Developing Robust Carbon Capture and Storage Laws in Malaysia Insights from Australia and the United States of America

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ABSTRACT

Malaysia's per capita carbon emissions were among the highest, necessitating serious measures by implementing strong environmental policies. This article critically analysed various factors affecting Malaysia's efforts to combat climate change, emphasising the role of Carbon Capture and Storage. Drawing from established frameworks in Australia and the United States, it explored necessary changes to enhance Malaysia's Carbon Capture and Storage legal framework. The study examined the country's Carbon Capture and Storage policy against international standards, identifying financial, technological, and regulatory barriers. It also highlighted the lack of economic incentives, government support, and a comprehensive regulatory framework for Carbon Capture and Storage infrastructure. Special attention was given to transboundary CO_2 transportation and storage, considering Malaysia's legal obligations under international agreements like the London Protocol. The research synthesised insights and provided key recommendations for enhancing Malaysia's Carbon Capture and Storage legal framework to promote sustainability and long-term carbon emission reduction.

Keywords: Carbon Capture and Storage; Legal Framework; Malaysia; Climate Change Policy; Transboundary CO_2 Transportation

INTRODUCTION

CO_2 emissions in Malaysia are on the rise. In 2022, the country emitted 291 million tonnes of CO_2, an increase from the 278.86 million tonnes emitted in 2021. Several factors contribute to this growth, including economic expansion, high fossil fuel consumption in the transportation sector, and growth in the energy sector (Solaymani, 2022). In response, Malaysia is trying to implement renewable energy as an alternative to CO_2 restraint to realise a goal of being a Low Carbon Nation by 2040 (Ministry of Economy of Malaysia, 2023).

One of the few successful methods is carbon capture and storage (CCS), which uses technology to trap CO_2 emissions. Traditional methods collect emissions after entering the atmosphere, whereas CCS technology captures emissions before entering the atmosphere (Rempel et al., 2023). In the policymaking framework, CCS is an intermediate technology for continued fossil fuel power generation and industrial applications until alternatives are available to fill the gap (Bandilla, 2020). Three steps are required: capturing the CO_2 from power generation or industrial processes, transporting it after capture to suitable geological storage sites, and storing it safely in those underground reservoirs (IEA, 2024). It is then compressed for transportation and transferred to pipelines, trucks, or ships to be taken away to storage sites, where they are injected deep into the ground (the similar way we dispose of our waste underground) for long-term containment (IPCC, 2006; IEAGHG, 2011).

From a philosophical viewpoint, exploring fairness, responsibility, and capacity is necessary to probe how CCS technologies may fit into the global context. In common, developed nations have used too big a share of the planet's carbon absorption capability and are thus responsible for their overuse of atmospheric CO_2. With

roots in John Locke's theory of property (Locke, 1988), Singer (1950) states that third-world nations have been adversely impacted. He opposes holding historically marginalised nations accountable for their emissions, asserting that the effects of emissions were not well understood before the 1990 Intergovernmental Panel on Climate Change (IPCC) assessment. Therefore, ensuring equal per capita emissions would help achieve global consensus. Similarly, Dale Jamieson argues that emissions before 1990 were inadvertent and should not be morally equated with those after 1990 (Santos, 2017).

According to the Global CCS Institute (2023), 392 active CCS projects are worldwide, with 41 operational facilities and 351 in development. The U.S. leads in CCS deployment, pioneering the technology in 1972 with the Terrell Natural Gas Processing Plant. Currently, the U.S. operates 15 facilities capturing 0.4% of its CO_2 emissions, with 121 more projects in development. These projects could boost capacity to 3% of annual emissions if completed. The Inflation Reduction Act of 2022 has been a game-changer for technology, further supporting its growth (Congressional Budget Office of the United States of America, 2023).

Australia has been at the forefront of developing CCS facilities, benefiting from its vast land, suitable geological formations, preexisting infrastructure, and cost-effective renewable energy. Australia's CCS programs are expected to store 20 million tonnes of CO_2 by 2035 (Walker & Dawkins, 2023). Legal frameworks for CCS were established through legislation in the late 2000s, such as the 2008 Offshore Petroleum Amendments (Greenhouse Gas Storage) Act, which improved offshore processes for absorbing, transporting, and storing greenhouse gases. This act recognised the safe, permanent CO_2 sequestration potential of offshore formations. State laws like Victoria's 2008 Greenhouse Gas Geological Sequestration Act and Queensland's 2009 Greenhouse Gas Storage Act created regulatory frameworks for responsible onshore CCS development.

Like other countries, Malaysia is exploring carbon capture, utilisation, and storage (CCUS) to transition from fossil fuels to more sustainable energy. CCUS, closely related to CCS, goes beyond just storing captured CO_2, exploring ways to reuse it in industries and potentially creating valuable byproducts (International Energy Agency, 2024). However, due to limited resources, utilising captured CO_2 for other purposes may take time. Stakeholders like Petroleum Nasional Berhad (PETRONAS) are prioritising CCS for the near future, with plans to implement CCS technologies in high CO_2 emission fields by 2050 (Khalid, 2021). Several challenges hinder Malaysia’s CCS deployment, including the absence of a comprehensive legislative framework, uncertainty regarding regulations, and a lack of financial incentives or government support. CCS projects are less profitable without subsidies or direct investment, slowing their progress. This article highlights the need for clear CCS regulations in Malaysia, drawing comparisons to countries like the US and Australia, where well-defined legislation has strengthened CCS frameworks. Studying these nations could help Malaysia develop effective CCS laws. Malaysia’s high per-person carbon footprint of 8.6 tonnes in 2022, compared to the global average of 4.7 tonnes, calls for urgent environmental action. To address this, Malaysia aims to become a low-carbon nation through its National Energy Policy 2022-2040 and Low Carbon Nation Aspiration 2040, focusing on cleaner energy sources and climate resilience. The country is exploring CCS technology to reduce emissions from primary sources. This article compares Malaysia's need for a strong legal framework for CCS projects to the US and Australia's.

