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Carbon Sequestration and Carbon Capture and Storage (CCS) in Southeast Asia

Nik Hisyamudin Muhd Nor[1], Siti Norhana Selamat[1], Muhammad Hanif Abd Rashid[1], Mohd Fauzi Ahmad[1], Saifulnizan Jamian[1], Sia Chee Kiong[1], Mohd Fahrul Hassan[1], Fariza Mohamad[1], Seiji Yokoyama[2]

[1]Department of Materials and Design Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Batu Pahat, Johor, Malaysia.
[2]Faculty of Mechanical Engineering, Toyohashi University of Technology, 1-1 Hibarigaoka Tempaku Toyohashi Aichi Japan.

E-mail: nhisyam@uthm.edu.my, sitinorhanaselamat@gmail.com, hd150060@siswa.uthm.edu.my, mohdfauzi@uthm.edu.my, saifulnz@uthm.edu.my, sia@uthm.edu.my, fahrul@uthm.edu.my, farizamd@uthm.edu.my, yokoyama@me.tut.ac.jp

Abstract. Southeast Asia is a standout amongst the most presented districts to unnatural weather change dangers even they are not principle worldwide carbon dioxide (CO_2) maker, its discharge will get to be significant if there is no move made. CO_2 wellsprings of Southeast Asia are mainly by fossil fuel through era of power and warmth generation, and also transportation part. The endeavors taken by these nations can be ordered into administrative and local level. This paper review the potential for carbon catch and capacity (CCS) as a part of the environmental change moderation system for the Malaysian power area utilizing an innovation appraisal structure. The country's recorded pattern of high dependence on fossil fuel for its power segment makes it a prime possibility for CCS reception. This issue leads to gradual increment of CO_2 emission. It is evident from this evaluation that CCS can possibly assume a vital part in Malaysia's environmental change moderation methodology gave that key criteria are fulfilled. With the reason to pick up considerations from all gatherings into the earnestness of an Earth-wide temperature boost issue in Southeast Asia, assume that more efficient measures can be taken to effectively accomplish CO_2 diminishment target.

1. Introduction

Long before the Industrial Revolution in the late of 18th century, human beings had only a moderate need for energy. They mostly relied on the energy and strength from human or animal to do work, and relied on the natural sources like wind and land to move something [1, 2]. To keep on living, human beings and all other living creatures require energy in the form of food and heat that were usually supplied by food, and sometimes by sunlight, wind, hot water and many more. Human also use energy for a number of other purposes, such as clothing, shelter, transportation, entertainment, cooling and the construction of tools [3].

However, rapid growth in industrialization in the late 18th century has triggered the start of the Industrial Revolution in Europe and spread to other part of the world. Steam engines and other machinery required coal as fuel source and this has released the first emissions of carbon dioxide (CO2) and other gases which has then led to the increase in the concentration of the greenhouse gas (GHG) in the atmosphere, declining of air quality in many cities and induced the global warming issue in the world [4].

Global warming issue is at a serious level overall including Southeast Asia, which comprises of Brunei, Myanmar, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, and Vietnam. The expansion in worldwide production of carbon dioxide (CO_2) is the major driver of the global warming which is an issue of incredible concern today [1]. Anthropogenic climate change due to combustion of fossil fuel has been found as the primary cause of CO_2 discharges into the air that lead to global warming [2]. Keeping in mind the end goal to diminish the outflows of CO_2 numerous innovation alternatives have been proposed and investigated so as to accomplish a reasonable low carbon vitality society [3]. There is no single innovation choice accessible that could totally tackle the discharges issue of world vitality needs and in all probability an arrangement of innovation arrangements would be required to avoid perilous anthropogenic impedance with the atmosphere framework [4]. Southeast Asia region is extremely exposed against the environmental changes as a large proportion of the general population and a great part of the monetary action are located along the coastlines. Nations in the area are dynamic members in global environmental change arrangements and some have set national targets, Indonesia means to lessen GHG emanations by 26% from nothing new (BAU) levels by 2020, or 41% in the event that it gets upgraded worldwide help; Malaysia looks to diminish the carbon force of total national output (GDP) by 40% by 2020 from 2005 levels, and Singapore intends to decrease GHG outflows by 16% from BAU levels by 2020 as appeared in Table 1.

