



Faculty of Economics and Business

**Impact of Non-renewable, Renewable Energy Consumption and
Economic Growth on CO₂ Emissions: Empirical Study of ASEAN-5**

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Impact of Non-renewable, Renewable Energy Consumption and Economic
Growth on CO₂ Emissions: Empirical Study of ASEAN-5

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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ABSTRACT

This study explores the impact of energy consumption on CO₂ emissions in ASEAN-5, aiming to deepen understanding of non-renewable and renewable energy's influence, along with economic growth, on CO₂ emissions. The objectives include (i) analysing the short and long-run impact of consumption of energy types and economic growth on CO₂ emissions, (ii) investigating the non-linear effects of both energies consumption on CO₂ emissions, and (iii) assessing the Environmental Kuznets Curve (EKC) hypothesis. Using Pooled Mean Group (PMG) and panel Non-linear Autoregressive Distributed Lag (NARDL) estimators, we examine data from ASEAN-5 (Thailand, Malaysia, Singapore, Indonesia, Philippines) over 31 years (1990–2020). The PMG results reveal that non-renewable energy consumption and economic growth increase CO₂ emissions, while renewable energy reduces them in the long run. Economic growth alone causes short-term environmental degradation. Panel NARDL findings indicate that higher unclean energy consumption leads to environmental degradation, decreasing it helps to reduce environmental problem in the long run, while increased clean energy consumption reduces CO₂ emissions in long run. Economic growth contributes to higher CO₂ emissions initially, decreasing when growth declines, supporting the EKC theory's long-run applicability. Therefore, policymakers should prioritize green investment for an unclean to green energy transition, with government and non-government agencies playing a crucial role in Communication, Education, and Public Awareness (CEPA) programs.

Keywords: Non-renewable energy consumption, Renewable energy consumption, Economic Growth, CO₂ emissions, EKC hypothesis, Non-linear autoregressive lag estimator

***Impak Penggunaan Tenaga Tidak Boleh Baharu and Tenaga Boleh Baharu Serta
Pertumbuhan Ekonomi Terhadap Pelepasan Karbon: Kajian Empirikal ASEAN-5***

ABSTRAK

Kajian ini meneroka impak penggunaan tenaga terhadap pelepasan CO₂ di ASEAN-5, dengan matlamat untuk meningkatkan pemahaman dalam impak tenaga boleh diperbaharui dan tidak boleh diperbaharui serta pertumbuhan ekonomi terhadap pelepasan CO₂ emission. Objektif kajian ini termasuk (i) menganalisis impak penggunaan jenis tenaga dan pertumbuhan ekonomi terhadap pelepasan CO₂ dalam jangka pendek dan panjang, (ii) mengkaji kesan bukan linear terhadap penggunaan kedua-dua jenis tenaga ke atas pelepasan CO₂, dan (iii) menilai hipotesis Environmental Kuznet Curve (EKC). Dengan menggunakan kaedah Pooled Mean Group (PMG) dan panel Non-linear Autoregressive Lag (NARDL), kami mengkaji data dari ASEAN-5 (Thailand, Malaysia, Singapura, Indonesia, Filipina) selama 31 tahun (1990–2020). Keputusan PMG menunjukkan bahawa penggunaan tenaga tidak boleh diperbaharui dan pertumbuhan ekonomi meningkatkan pelepasan CO₂, manakala tenaga boleh diperbaharui mengurangkan pelepasan tersebut dalam jangka panjang. Pertumbuhan ekonomi turut menyebabkan degradasi alam sekitar dalam jangka pendek. Penemuan Panel NARDL menunjukkan bahawa peningkatan penggunaan tenaga yang tidak bersih menyebabkan degradasi alam sekitar, manakala mengurangkannya dapat membantu mengurangkan masalah alam sekitar dalam jangka Panjang. Selain itu, peningkatan penggunaan tenaga bersih mengurangkan pelepasan CO₂ dalam jangka panjang. Pertumbuhan ekonomi menyumbang kepada peningkatan pelepasan CO₂ pada awalnya, dan akan berkurang apabila pertumbuhan ekonomi menurun. Penemuan ini menyokong kerelevanan teori EKC dalam jangka panjang. Oleh itu, penggubal dasar seharusnya memberi keutamaan kepada pelaburan hijau untuk melakukan

peralihan tenaga dari yang kotor kepada hijau. Akhir sekali, kerajaan dan agensi bukan kerajaan memainkan peranan penting dalam program Komunikasi, Pendidikan, dan Kesedaran Awam (CEPA) atas transaksi tenaga.