LITERATURE REVIEW

Malaysia's Current Approach to Carbon Capture and Storage

The energy sector is vital to Malaysia's socioeconomic advancement. The sector must be safeguarded against domestic and global trends to sustain its prosperity. This guarantees the enduring viability and competitiveness of Malaysia's energy sector. A primary objective is to conform to Sustainable Development Goal 7, which advocates universal access to affordable, reliable, sustainable, and modern energy. The energy sector must be strategically aligned to fulfil the objectives of the Twelfth Malaysia Plan (Prime Minister’s Office of Malaysia, 2022). The Twelfth Malaysia Plan 2021–2025 (TWP) modifies Malaysia's current development trajectory. The Twelfth Plan recognises previous achievements while advancing beyond mere incremental improvement. It signifies a new epoch of transformative reforms, propelled by Keluarga Malaysia's objective of unity and prosperity (Prime Minister's Department, 2022). The Twelfth Plan is founded on three principal characteristics.

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Initially, Malaysia's economy needed a recalibration to improve its position. The second priority is to enhance security, well-being, and inclusion to ensure that all Malaysians benefit from advancement. The last element advocates for sustainability for future generations. A significant component of the TWP is sustainable development. This necessitates a coordinated national strategy involving government entities, corporations, and citizens collaborating harmoniously. This comprehensive policy will accelerate Malaysia's transition to a low-carbon economy. It would highlight safeguarding the nation's natural resources and enhancing resilience against climate change and disasters (Prime Minister's Office of Malaysia, 2021).

The National Energy Policy 2022-2040 (NEP) (2022) guides the transition from high-carbon fossil fuels to cleaner renewable energy. This shift is expected to accelerate with advancements in technology and climate legislation. Governments, businesses, and investors are collaborating to promote environmental sustainability. The NEP envisions Malaysia's energy landscape providing affordable, reliable energy for all, leading in environmental sustainability and the ASEAN green economy while efficiently utilising energy and natural resources.

The government published the National Energy Transition Roadmap (NETR) derived from the NEP. This extensive strategy transitions Malaysia's energy systems from fossil fuels to more sustainable alternatives. It mitigates climate change, enhances energy security, and guarantees the long-term sustainability of electricity generation, transportation, industries, and residences. The NETR aims to attain net zero emissions by 2050. It aims to elevate renewable energy to 31% by 2025, 40% by 2035, and 70% by 2050. Six mechanisms, comprising energy efficiency, renewable energy, hydrogen, bioenergy, green transportation, and carbon capture, will facilitate the attainment of this clean energy transition. All levers will be employed in ten principal projects (Ministry of Economy of Malaysia, 2023).

The NETR prominently incorporates Carbon Capture, Utilisation and Storage (CCUS) technology. Malaysia has set ambitious goals, intending to establish three CCUS hubs with a cumulative storage capacity of 15 million tonnes by 2030. These hubs will be strategically positioned, with two on the Peninsula and one in Sarawak. Among the NETR's flagship initiatives are Malaysia's notable CCUS projects, Kasawari and Lang Lebah (PETRONAS, 2023a; PETRONAS, 2023b; PETRONAS, 2024; Reuters, 2024; Upstream Online, 2024). The country's existing infrastructure positions it as an exemplary candidate for CCUS centres, primarily because depleted gas fields featuring injection wells and platforms serve as optimal storage sites. Malaysia's distinctive geographical location within the Asia-Pacific region enables it to effectively store captured carbon from significant emitters like Australia and Japan. However, being recognised as a "gateway" could yield additional economic advantages (The Star, 2024).

Malaysia has emerged as a significant leader in CCS technology within Southeast Asia. In late 2021, PETRONAS and Xodus unveiled the ambitious Kasawari CCS project (Xodus, 2021). This initiative, located off the coast of Sarawak, aims to capture carbon dioxide emissions from a sour gas field and inject them into a depleted gas reservoir for long-term storage (Sivanantham & Vei, 2022). Operations for Kasawari are projected to commence by the end of 2025. Its primary objective is to substantially reduce CO_2 emissions by capturing an estimated 3.7 million metric tonnes (MTPA) annually. Thus, Kasawari is poised to become one of the most significant CCS projects globally (Khalid, 2021). In addition, it is actively working with other leading companies in the industry further to reduce the development of CCS in the region. These Memorandums of Understanding with ExxonMobil and POSCO highlight a common interest in investigating opportunities for proven technologies within Southeast Asia, notably in Malaysia (WMW, 2021). Still, the viability of these actions hinges on continued cooperation and development in CCS technology, as the hurdles associated with it are still relatively high. Establishing a Storage Site Agreement (SSA) between Petroleum Sarawak Berhad (PETROS), the CCS subsidiary of PETRONAS, and a Japanese consortium comprising JAPEX, JGC, and Kawasaki Kisen Kaisha (KLINE) represents a significant change in Malaysia's CCS industry (PETRONAS, 2024). It will target the offshore Sarawak M3 depleted gas field in a collaborative effort. The agreement will enable important feasibility studies carefully examining the underground storage and around this location for CO_2. The studies will include technical and economic feasibility assessments and planning for the infrastructure to store CO_2, such as pipelines and onshore terminals.