Table 1. Summary of energy policies in Southeast Asia countries [5]

Country	Sector	Policies and Targets
Brunei Darussalam	Efficiency	45% reduction in energy intensity compared to 2005 levels by 2035
	Renewables	electricity generation from renewable energies achieve 10% by 2035
Cambodia	Efficiency	20% reduction in energy consumption by 2035
Indonesia	Efficiency	1% reduction in energy intensity per year until 2025
	New and renewable energy	23% and 31% increase in sharing of “new and renewable energy” in primary energy by 2025 and 2050 respectively
	Climate change	26% reduction of GHG emission by 2020, and 41% reduction with the assistance from international communities
Laos PDR	Efficiency	10% reduction of final energy consumption
	Renewables	Renewable energies achieve 30% share by 2025
Malaysia	Efficiency	Promote improvement of the energy efficiency in industry, buildings and domestic sectors
	Renewables	Boost capacity of renewable energies to 2,080 MW by 2020 and 4,000 MW by 2030. Plans for renewable energy and, site selection and regulatory studies are developed.
	Nuclear	Plans for nuclear energy are developed and, site selection and regulatory studies are being carried out.
	Climate change	40% reduction in carbon intensity of GDP by 2020 (from 2005 levels).
Myanmar	Efficiency	10 % reduction in energy demand (from BAU level).
	Renewables	Renewable energy in total generation capacity achieves 15% to 18% share by 2020.

Philippines	Efficiency	Achieve energy savings equivalent to 15% of annual final demand relative to BAU by 2020
	Renewables	Triple the capacity of renewable power generation to 15GW by 2030.
Singapore	Efficiency	35% reduction in energy intensity by 2030 from 2005 levels
	Climate change	7% to 11% reduction in GHG emissions by 2020. The rate will be increased to 16%, if there is a legal binding agreement globally on climate change. 36% reduction in GHG emissions intensity by 2030 from 2005 levels.
Thailand	Efficiency	30% reduction in energy intensity by 2036 through the elimination of fossil-fuel subsidies and improvements on the energy efficiency.
	Renewables	20% increase in the power generation from renewable energy and 20% increase in the biofuels based transport by 2036.
	Nuclear	Two commercial nuclear reactors have been planned since 2007, although progress has delayed since the Fukushima Daiichi accident.
Vietnam	Efficiency	5 to 8 % reduction in energy consumption by 2015 and 8-10% by 2020.
	Renewables	4.5% and 6% increase in the share of renewables in electricity generation by 2020 and by 2030 resepectively.
	Nuclear	10.7 GW capacity of nuclear power is being developed until 2030.

Table 2 demonstrates the progressions of CO_2 outflow in term of tons per capita of these nations contrasted with Southeast Asia nations showing that Brunei, Singapore, Indonesia, Malaysia, and Thailand have comparable CO_2 emission with developed nations. The radical addition of the CO_2 outflow was identified with the flourishing mechanical advancement in the nations, for example, Indonesia, Malaysia, Thailand and Vietnam. Also, there is a misguided judgment that CO_2 discharge from Southeast Asia is less significant contrasted with the real emitters, United States and China. Indonesia, with the fourth most elevated populace on the planet, contributed 4.73% of aggregate world nursery gasses discharge[6]. It is an interest of quick regard for the CO_2 outflow in this area. The greatest test and weight confronted by Southeast Asia nations now is to find a determination to keep the advancement and an Earth-wide temperature boost relief in parity [5], [7]. In order to achieve mid to long term CO_2 reduction targets, cost effective CO_2 capture from fossil fuel power plant and subsequent sequestration options need to be evaluated keeping in view of world's growing demand of energy. There are several technologies available for carbon capture and storage (CCS) such as absorption, adsorption, gas separation, membrane and cryogenic separation. The aim of this literature review is to provide a current understanding of the potential of various CCS technologies for Southeast Asia.

Table 2. CO_2 emission in Southeast Asia [5].

Country	**CO_2 Emission (tons per capita)**		**Variation (%)**
	1990	**2009**	
Cambodia	0.005	0.33	560.0
Brunei	25.47	23.69	-7.0
Indonesia	0.81	1.90	134.6
Laos	0.06	0.30	400.0
Malaysia	3.11	7.10	128.3
Myanmar	0.11	0.23	109.1
Philippines	0.68	0.75	10.3
Singapore	15.41	6.39	-58.5
Thailand	1.68	3.95	135.1
Vietnam	0.32	1.65	415.6

2. CCS development in Southeast Asia

2.1. CCS Background

Essentially, there are three principle segments of the CCS process called catch, transport and capacity. The catch step includes catching, getting dried out, and compacting CO_2 from vast stationary discharge sources. For fuel-blazing procedures, for example, people with significant influence plants, partition advances can be utilized to catch CO_2 after ignition or to decarbonize the fuel before burning. The vehicle step requires through tankers, pipeline or boat to exchange caught CO_2 to a suitable stockpiling site which typically situated at far from the CO_2 source. This is conceivable when the caught CO_2 gas is compacted to a high thickness at the catch office. Potential stockpiling strategies can be makeshift (infusion into underground topographical arrangements, infusion into the profound sea) or for all time (modern fixation in inorganic carbonates) [8]. Rubin *et al.* reports that just a few CCS were viewed as experienced advances, for example, pipeline, industrial separation and enhance oil recuperation. Additionally, sea storage still in research stage while mineral carbonation and geological storage considered at exhibit stage entering monetarily feasible.

