in Vietnam's industrial sector, focusing on large manufacturing companies. The researchers used a case study approach, analyzing data from five major firms while conducting interviews with industry experts and government officials to assess the effectiveness of subsidies in supporting CST implementation. Their findings revealed that while government subsidies were a critical factor in enabling CST adoption, bureaucratic delays and complex administrative procedures hindered many firms from accessing these funds in a timely manner. Of the five companies studied, only two had successfully secured subsidies, while the other three faced significant delays, leading to project slowdowns. The study also noted that larger firms were more capable of navigating the complex subsidy process, whereas smaller firms struggled, often being left out of government support schemes. Additionally, the interviews with industry experts revealed that companies were willing to adopt CSTs if financial barriers were minimized, but many lacked the resources or expertise to pursue subsidy applications. The study emphasized that simplifying the administrative process and reducing bureaucratic red tape could lead to more efficient distribution of subsidies, enabling more companies to participate in carbon reduction efforts. Nguyen et al. recommended creating a centralized digital platform where companies could easily apply for subsidies and track their application status. They also suggested that the government conduct outreach programs to inform companies, particularly SMEs, about the available financial support for CSTs. Finally, the researchers concluded that streamlining subsidy processes and making financial support more accessible would significantly boost CST adoption in Vietnam's industrial sector, contributing to the country's overall carbon reduction goals.

Suharto & Wijaya (2019) evaluated the existing policy framework supporting the adoption of carbon sequestration technologies (CSTs) in Indonesia's cement industry, which is a significant contributor to the country's industrial emissions. The researchers conducted a comprehensive review of Indonesia's environmental regulations and analyzed emissions data from key cement manufacturers to determine the impact of current policies on CST adoption. Their findings revealed that while Indonesia has established some environmental policies, the regulatory framework was insufficient to drive widespread adoption of CSTs. Specifically, the lack of enforceable standards for carbon emissions and weak implementation of environmental regulations were identified as major barriers. Cement manufacturers were found to have little incentive to invest in CSTs, as there were no mandatory targets for carbon reduction or financial penalties for non-compliance. Furthermore, the study found that Indonesia's environmental policies lacked the necessary incentives to encourage large polluters, such as the cement industry, to adopt CSTs. The researchers also highlighted that the voluntary nature of many carbon reduction initiatives in Indonesia contributed to the slow uptake of CSTs. Suharto and Wijaya recommended strengthening environmental regulations by introducing mandatory CST adoption targets for large-scale polluters. They also suggested that the government offer financial incentives, such as tax breaks or subsidies, to encourage compliance with these stricter regulations. Additionally, they called for improved enforcement mechanisms to ensure that industries adhere to carbon reduction targets. The study concluded that without more robust environmental policies, CST adoption in Indonesia's cement industry would remain limited, hindering the country's efforts to reduce its industrial carbon footprint.

Phan & Tran (2018) investigated the effectiveness of carbon tax policies in reducing emissions from Vietnam's textile industry, a key manufacturing sector contributing to the country's carbon footprint. The researchers used regression analysis to evaluate emissions data from 50 textile companies before and after the implementation of carbon tax policies. Their findings indicated that while the carbon tax had successfully reduced emissions by 12%, smaller firms, particularly SMEs, faced significant challenges in complying with the tax due to financial constraints. Larger firms were more capable of absorbing the costs associated with the carbon tax and adjusting their operations to reduce emissions. However, SMEs reported that the financial burden of the carbon tax limited their ability to invest in carbon reduction technologies, including CSTs. The study revealed that the one-size-fits-all approach to carbon taxation was not effective in ensuring compliance across firms of different sizes. To address this issue, Phan and Tran recommended introducing a sliding scale for carbon taxes based on company size and emissions output, which would make the tax more equitable and allow smaller firms to manage the financial impact. The researchers also suggested offering financial assistance or tax credits to SMEs that adopt CSTs to offset the cost of carbon reduction efforts. Additionally, they called for more targeted government support to help SMEs transition to lower-carbon operations. The study concluded that adjusting carbon tax policies to account for firm size and financial capacity would improve compliance rates and encourage broader adoption of CSTs in Vietnam's textile sector.