This collaboration can significantly impact the substantial abatement of greenhouse gas emissions in Malaysia, Asia Pacific, and beyond. Nevertheless, this is still a significant development and could become the standard for large-scale carbon capture in the region (PETRONAS, 2024). Although challenges remain, the potential benefits cannot be overstated because they may contribute significantly to global efforts in combating climate change. Implementing CCS in Malaysia remains fraught with difficulties, even though initial commitments suggested a smoother path forward. Currently, carbon capture, utilisation and storage are not subject to regulatory oversight within the country. The Malaysian Ministry of Environment and Natural Resources is working with the Global CCS Institute to rectify this deficiency. This partnership aims to educate Malaysian stakeholders on the effective use of CCUS.

However, a standalone CCUS bill, introduced by the Ministry of Economy under the leadership of Rafizi Ramli, has the potential to signify a pivotal shift in this landscape. This legislation is anticipated to receive Cabinet approval by the end of 2024. The proposed law aspires to attract investment, manage associated risks and promote bilateral agreements by creating a well-defined legislative framework for CCS projects. The overarching aim is to position Malaysia as a regional hub for CCS. Notably, the bill encompasses the entire CCS process from emission capture to the transportation, utilisation and secure underground storage of CO_2. Although the initial emphasis is placed on offshore storage, exploring onshore storage options is expected to follow (Bernama, 2024).

The trajectory ahead is undoubtedly fraught with obstacles. Deputy Chief Minister of Sabah Jeffrey Kitingan asserts that the CCUS bill is superfluous for both Sabah and Sarawak. He posits that the Federal Constitution endows these states with authority over land and forestry areas profoundly influenced by the bill's emphasis on underground carbon storage. Furthermore, Sabah prefers to manage its carbon credits independently, evident in its ongoing practice of selling credits derived from its forests. The state also maintains that its jurisdiction encompasses the ocean, which could potentially contribute to carbon storage initiatives. Although Sabah is already formulating its carbon capture and utilisation legislation, the federal bill may be considered redundant (Lee, 2024). However, these developments raise questions about the alignment of state and federal interests in environmental policy.

Malaysia encountered significant financial and market obstacles before fully adopting CCS technology. The elevated costs associated with CCS frequently deter potential emitters from engaging in such initiatives. However, the government should contemplate implementing strategic incentives and competitively priced funding to enhance the adoption of CCS. Targeted governmental incentives might prove beneficial in replicating successful models witnessed in other sectors. For instance, specific subsidies could motivate businesses to utilise captured CO_2 in certain industries. The government's Budget 2024 presents a promising indication of progress; it has revealed that the Petroleum Income Tax Act 1967 Revision Committee is actively investigating and establishing tax incentives for CCS initiatives (Belanjawan 2024 Speech, 2023). To the extent that completing these incentives by yearend would represent an important step forward, it is a task that must be approached with considerable care given how much could hang in the balance for CCS more generally.

There is a related problem in the Malaysian voluntary carbon market: not enough companies are trading in carbon credits, which might obstruct the effectiveness of the market (Mamora, 2024). On the other hand, insufficient market activity will discourage enterprises from participating in CCS in Malaysia. The absence of transboundary CO_2 transport and storage is a missed opportunity. However, mechanisms such as the London Protocol or the EU CCS Directive could allow Malaysia to access new markets. This may pave the way for additional investment; however, challenges still exist. In order to fully roll out CCS, all the financial and market barriers must be overcome; thus, additional steps include implementing financial incentives, promoting an active carbon market through an extra syllabus on carbon trading, and strengthening international cooperation. Here are the steps required to lower our carbon output and ramp up CCS campaigns.

Current Legal and Regulatory Landscape in Malaysia

The legislative and regulatory framework for CCS in Malaysia is now fragmented and too broad to support the development of a substantial CCS industry. Although current legislation, including the Environmental Quality

Act 1974 and the Petroleum Development Act 1974, establishes a basis for environmental protection and resource management, it fails to explicitly encompass carbon capture and storage, resulting in notable regulatory deficiencies. The legal framework for CCS-related activities encompassing CO_2 capture, transportation, storage, and long-term monitoring is either non-existent or very tenuously linked to current legislation, resulting in a legislative gap that may impede CCS implementation in Malaysia. The Environmental Quality Act 1974 (EQA) is the foundation of Malaysia's environmental legislation, establishing the legal framework for pollution regulation and environmental safeguarding. The act effectively addresses immediate pollution management but fails to consider the unique complications of CCS, including CO_2 injection into geological formations and the long-term obligation associated with stored CO_2. This results in significant legal ambiguities, particularly regarding accountability for potential leaks from storage facilities and the methodology for long-term oversight of these locations. Moreover, the EQA does not guide CCS operations' licensing and permitting processes, worsening legal complexities.

The Petroleum Development Act 1974 (PDA) regulates Malaysia's oil and gas industry, conferring exclusive authority to PETRONAS to manage and develop the nation's petroleum resources (Petroleum Development Act 1974, 1974). Considering that depleted oil and gas fields are frequently seen as optimal locations for CO_2 storage, the PDA may theoretically regulate specific CCS operations. The legislation was intended for oil and gas extraction rather than for the long-term storage of CO_2. The text lacks clarification regarding the regulation of CO_2 injection into these fields and the organisation responsible for assuring the safety and integrity of the stored CO_2. In the absence of explicit legislative revisions to the PDA or the enactment of new legislation, legal ambiguity exists regarding whether CO_2 storage is under PETRONAS jurisdiction or if another regulatory authority should take responsibility.