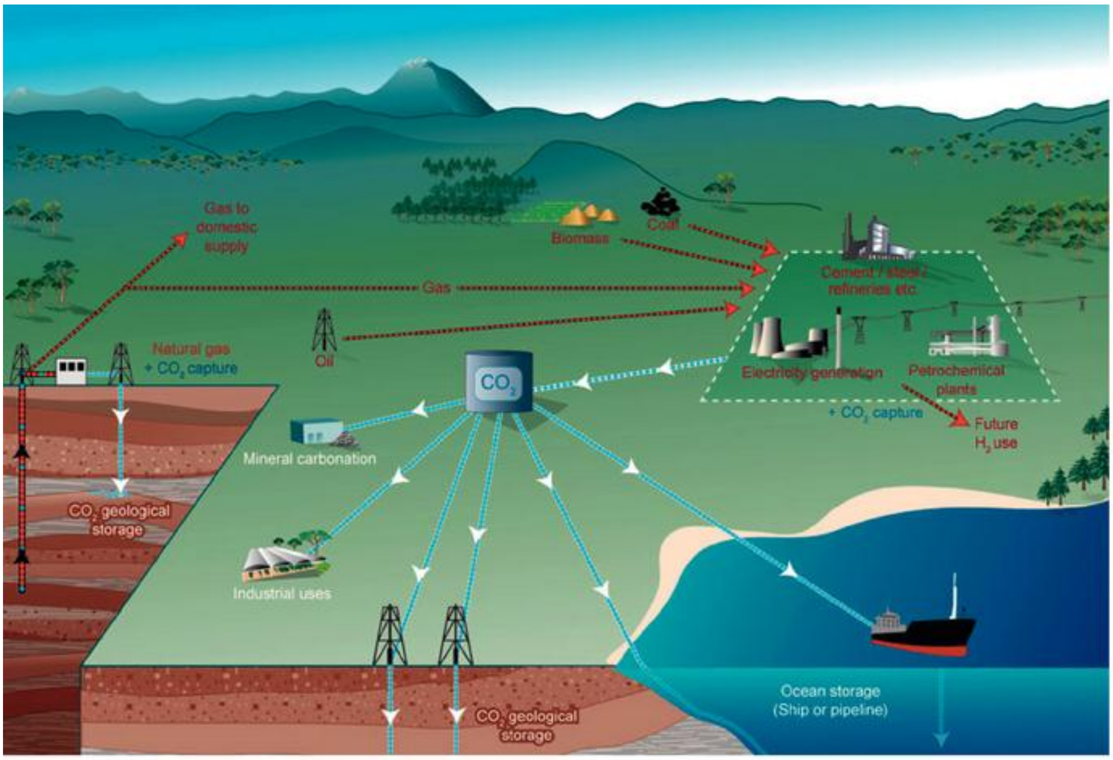

Figure 1. Schematic diagram of possible CCS system [9].

Malaysia second-biggest oil maker in Southeast Asia as of now records for more than 1/6 of Southeast Asia's aggregate vitality related CO_2 outflows, an offer that remaining parts stable until 2040. Its per-capita CO_2 discharges are more three times higher than the Southeast Asian normal over the Outlook period and more than one-and-a-half times higher than the OECD normal by 2040, which has been declining subsequent to 2007 and is relied upon to proceed [5], [6], [8]. However, Malaysia right now has restricted abilities in investigating and creating practical CO_2 partition innovations. There have been a set number of surveys on the potential and specialized possibility for CCS in Malaysia [10], [11]. There has been no expansive scale financed research activity for CCS in Malaysia and it is likely that the catch innovation as with most environmental change alleviation advancements would have been produced by industrialized countries [12].