Kata kunci: *Penggunaan tenaga yang tidak boleh diperbaharui, Pengeluaran tenaga yang boleh dipulihkan, Pertumbuhan ekonomi, Pelepasan CO₂, hipotesis EKC, Kaedah Non-linear Autoregressive Lag*

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LIST OF ABBREVIATIONS

ARDL	Autoregressive Distributed Lag
ASEAN-5	Association of Southeast Asian Nation Five Countries
C2ES	Center for Climate and Energy Solutions
CADF	Cross-section Augmented Dickey Fuller
CD test	Cross-sectional Dependence Test
CIPS	Cross-section Im-Pesaran-Shin
CO ₂	Carbon Dioxide
EKC	Environmental Kuznets Curve
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
NARDL	Non-linear Autoregressive Distributed Lag
NICCDIES	National Integrated Climate Change Database Information and Exchange System
PMG	Pooled Mean Group
R&D	Research & Development
RECs	Renewable Energy Certificates

CHAPTER 1

INTRODUCTION

1.1 Introduction

Global warming and climate change are causing significant environmental impacts, with human activities like fossil fuel usage driving these effects. Satellite data shows the disappearance of glaciers, elevated sea levels, and frequent wildfires (European Space Agency, 2022). The Intergovernmental Panel on Climate Change in 2022 (IPCC, 2022) has declared a "Code Red for Humanity" to address climate change, highlighting the vulnerability of 3.3 billion people and biodiversity decline. The energy sector is the main focus, with 25% of global energy consumption coming from renewables in 2023. The relationship between non-renewable, renewable energy consumption, economic growth and environmental degradation is crucial, with the ASEAN-5 region being a key focus.

The Association of Southeast Asian Nations (ASEAN) was established on August 8, 1967, in Bangkok, Thailand, through the ratification of the ASEAN Declaration or Bangkok Declaration. Thailand, Indonesia, Malaysia, the Philippines, and Singapore were the founding members of ASEAN. The ASEAN-5 countries, which were chosen for their economic development relative to other ASEAN members, established this region. Having been the organization's architects, they continue to be the most influential ASEAN members in the twenty-first century (Zhu et al., 2016).

The rationale behind choosing the ASEAN-5 countries for examination in this study is multifaceted. Firstly, these nations boast a combined population exceeding 680 million, representing a substantial portion of the global workforce, ranking just behind India and

China (World Population Review, 2022). Notably, Indonesia leads the pack in terms of GDP, reaching 1.19 trillion dollars in 2021, with Thailand and Singapore closely following with 505.98 billion dollars and 396.99 billion dollars, respectively (Asia Fund Managers, 2022; Trading Economics, 2022). Moreover, the 2021 ASEAN Power Update reports indicate that Indonesia, Thailand, Malaysia, Philippines, and Vietnam possess the largest installed power capacities, underscoring their significance in the realm of energy (ASEAN Power Update, 2021). The correlation between robust economies and substantial energy consumption makes these countries pivotal subjects for our study. Secondly, these nations are endowed with abundant natural resources and have implemented economic policies that attract significant foreign investment. Consequently, the region has emerged as one of the world's fastest-growing economies (Tuna & Tuna, 2019). The convergence of thriving economies, substantial usage of energy, and strategic economic policies makes the ASEAN-5 countries highly pertinent for an in-depth analysis of the intricate relationship between energy consumption and CO₂ emissions.