Moreover, some supplementary legislation may pertain to elements of CCS yet necessitate substantial amendment or growth. The Occupational Safety and Health Act 1994 (OSHA) may govern the safety standards for workers engaged in CO_2 transportation and injection (Occupational Safety and Health Act 1994, 1994). OSHA currently lacks regulations addressing the dangers related to CCS, including CO_2 pipeline failures and the technical challenges of maintaining pressurised CO_2 in storage formations. The lack of sector-specific laws for CCS creates a significant legal void in safeguarding the health and safety of workers and the public.

Challenges in Establishing a Robust CCS Framework

A significant obstacle to establishing a stable legal framework for CCS in Malaysia is the absence of comprehensive legislation addressing technology. The lack of a specific CCS law leaves essential liability, enforcement, and compliance issues unaddressed. The long-term obligation to store CO_2 presents a considerable legal hurdle. In nations such as Australia, long-term liability is governed by explicit stipulations within the Offshore Petroleum and Greenhouse Gas Storage Act 2006, which designates the government as responsible for overseeing storage facilities after a specified duration. Malaysia does not possess such laws, prompting enquiries regarding liability for CO_2 leaks or environmental harm that could arise decades after the subterranean injection of CO_2. Without explicit legal advice, prospective investors and operators may hesitate to participate in CCS activities, apprehensive about unexpected legal and financial liabilities.

A notable legal difficulty is the absence of a regulatory framework to govern the complete lifecycle of CCS plants. The regulatory authorities in Malaysia, including PETRONAS, the Department of Environment (DOE), and the Energy Commission, possess overlapping jurisdictions that could hinder the licensing and execution of CCS projects. The absence of a cohesive regulatory authority to supervise CCS may result in legal ambiguities over compliance and enforcement. Conversely, nations such as the United States have implemented extensive regulatory frameworks under the Clean Air Act (1963) and the Safe Drinking Water Act, which explicitly define the responsibilities of different agencies in overseeing CCS. Malaysia would gain from creating a centralised organisation tasked with licensing, monitoring, and enforcing CCS legislation to prevent regulatory fragmentation and jurisdictional disputes. Moreover, environmental impact assessments (EIAs) under Malaysian legislation are still insufficient to address the concerns linked to CCS. Although Environmental Impact Assessments (EIAs) are required by the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 2015, the current EIA framework fails to consider the long-term environmental

consequences of CO_2 storage or the possible hazards associated with CO_2 migration from storage locations. Other nations, including the European Union (European Union, 2014), have incorporated CCS within their Environmental Impact Assessment Directive, guaranteeing that any potential environmental hazards linked to CCS be meticulously evaluated prior to project approval. Malaysia must revise its EIA legislation to incorporate thorough evaluations of the geological, environmental, and safety concerns linked to CCS.

Furthermore, financial incentives and responsibility procedures are essential legal components that Malaysia's existing framework fails to address sufficiently. CCS requires substantial capital expenditure, and in the absence of financial assistance, private investment in the technology is predicted to be minimal. Countries like the United States have instituted tax credits and carbon pricing schemes to promote the development of CCS, exemplified by the 45Q tax credit for carbon capture. Malaysia may consider analogous legal mechanisms, such as carbon credits or emissions trading schemes, to promote investment in carbon capture and storage (45Q Tax Credit for Carbon Sequestration, 2020). Furthermore, instituting a liability cap for private operators akin to the U.S. framework could offer legal clarity, incentivising corporations to engage in CCS projects without the apprehension of boundless responsibility.

Another legal obstacle is transboundary CO_2 transit and storage. Malaysia has not yet implemented legal frameworks for the transboundary transfer of captured CO_2, which may become essential if the nation has inadequate storage capacity. International accords, such as the London Protocol and the Paris Agreement, establish protocols for transboundary CO_2 transfer; however, Malaysia's legal framework lacks clarity on the domestic implementation of these provisions. Addressing transboundary transportation is crucial for Malaysia to collaborate with surrounding nations on regional CCS projects.

Opportunities and Recommendations for Legal and Policy Development

Notwithstanding these hurdles, distinct opportunities exist for Malaysia to establish a comprehensive legislative framework for CCS. The primary task is to formulate specific CCS legislation that targets the legal and regulatory flaws currently impeding CCS advancement. This legislation must ensure thorough coverage of the entire CCS process, encompassing capture, storage, and long-term monitoring while delineating the roles and duties of several government entities. A singular regulatory body potentially parallel to the Energy Commission ought to supervise CCS initiatives' licensing, compliance, and enforcement. This centralised authority would guarantee the streamlining of all regulatory duties, mitigating the danger of jurisdictional conflicts and offering clarity for investors and operators.Malaysia ought to establish financial incentives to promote private sector participation in CCS. This may encompass tax credits for carbon capture, subsidies for developing CCS infrastructure, and implementing a carbon pricing mechanism that penalises high-emission industries while rewarding corporations that invest in emission-reducing technology such as CCS. These incentives would cultivate a more advantageous investment climate and facilitate the implementation of CCS technologies in Malaysia. The legal framework must also consider the matter of long-term liability for CO_2 storage. Malaysia can adopt worldwide best practices, exemplified by Australia’s Offshore Petroleum and Greenhouse Gas Storage Act, which transfers liability to the government during a specific duration of effective storage monitoring (Offshore Petroleum and Greenhouse Gas Storage Act 2006, 2006). Implementing a liability transfer system would mitigate the legal and financial concerns linked to long-term CO_2 storage, enhancing the appeal of CCS projects to investors.