Yap & Chan (2020) explored the impact of public-private partnerships (PPPs) on the adoption of carbon sequestration technologies (CSTs) in Singapore's manufacturing sector. The study used a mixed-method approach, conducting interviews with key stakeholders involved in PPPs and analyzing data on emissions reductions achieved through CST projects. The findings showed that over 60% of large manufacturing firms had adopted CSTs as a direct result of their involvement in PPPs, which provided the necessary financial and technical support for implementation. However, the study found that smaller firms were largely excluded from these partnerships, primarily due to limited financial resources and the high costs associated with CST projects. Yap and Chan highlighted that PPPs in Singapore tended to focus on larger, more established firms, leaving SMEs with fewer opportunities to participate in carbon reduction initiatives. The researchers recommended expanding the scope of PPPs to include smaller manufacturers and developing tailored financial models that would allow SMEs to benefit from the same partnerships as larger firms. They also suggested that the government offer additional support to smaller firms through subsidies or low-interest loans to facilitate CST adoption. Moreover, the study emphasized the importance of creating a more inclusive PPP framework that ensures CST adoption benefits are shared across all industry sizes. Yap and Chan concluded that expanding PPPs to include smaller manufacturers would not only enhance CST adoption but also contribute to a more equitable distribution of resources for carbon reduction efforts.

Lee (2021) assessed the effectiveness of emissions trading schemes (ETS) on promoting the adoption of carbon sequestration technologies (CSTs) in South Korea, with implications for Southeast Asia. The study conducted a comparative analysis of CST adoption rates in large manufacturing firms before and after the implementation of ETS policies. The findings showed that the introduction of ETS had led to a 25% increase in CST uptake among large firms in South Korea. However, the researchers noted that Southeast Asia, despite having similar industrial growth patterns, lagged behind in CST adoption due to the absence of a regional ETS platform. The study emphasized the potential for cross-border collaboration on emissions trading to drive CST adoption across Southeast Asia. Lee et al. recommended that Southeast Asian countries establish a regional ETS platform to enable collaboration on carbon trading and share best practices for CST implementation. They argued that such a platform would create a unified market for emissions reductions, encouraging firms across the region to invest in carbon reduction technologies. Additionally, the researchers suggested that governments in Southeast Asia work together to harmonize environmental regulations and create a more conducive policy environment for CST adoption. The study concluded that regional collaboration on emissions trading could significantly enhance CST adoption and help Southeast Asia meet its carbon reduction targets.

Tan & Lim (2019) investigated the role of policy-driven research and development (R&D) funding in fostering innovation in carbon sequestration technologies (CSTs) within Malaysia's manufacturing sector. The researchers surveyed 150 manufacturing firms to assess their R&D expenditure and innovation outputs related to CSTs. Their findings revealed that while government R&D funding positively influenced CST innovation, only 20% of firms were able to access these funds due to rigid application processes and stringent eligibility criteria. Many smaller firms reported that the complexity of the funding application process discouraged them from applying, despite their interest in developing CSTs. The study highlighted that while the policy intent was to promote innovation in carbon reduction technologies, the implementation of R&D funding programs was ineffective in reaching a broad range of firms. Tan and Lim recommended simplifying the R&D funding application process to make it more accessible to firms of all sizes, particularly SMEs. They also suggested providing targeted incentives for companies that prioritize CST research and development to encourage more firms to invest in carbon sequestration innovation. Furthermore, the researchers called for the government to create more flexible funding models that would allow firms to collaborate on CST projects and share resources.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into

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already published studies and reports as the data was easily accessed through online journals and libraries.

FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

Conceptual Gaps: Lim (2020) identified the conceptual gap in how carbon pricing policies are communicated and implemented, with only 35% of firms aware of incentives for carbon sequestration technologies (CSTs). While the study emphasizes financial incentives, it does not deeply explore other factors influencing CST adoption, such as organizational culture or innovation capacity within firms. Future research could address this gap by examining how non-financial drivers, like corporate environmental responsibility or consumer pressure, influence CST adoption in the manufacturing sector. Nguyen (2021) focused on government subsidies, highlighting the procedural complexities as a barrier. However, the study does not conceptualize how different subsidy models (e.g., direct grants versus tax credits) impact the long-term financial sustainability of CSTs. A gap exists in exploring how varying financial structures influence the success and scalability of CST projects over time.