Furthermore, energy serves as a critical force propelling economies and societies at global and local scales, exerting influence on the attainment of Sustainable Development Goals (SDGs), with a particular focus on SDG 7 (ensuring access to affordable and clean energy) and SDG 13 (taking action against climate change). Its significance is underscored in poverty reduction (SDG 1), educational empowerment (SDG 4), and healthcare (SDG 3), while the shift to renewable energy in specific regions holds the potential for job creation and the establishment of sustainable communities (SDG 11). However, the utilization of energy, especially non-renewable sources, introduces health and environmental risks, impacting agriculture and exacerbating issues like food security problem. Achieving SDG 7 requires collaborative efforts, recognizing the interconnected nature of SDGs and

emphasizing holistic, interdisciplinary approaches to address socio-economic and environmental challenges.

Renewable energy emerges as a crucial and effective solution for mitigating CO₂ emissions, surpassing fossil fuels in cleanliness and sustainability. Globally, it has become the primary source for new power capacity additions, with many countries integrating significant shares of renewables into their grids. Renewable energy, as a crucial participant in the supply side, is essential for accomplishing the goal of the Paris Agreement. In the context of ASEAN, the region stands to gain from global trends in renewable energy. According to the International Renewable Energy Agency, by 2025, ASEAN countries could generate clean electricity at a lower cost than non-renewable sources. The abundant renewable energy resources in the region, particularly solar thermal and modern bioenergy, offer cost-effective opportunities for deployment, especially in heating and cooking applications. As ASEAN progresses into Phase II (2021-2025) of the ASEAN Plan of Action for Energy Cooperation, the focus shifts towards building the ASEAN Power Grid, expanding multilateral electricity trading, and increasing the share of renewable energy for a resilient and sustainable energy future in line with climate change mitigation efforts.

Therefore, despite the severe impact of the Covid-19 pandemic on ASEAN economies, leading to a downgrade in the economic growth forecast from 4.4% to 4.0% in 2021 due to pandemic restrictions imposed by some ASEAN countries to curb the virus's spread, the region is poised for sustained and robust economic growth. According to the Asian Development Bank (ADB, 2021), the economic growth is projected to increase to 5.2% in 2022, surpassing the global average. This growth trend is expected to persist in the following decade. However, the concomitant strong economic growth, driven by rising

income levels and population expansion, is anticipated to result in increased energy consumption. This, in turn, implies a significant rise in greenhouse gas (GHG) emissions, particularly CO₂ emissions, leading to environmental degradation. Therefore, the role of ASEAN in shaping the trajectory of climate policy on a global scale becomes pivotal in achieving lower emissions solutions.