Moreover, Malaysia must revise its Environmental Impact Assessment (EIA) legislation to include risk evaluations relevant to CCS. These revisions must guarantee that CCS projects are subjected to thorough assessments of potential environmental and safety hazards, including the danger of CO_2 migration from storage locations. Furthermore, Malaysia should pursue international collaboration on transboundary CO_2 transportation by ratifying pertinent treaties and agreements, such as the London Protocol, to enable cross-border CCS projects (London Protocol, 1996). Establishing a comprehensive legal framework for CCS in Malaysia is crucial for the nation to fulfil its climate obligations and engage in international initiatives to diminish carbon emissions. The existing legal framework is insufficient to facilitate the extensive implementation of CCS technologies (National Climate Change Policy, 2009). To meet these issues, Malaysia must formulate comprehensive CCS legislation, implement financial incentives, optimise regulatory monitoring, and manage long-term liability and environmental risks. By drawing upon international best

practices and adapting them to the Malaysian context, the country may achieve leader status in CCS technology and provide sustainable development.

METHODOLOGY

The study adopted a comparative legal and policy analysis methodology to evaluate Malaysia's Carbon Capture and Storage (CCS) frameworks against international benchmarks, particularly those of Australia and the United States. This approach involved examining legislative documents such as Malaysia's Environmental Quality Act 1974 and Australia's Offshore Petroleum and Greenhouse Gas Storage Act 2006, alongside global agreements like the Paris Agreement. Case studies, including Australia's Gorgon Project and PETRONAS-led initiatives in Malaysia, provided practical insights into CCS implementation, highlighting technological advancements and regulatory challenges. Data were sourced from policy reports, academic journals, and stakeholder inputs to explore thematic areas like legal frameworks, financial barriers, and technological requirements. The analysis synthesised these insights into actionable recommendations for enhancing Malaysia's CCS policies, addressing gaps, and fostering international collaborations to align with global sustainability goals.

FINDINGS AND DISCUSSION

The Legal Framework in Australia for Carbon Capture and Storage

The carbon capture system can store around 5.5 billion tonnes of CO_2, limiting emissions to nearly 18 billion tonnes or 16.5 billion tonnes when accounting for constraints on petroleum exports and enhancements in vehicle efficiency (Foran, 2011). Australia accounts for less than 2% of global greenhouse gas emissions; however, it possesses one of the highest per capita emission rates worldwide (Cook, 2017). The decomposition of fossil fuels for stationary energy generation contributes to approximately 66% of carbon dioxide emissions (Shirmohammadi et al., 2020.) Australia has ratified the Conference of the Parties (COP) 21 Paris Agreement. It is committed to decreasing absolute and per capita emissions in the forthcoming years to meet its international greenhouse gas commitments. Australia is diligently implementing multiple ways to attain its objective of net zero greenhouse gas emissions by 2050, alongside a substantial 43% reduction in emissions by 2030. The revised 2030 objective is to decrease greenhouse gas emissions by 43% relative to 2005 levels, reflecting a substantial augmentation of 15 percentage points from the prior target. Corporations frequently struggle with the carbon dioxide emissions generated by their industrial operations in the current corporate environment despite their continuous efforts to adopt more sustainable energy sources. In contrast to the power sector, which can utilise various decarbonisation strategies, including adopting renewable energy, these businesses encounter a more limited array of possibilities for emission reduction. Consequently, CCUS are feasible for several industries to significantly reduce emissions and attain net zero targets (Walker & Dawkins, 2023).

Australia is a leading leader in CCS, initiating research in 1998 with the Geological Disposal of CO_2 (GEODISC) Project, the inaugural extensive assessment of the continent's CO_2 storage potential. This initial exploration placed Australia among the select nations to engage in CCS. Substantial advancements ensued with the Gorgon Project, Australia's inaugural large-scale carbon capture and storage endeavour, creating a conducive foundation for the technology (Marshall, 2022).

The Australian federal government has instituted a thorough legislative framework for CCS initiatives that is relevant at both federal and state levels. The Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGS Act) is fundamental to this system, governing activities in Commonwealth waters beyond three nautical miles from the land. The Environment Protection (Sea Dumping) Act 1981 regulates marine garbage dumping and the establishment of artificial reefs, upholding stringent environmental requirements.

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) safeguards Australia's natural environment and fosters sustainable development. The National Greenhouse and Energy Reporting Act 2007 requires organisations to report carbon emissions. This is a greater degree of accountability and

transparency consistent with Australia's commitments under the United Nations Framework Convention on Climate Change, supporting efforts nationally and internationally to act about climate change.

In addition, the State of Victoria enacted the Greenhouse Gas Geological Sequestration Act 2008, commonly referred to as the "Onshore Act," which serves as a regulatory framework for the geological storage of greenhouse gases within the state's jurisdiction (Department of Energy, Environment and Climate Action, 2024). Complementing this, the Offshore Petroleum and Greenhouse Gas Storage Act 2010 ("Offshore Act") was introduced, extending existing petroleum legislation to include geological storage in state waters. The Onshore Act, on the other hand, establishes new regulatory arrangements modelled after the state's existing Petroleum Act. Together, these Acts form the key regulatory regimes for greenhouse gas storage in Victoria. By January 2015, other Australian states, including Queensland, Western Australia, and South Australia, had also enacted laws addressing various aspects of carbon capture and storage (CCS) (Global CCS Institute, 2015).