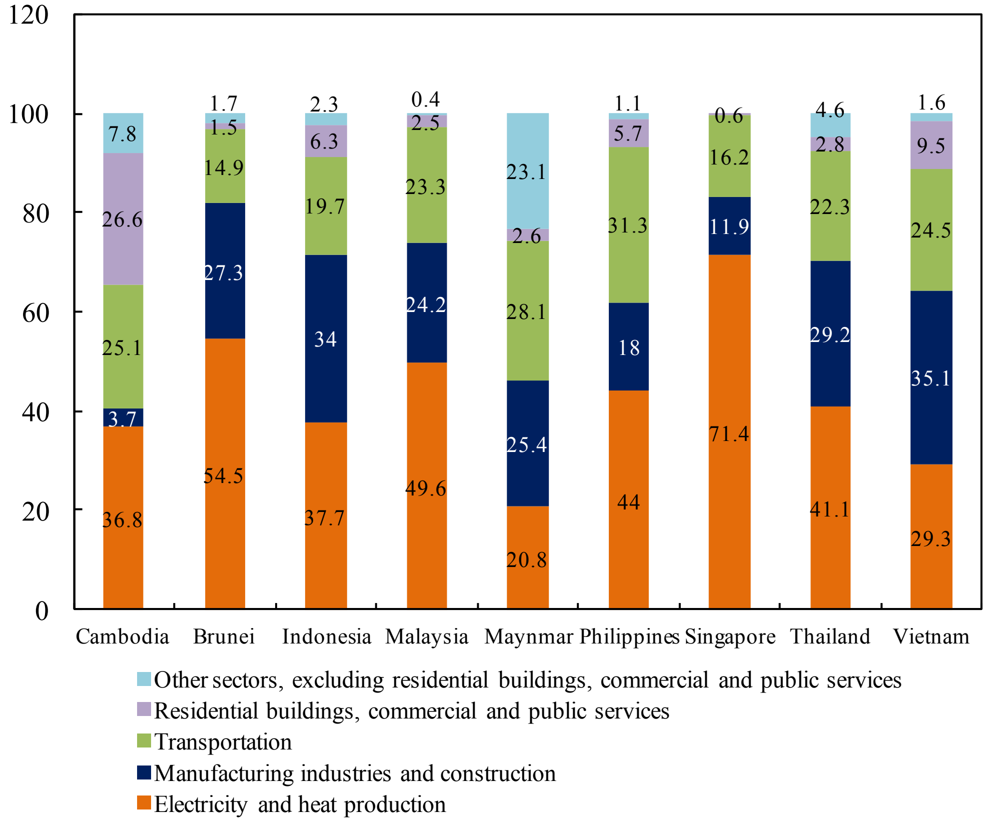

Figure 2. Energy-related CO2 emissions by sector in Malaysia [6].

2.2. CO_2 Capture Technology
Catching CO_2 can be accomplished utilizing one of the three principle strategies in particular by means of post-burning catch, pre-ignition catch or oxyfuel burning [12]. CO_2 in pipe gas can be isolated and caught from various stationary emanation sources, for example, fossil fuel power plants, bond creation, refineries, normal gas preparing, steel plants, and biomass plants. In some of these sources, for example, common gas–processing plants where CO_2 should be isolated from crude gas for creating deals quality regular gas, CO_2 partition is as of now a standard part of the procedure. Caught CO_2 needs just to be dried and packed before transportation and capacity.

2.3. CO_2 Storage Technology
There are a few potential storage choices, for example, the captured CO_2 infused into profound geographical developments, (for example, develop or exhausted oil and gas fields), profound coal creases that can't be mined, and saline aquifers. Infused CO_2 will be put away as a thick stage supercritical liquid and could be caught through various diverse components, for example, basic and stratigraphic catching, lingering gas catching, dissolvability catching, mineral catching, and hydrodynamic catching. A few issues of capacity would decide the most doable innovation to be grow, for example, the expense of capacity, including the expense of transportation from the source to the capacity site, ought to be minimized. The

danger of mischances such gas spillage ought to be disposed of and ecological effect ought to be negligible. The capacity technique ought not abuse any national or worldwide laws and regulations. Yet, mineral carbonation is the main known type of changeless CO_2 stockpiling that is by all accounts essentially practical. Vast amounts of normal minerals and modern squanders are accessible for use in altering CO_2. Around 10–15% of the aggregate climatic CO_2 is transmitted from little and medium CO_2 emitters (<2.5 M ton CO_2), which are potential wellsprings of CO_2 for mineral carbonation [13], [14]. The thought of mineral carbonation was initially proposed by Seiftriz in 1990. Mineral carbonation, the response of metal bearing oxides with CO_2 to shape insoluble strong carbonates, emulates the regular weathering of silicate rocks, which happens over topographical time scales [15]. Besides, mineral carbonation on industrial by product such as steelmaking slag [13], [16]–[18], cement waste [19], [20] and fly ash should also be taken into consideration as the CO_2 emission mostly sourced from the industrial plant itself.