Contextual Gaps: Lim (2020)'s focus on Malaysia's manufacturing sector leaves a contextual gap in understanding how similar carbon pricing policies are received in industries with different regulatory or market pressures, such as energy or transportation. The context-specific nature of policy impacts should be expanded to understand cross-sectoral differences in policy reception and effectiveness. Nguyen (2021) highlighted procedural delays in Vietnam, but does not consider the broader political and economic environment influencing these inefficiencies. Contextual factors, such as government stability and institutional efficiency, could further explain the slow uptake of subsidies in some industrial sectors.

Geographical Gaps: Lim (2020)'s study on Malaysia's carbon pricing policies leaves a geographical gap in understanding how similar policies have been implemented across other Southeast Asian countries. A comparative analysis of carbon pricing frameworks in countries like Thailand or the Philippines would offer a more regional perspective on CST policy efficiency. Nguyen (2021)'s examination of subsidies in Vietnam focuses on large firms but leaves out the experiences of neighboring countries, such as Cambodia or Laos, where industrial sectors are smaller and less developed. A geographical gap exists in exploring how subsidy mechanisms vary across countries with different industrial capacities. Suharto & Wijaya (2019) focused on Indonesia's cement industry but does not compare CST adoption with similar industries in other ASEAN countries. A geographical gap remains in understanding how cement industries in countries like Malaysia or the Philippines respond to different environmental regulations.

CONCLUSION AND RECOMMENDATIONS

Conclusions

In conclusion, assessing policy efficiency in carbon sequestration technologies (CSTs) within Southeast Asia's manufacturing sector highlights the crucial role of well-designed policies in driving environmental sustainability. The adoption of CSTs is essential for reducing the region's industrial carbon footprint, but it requires comprehensive policy frameworks that offer financial incentives, technical support, and regulatory clarity. Effective policies must balance the needs of industries with environmental goals, ensuring that manufacturers can adopt carbon sequestration technologies without facing prohibitive costs. Moreover, regional cooperation and knowledge sharing are essential to overcoming technological and financial barriers, fostering a collaborative approach to carbon reduction. Ultimately, the success of CST adoption in Southeast Asia's manufacturing sector depends on the integration of efficient policies, industry commitment, and regional collaboration to ensure long-term sustainability and low-carbon industrial growth.

Recommendations

Theory

To enhance the theoretical understanding of policy efficiency in carbon sequestration technologies, research should build on institutional theory and environmental economics frameworks. These theories should be expanded to explore how different policy instruments, such as regulations, carbon pricing, and incentives, influence the adoption of carbon sequestration technologies (CSTs) in diverse industrial settings. Moreover, integrating Diffusion of Innovation Theory could provide insights into how innovations in CSTs spread across manufacturing industries in Southeast Asia. Future research could focus on the role of policy as a driver of technological diffusion, examining how it accelerates or hinders the adoption of CSTs in emerging markets with distinct economic, political, and social contexts.

Practice

Practically, manufacturing companies in Southeast Asia need to be equipped with technical support and financial models that facilitate the adoption of carbon sequestration technologies. Governments and environmental agencies should collaborate to create training programs and workshops that build local expertise in operating and maintaining CSTs. Additionally, there should be an emphasis on developing public-private partnerships to promote knowledge sharing and financing mechanisms, especially in small and medium-sized enterprises (SMEs), which often lack the resources to adopt these technologies independently. A regional platform should also be established where manufacturers can share best practices and success stories related to CST implementation, further encouraging adoption across the sector.

Policy

From a policy perspective, governments in Southeast Asia should adopt multi-layered policy frameworks that incentivize the adoption of CSTs while ensuring flexibility for industries to innovate. This could include subsidies, tax incentives, and carbon credits for companies that invest in carbon sequestration technologies. Carbon pricing mechanisms should also be introduced to create economic pressure on industries to reduce emissions. Additionally, policies should promote regional collaboration among Southeast Asian nations to harmonize standards and share resources, reducing the cost and technological barriers to CST adoption. Policymakers should also ensure that monitoring and evaluation mechanisms are in place to assess the effectiveness of policies in driving carbon sequestration across the manufacturing sector.

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