The Underground Water Management Act 2009 was enacted in Queensland to govern subsurface activities, including CCS, demonstrating the state's proactive approach to environmental management. Western Australia revised its enduring Petroleum and Geothermal Energy Resources Act 1967 to include extensive rules focused on greenhouse gas storage following advancing environmental standards. Likewise, South Australia's Petroleum and Geothermal Energy Act 2000 and the associated Petroleum and Geothermal Energy Regulations 2000 create a specific regulatory framework for CCS activities within its authority. The state-level activities are supported by the federal regulatory framework created by the Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGS Act) and other relevant Commonwealth laws (Dixon et al., 2015).

Implementing federal and state legislation in Australia has created three separate frameworks regulating storage activities. Initially, State or Territory Onshore Legislation refers to laws governing the sequestration of greenhouse gases within a state's terrestrial regions. Secondly, State or Territory Offshore Legislation pertains to the sequestration of greenhouse emissions in offshore waters within a state's control. Finally, Commonwealth Offshore Legislation governs greenhouse gas storage in Commonwealth waterways, except for Western Australia. Coastal waters extending up to three nautical miles from the shore are governed by states or territories, and those from three to 12 nautical miles are under Commonwealth control (Contact, 2023).

Additionally, the Australian Government established a new $141 million Carbon Capture Technologies Program as part of the October 2022-23 Budget. It focuses on supporting the development of carbon dioxide removal and utilisation technologies that will be crucial in achieving our net zero targets. This scheme would fund R&D projects for capture technologies, which include but are not limited to direct air capture, as well as utilisation technologies that afford permanent and stable storage, such as in cement or other construction materials. Budget 2022-23 spends $1.3 billion to strengthen energy security, reduce energy costs, cut emissions, and support Australia's target of reaching net zero by 2050. (Ministry for the Department of Industry, 2023).

Before the 2022-23 budget, Australia financed CCS research through multiple initiatives, including the Australian Petroleum Cooperative Research Centre, with assistance from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Geoscience Australia. The federal government's CCS Flagship initiative and the Global CCS Institute have been pivotal, while the University of Melbourne's Peter Cook Centre for CCS Research has been significant. This has been further enhanced by industry-backed initiatives such as the Callide Oxyfuel Project and the Surat Basin storage, which the Australian Coal Association financed. The Gorgon Project in Australia commenced operations in 2019 as the nation's inaugural commercial-scale carbon capture and storage initiative, sequestering over 7 million tonnes of CO_2 to date, thus establishing itself as one of the most significant CCS projects globally (Cook, 2017).

Furthermore, Australia has been achieving notable advancements in CCS programs. The Gorgon plant in Australia was the inaugural commercial-scale CCS initiative and remains the nation's sole fully operational commercial CCS plant. The Gorgon natural gas field was identified in 1980, and development began in the early 2000s; however, CO_2 injection into a salty aquifer in the Dupuy Formation, approximately 2 kilometres

beneath Barrow Island in the Barrow Subbasin off the coast of Western Australia, began only in late 2019. Since then, the project has sequestered over 7 million tons of CO_2. The Gorgon Project is expected to inject around 3.5 to 4 million tonnes of carbon dioxide annually, positioning it as one of the most significant carbon capture and storage initiatives globally (Chevron Global, 2024).

CCS initiatives in Australia provide significant insights regarding the necessity for governmental endorsement, financial investment, and innovation. Nonetheless, problems emerge, including public opposition based on environmental concerns, elevated prices relative to renewable energy, and the potential risk of CO_2 leakage (Yeung et al., 2024). Nonetheless, the economic viability of the CSS remains contentious, particularly for coal and natural gas businesses.

Despite these numerous hurdles, Australia continues to advance in developing CCS technology. The nation is advancing and broadening its portfolio of CCS projects, showcasing sustained achievement amid several hurdles. Other nations might draw insights from Australia's experience by capitalising on its achievements and addressing its problems by using CCS in a worldwide initiative to reduce carbon emissions.

The Legal Framework in The United States of America for Carbon Capture and Storage

CCS is considered one of the major technologies in the climate change mitigation landscape for its potential CO_2 emission reductions, which are well integrated into the current energy infrastructures. It is important to understand the contribution of the US, being one of the major emitters of GHG emissions globally; hence, subnational dynamics are vital in understanding this country. Given the set of circumstances, such as disparity in commitments towards reduction in emissions and cultural and geographical factors that shape unique energy systems, subnational organisations yield a considerable level of influence over decisions related to the application of CCS. This literature review explores the trends of complex interrelationships between these variables at the state level for implementing CCS. This synthesises existing research in a manner that could better explore ways of reducing energy-related emissions in the pursuit of climate mitigation goals (Parker et al., 2011).