2.4. Costing for CCS System

For the plants with topographical stockpiling and no EOR credit, the expense of CCS reaches from 0.02–0.05 US$/kWh for PC plants and 0.01–0.03 US$/kWh for NGCC plants (both utilizing post-burning catch). For IGCC plants (utilizing pre-ignition catch), the CCS cost ranges from 0.01–0.03 US$/kWh in respect to a comparative plant without CCS. For all power frameworks, the expense of CCS can be diminished by around 0.01–0.02 US$/kWh when utilizing EOR with CO_2 stockpiling in light of the fact that the EOR incomes somewhat make up for the CCS costs. The biggest cost diminishments are seen for coal based plants, which catch the biggest measures of CO_2. In a few cases, the low end of the CCS cost extent can be negative, showing that the expected credit for EOR over the life of the plant is more noteworthy than the most reduced reported expense of CO_2 catch for that framework. This may likewise apply in a couple cases of ease catch from modern procedures. Table 3 indicates the summary of the expenses of CO_2 capture, transport and storage reported in altogether with monitoring expenses.

Table 3. Cost ranges for the components of a CCS system as applied to a given type of power plant or industrial source year 2002 [9].

CCS system components	Cost range	Remarks
Capture from a coal- or gas-fired power plant	15-75 US$/t$CO_2$ net captured	Net costs of captured CO_2, compared to the same plant without capture.
Capture from hydrogen and ammonia production or gas processing	5-55 US$/t$CO_2$ net captured	Applies to high-purity sources requiring simple drying and compression
Capture from other industrial sources	25-115 US$/t$CO_2$ net captured	Range reflects use of a number of different technologies and fuels.
Transportation	1-8 US$/t$CO_2$ transported	Per 250 km pipeline or shipping for mass flow rates of 5 (high end) to 40 (low end) MtCO_2 yr-1.
Geological storage	0.5-8 US$/t$CO_2$ net injected	Excluding potential revenues from EOR or ECBM
Geological storage: monitoring and verification	0.1-0.3 US$/t$CO_2$ injected	This covers pre-injection, injection, and post-injection monitoring, and depends on the regulatory

		requirements
Ocean storage	5-30 US$/t$CO_2$ net injected	Including offshore transportation of 100-500 km, excluding monitoring and verification
Mineral carbonation	50-100 US$/t$CO_2$ net mineralized	Range for the best case studied. Includes additional energy use for carbonation

ASEAN countries were considered as a rapid developing region where the energy demand projected to keep rising even though there are also efforts to reduce the nation energy consumption as mention in their policies. Malaysia through the nation Economic Transformation Plan (ETP). Through its strides towards modernization and industrialization, the nation has persistently appreciated a steady, solid power supply at generally low costs. The danger of environmental change would bring upon change towards this situation. The backing and cooperation towards GHG discharge decreases would be required from all countries. Malaysia is quick turning into an industrialized country and thusly, has a more noteworthy part in the battle against environmental change. CCS in its present structure is costly and later on in the wake of considering all the conceivable cost change would at present be more expensive than the current customary fossil fuel based vitality. This is a hard truth which is hard to be acknowledged by numerous. The lawmaker, the businesses and the overall population must be set up to adjust to an all the more unreasonable vitality situation if there is to be any genuine advancement towards environmental change alleviation.

Clearly, the battles to moderate environmental change including CCS may look extravagant. Nevertheless, with the start of environmental change, alleviation endeavors may avert future harm, which could cost considerably more [21]. Proper endeavors host been done by the gatherings included under the name of an Earth-wide temperature boost moderation. Be that as it may, accord is constantly difficult to be come to in this issue. From the workshops, gatherings, or meetings held, we can scarcely see a conceivable result from them. This condition is going on in Southeast Asia as well as the entire world. Case in point, Copenhagen Accord, which was considered as the continuation of Kyoto Protocol, turned out as a feebly bound collaboration, which its suggestion is misty.

3. Conclusion

This paper has generally described and reported efforts taken on global warming mitigation in Southeast Asia countries using CCS technology. In addition, environmental strategies achieve very little unless it is tied to socio-economic and trade or international obligations. These factors have made the efforts unable to achieve their expected result. Technology and fund transfer from developed countries is vital as an aid to these vulnerable countries while criticism will make no influence. Aside from that, in order to create a sustainable development along with global warming mitigation, more frequent internal cooperation among ASEAN countries is needed.

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