In the face of developing a regulatory framework for CCS activities in the US, a multiagency and multilayered approach has been developed. The Environmental Protection Agency is mandated to oversee the activities of CCS projects under the Underground Injection Control Program (UIC programme), ensuring that CO_2 in underground formations adheres to regulations. Permits and regulations for CCS projects mostly fall to the states, especially insofar as they involve Enhanced Oil Recovery operations. Two new recent laws, the Consolidated Appropriations Act of 2021 and the Infrastructure Investment and Jobs Act, included funding and incentives for CCS to develop further. Section 45Q of the Internal Revenue Code tax credit, on the other hand, incentivises CCS by financing the projects that meet the set qualifications. Another work elaborated on this, stating that one of the critical methods used by the US federal government to reduce climate change is carbon capture and storage, otherwise known as CCS. Most policies and research have targeted CCS technology developments and applications in heavy industry and power production. One such tool is a tax credit that incentivises companies to absorb and store CO_2. In addition to the above, DOE has also provided funding for CCS research and development. This aligns with Singer's philosophy that all social groupings should bear an equal burden of the benefits and costs associated with CCS. Further, Singer's global responsibility would imply that the better-off countries should extend financial and technological support to the poorer countries to aid in deploying CCS. However, deployments of CCS have been delayed because of various barriers, such as very high costs and uncertain legislation. More comprehensive federal and state rules are required for the proper advancement of the deployment of CCS. Understanding the current status of CCS policies is thus important to advance them towards carbon neutrality (Thielges et al., 2022).

CCS governance at the international level is a multifaceted issue of transportation and storage of CO_2 across boundaries. Even though specific legislative provisions for CCS have not been given, the Paris Agreement acknowledges its key role in climate change mitigation. Further, various international agreements have given frameworks on marine-based CCS and carbon trading, such as the Kyoto Protocol and stored CO_2 as per the London Protocol (Ring et al., 2021). Still, there is a lack of international legislation related to the responsibility, control, and verification of CCS activities. On the other hand, similar to most states in the

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country, Alabama, for example, has taken action to establish environmental rules related to the storage operation of CO_2 (Hand Arendall Harrison Sale LLC, 2024). Alabama's regulations on CO_2 storage are guided by the draft rules developed under the Alabama Water Pollution Control Act (AWPCA), approved by the Alabama Department of Environmental Management (ADEM), providing a structured framework for managing environmental impacts.

Alabama has established its own rules and regulations governing CO_2 storage facilities. However, the state has not yet obtained Class VI program primacy from the Environmental Protection Agency (EPA). As a result, Class VI wells in Alabama remain subject to federal oversight under 40 CFR § 146.81, administered through EPA Region 4 (Environmental Protection Agency [EPA], 2024). Despite the lack of primacy, Alabama's regulatory framework reflects a strong commitment to environmental safety by implementing comprehensive rules to govern CO_2 storage. This approach ensures the sustainability of operations and the protection of natural resources. While federal supervision provides an overarching structure, state-level regulatory efforts remain crucial for effectively administering and implementing CO_2 storage technologies.

Oil and gas production and exploration have been in practice in California for many years, which is a testimony to the number of significant annual figures the state has been able to post as its contribution to the energy sector. Besides established methods, however, there is an increased interest in CCUS technology development to reduce greenhouse gas emissions. Based on the abovementioned important concerns, the author reviews the present status of CCUS activities undertaken in California today with a focus on, among other things, legislative frameworks, infrastructural development, emission data, storage capacity, and ongoing research programs.

California has a very high emission profile yet, at the same time, has a reasonably good prospect for storing CO_2. That potential develops mainly in saline formations and oil and natural gas reserves. The transport sector is the state's most important source of emissions because the portfolio includes the major sectors of industry, transportation, agriculture, and energy generation. Nevertheless, California's capacity to store CO_2 allows it to deploy CCUS technologies to mitigate its emissions. In California, most of the research into CCUS technologies is carried out in conjunction with such schemes as the West Coast Regional Carbon Sequestration Partnership WESTCARB. Like injection into saline deposits and other geological sinks, the DOE co-founded this under the California Energy Commission. The CCUS projects in California are drawing more interest from other parties. Several projects are applying for permits on geologic sequestration. For this reason, a Class VI permit application is pending before EPA Region 9, considered novel by many since it demonstrates the state's commitment to progressing with CCUS infrastructure development. Perhaps of more interest, however, is a BECCS project in Mendota, California, that is anticipated to be one of the first-Class VI projects authorised in the state. In California, CCUS activities continue to move in a direction that reflects a coordinated effort to rise against climate change by slashing CO_2 emission levels and studying advanced carbon capture and storage options. Supported by favourable regulatory frameworks, large storage capacity, and current research programs, California is well-positioned to spearhead CCUS technology development and make a considerable mark in worldwide efforts toward emissions reduction.

Therefore, taking a glimpse at the CCS activities in the United States is subject to a robust regime overseen by the EPA. At the same time, recent legislative provisions include incentives and funding to support deployments, like the Inflation Reduction Act (IRA) of 2022 and the Infrastructure Investment and Jobs Act (IIJA) of 2021, further supporting CCS activities in the US. Supporting federal oversight is state law, including provisions such as those in Alabama that demonstrate their commitment to public safety and environmental protection.

While agreements such as the Paris Agreement recognise the importance of CCS, international problems related to cross-border CO_2 transit, liability, and monitoring persist. On the other hand, projects like those in California show an increasing interest in CCUS technologies, which are also supported by strong academic collaborations and regulatory frameworks.

Way Forward

Malaysia can develop strong CCS legislation, like in Australia and the United States of America, to attract investments and protect the environment. To begin with, both countries have clear legislation: the Offshore Petroleum and Greenhouse Gas Storage Act in Australia and the U.S. Environmental Protection Agency's Underground Injection Control program. This will help spell out federal and state roles to avoid conflict and ensure smooth sailing for the technology deployment.

The government of Malaysia needs to take further steps in implementing the financial incentives proposed for the 2024 Budget Plan, like tax credits and subsidies aimed at promoting CCS technology development and deployment. After all, these financial incentives will be primary motivators toward developing and deploying CCS technologies. Financial incentives akin to the Internal Revenue Code Section 45Q tax credit exist to make qualified CCS projects more economically viable, like the Investment Tax Allowance, Tax deductions, Import Duty and Sales Tax Exemptions, and initiatives and incentives under the New Industrial Master Plan 2030 are some examples. Similarly, the Australian federal government has provided funds for different programs, including the Carbon Capture Technologies Program and Australian National Low Emissions Coal Research and Development. In this way, these incentives lower financial barriers to CCS projects and can develop private sector participation and innovation. Similarly, incentives for Malaysia would mean investing in CCS and making adaptation more feasible for the industries. It will help overcome high capital costs associated with any CCS project and facilitate broad dissemination to help Malaysia move towards a low-carbon economy. Second, the need of the hour is to, firsthand, enhance the collaboration between the public and private sectors for the development of carbon capture and storage projects across the country.

To accelerate CCS implementations, Malaysia could seek the help of the World Bank and Asian Development Bank to provide funding and technical assistance for CCS projects to facilitate the accelerating development of CCS technologies.

The Federal Government should build upon the successes of Sarawak's experiences with PETRONAS and PETROS by considering partnerships with industry players and research institutions such as universities like Universiti Teknologi Malaysia (UTM), Universiti Kebangsaan Malaysia (UKM) and Universiti Malaya (UM) and organisations such as the Petroleum Research Fund (PRF), Malaysian Oil & Gas Services Council (MOGSC), Academy of Sciences Malaysia (ASM) and Malaysian Industry-Government Group for High Technology (MiGHT) to draw light of CCS even more. This will enable it to attract various areas of expertise and innovation akin to the Australian Gorgon Project and the United States.

Investment in R&D is required for these CCS technologies to be improved and the so-called technical hurdles to be overcome. Supporting R&D and facilitating partnership models are crucial to effective CCS in Malaysia, while investments and climate objectives will be attractive. Malaysia should emphatically invest in the much-needed infrastructure for transporting and storing CO_2.

This would allow for the wide-scale deployment of CCS technologies in the industry. Infrastructure plays an integral role in any workable CCS strategy. Australia and the United States have invested a lot in infrastructure to complement the work in CCS. Examples of specific infrastructure are the Gorgon Project in Australia, which was installed to inject CO_2 into a saline aquifer, and the different projects developed in the United States, which have pipelines and storage facilities for captured CO_2. Indeed, Malaysia is working hard to expand its infrastructure toward CCS under the National Energy Transition Roadmap, or NETR, which covers the construction of extra facilities and pipelines. However, the federal government should do more than that by ensuring that infrastructure development for the nationwide transportation of CO_2 is well-planned and hastened. It is not limited to pipeline laying but also to finding and developing the proper storage locations, such as depleted gas fields and saline aquifers. These will enhance Malaysia's capacity to control CO_2 emissions from various sources, ensure effective implementation of CCS projects, and make vital contributions to its targets for reducing greenhouse gas emissions. Malaysia should, therefore, put in place the necessary monitoring and reporting mechanisms to ascertain the safety, reliability, and accountability of CCS projects.

Such transparency is vital to ensure the integrity of CCS activities. The United States has the UIC program of the EPA that stringently implements measures on leakage and protection from CO_2. In Australia, rigid monitoring is mandatory to ensure the effectiveness and security of the CCS initiatives. The stakeholders, public, investors, and regulators will gain confidence upon adopting such schemes in Malaysia. Such activities should involve continuous monitoring at the site for CO_2 storage, periodic performance reports, and independent verification of the results. This also stipulates that a precise transparency mechanism will enable Malaysia to determine problems and quickly resolve them for long-term success. Effective monitoring will also generate valuable data to enhance CCS technologies and contribute to the international effort to mitigate carbon emissions.

CONCLUSION

CCS, therefore, has enormous potential to contribute to the fight against climate change, as evidenced by their respective legislative frameworks in Australia and the U.S. Although these countries acknowledge the potential of CCS, proper implementation should be done through vigilant regulation. Australia and the U.S. have healthy legal systems for CCS, but complications on international CCS place additional demands for global cooperation.

For Malaysia to progress in this field, a strong legal system must be present, like that of Australia and the U.S. With financial incentives, CCS projects will become more attractive, and the opportunities for public-private partnerships will develop. The infrastructures of transit and storage of CO_2 should be invested in. Transparent monitoring systems would, at the same time, ensure the safety and accountability of operations.

Although CCS faces tough challenges due to public acceptance and economic feasibility, continuous research and development might resolve these issues. By lessons garnered from existing frameworks and encouragement of innovations, CCS can actively contribute to achieving net zero emission levels that reduce the increase in global temperatures, hence allowing a sustainable future for our planet.

Finally, a holistic strategy can be adapted to support further CCS technologies like deforestation and reforestation to facilitate the CCS. Since CCS provides a technological solution for capturing industrial CO_2 emissions, reforestation offers natural carbon sinks through photosynthesis. However, reforestation lacks the permanence of geological storage, as stored carbon can be released through deforestation or wildfires. Integrating reforestation with CCS, such as through Bioenergy with Carbon Capture and Storage (BECCS), creates a balanced approach, addressing emissions technologically and naturally. By combining legislative frameworks, financial incentives, and public awareness, this comprehensive strategy enhances the effectiveness of climate change mitigation efforts.

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