1.2 Background of ASEAN-5

1.2.1 CO₂ Emissions in ASEAN-5

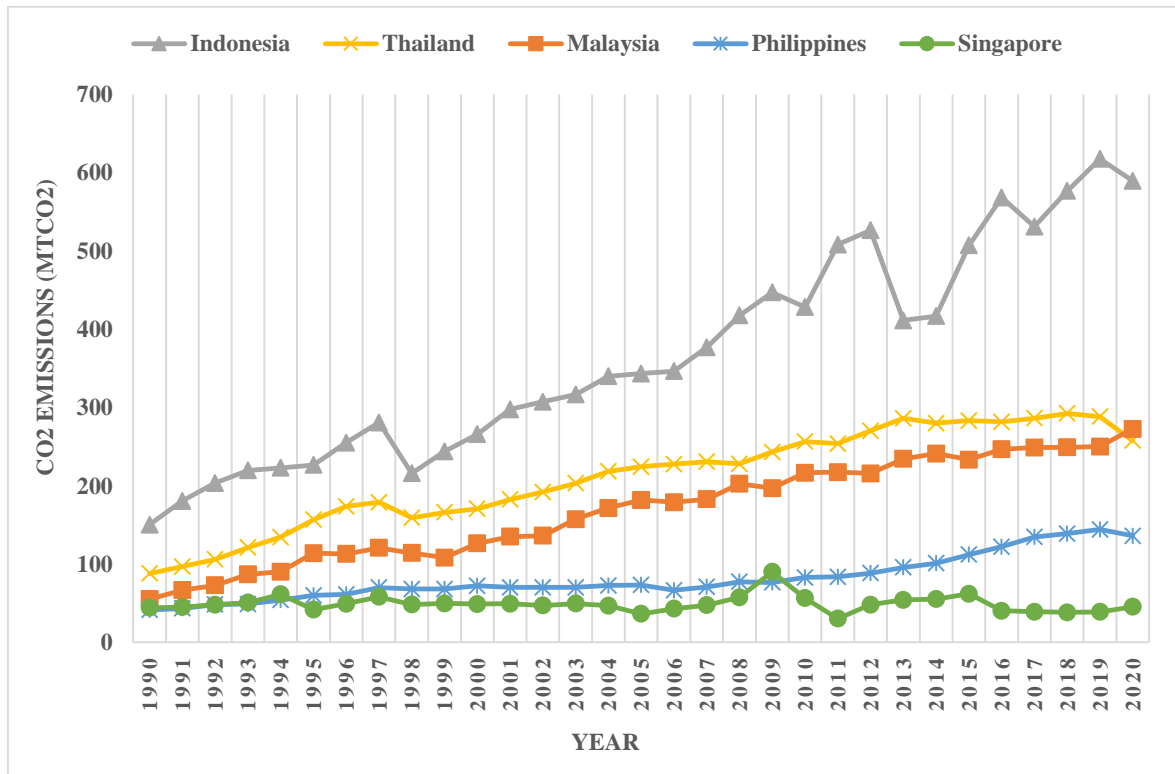


Figure 1.1: CO₂ emissions (MtCO₂) of ASEAN-5 Countries (1990-2020)

Source: Global Carbon Atlas (2022)

Figure 1.1 shows the CO₂ emissions from ASEAN-5 countries, which comprise around 95% of ASEAN GDP. Based on the Figure 1.1, 4 out of 5 countries had experiencing raising in CO₂ emissions, meanwhile Singapore shows a sign of decreasing in CO₂

emissions. In 1998, all ASEAN-5 nations experienced a decline in CO₂ emissions, particularly Indonesia, which exhibited the most significant reduction at 64.77 MtCO₂, surpassing Thailand (19.82 MtCO₂), Singapore (9.72 MtCO₂), Malaysia (6.58 MtCO₂), and the Philippines (1.8096 MtCO₂). The reduction in CO₂ emissions across these countries can be attributed to the financial crisis of 1998. The crisis led to a sharp decline in oil and gas prices, impacting the respective sectors significantly. Diminished demand, coupled with a contraction of credit for purchases, lower corporate earnings resulting in layoffs, contributed to the observed decrease in emissions during this period.

Following a surge in CO₂ emissions across all ASEAN-5 countries, except Singapore, where emissions dropped to 38.94 MtCO₂ in 2019, innovative carbon capture and storage (CCS) technology played a pivotal role. Implemented in Singapore's power plants and industrial processes, CCS significantly reduced carbon footprints (Linga, 2020). Indonesia, ranking as the world's fourth-largest CO₂ emitter, faces environmental degradation from deforestation, peatland megafires, and fossil fuel combustion. Surpassing Australia, Indonesia leads in global thermal coal exports, aiming to bridge electricity gaps between affluent and less-connected islands. Consequently, Indonesia remains the top CO₂ emitter, followed by Thailand, Malaysia, and the Philippines, while Singapore, utilizing effective carbon capture technology, stands as the least emitter.

1.2.2 Non-Renewable Energy Consumption in ASEAN-5

Figure 1.2 shows the non-renewable energy consumption per capita of ASEAN-5 countries. Based on Figure 1.2, it shows a sign of rising in non-renewable energy consumption for every ASEAN-5 country. Singapore recorded highest non-renewable

energy consumption among ASEAN-5 members, and followed by Malaysia, Thailand, Indonesia and Philippines.

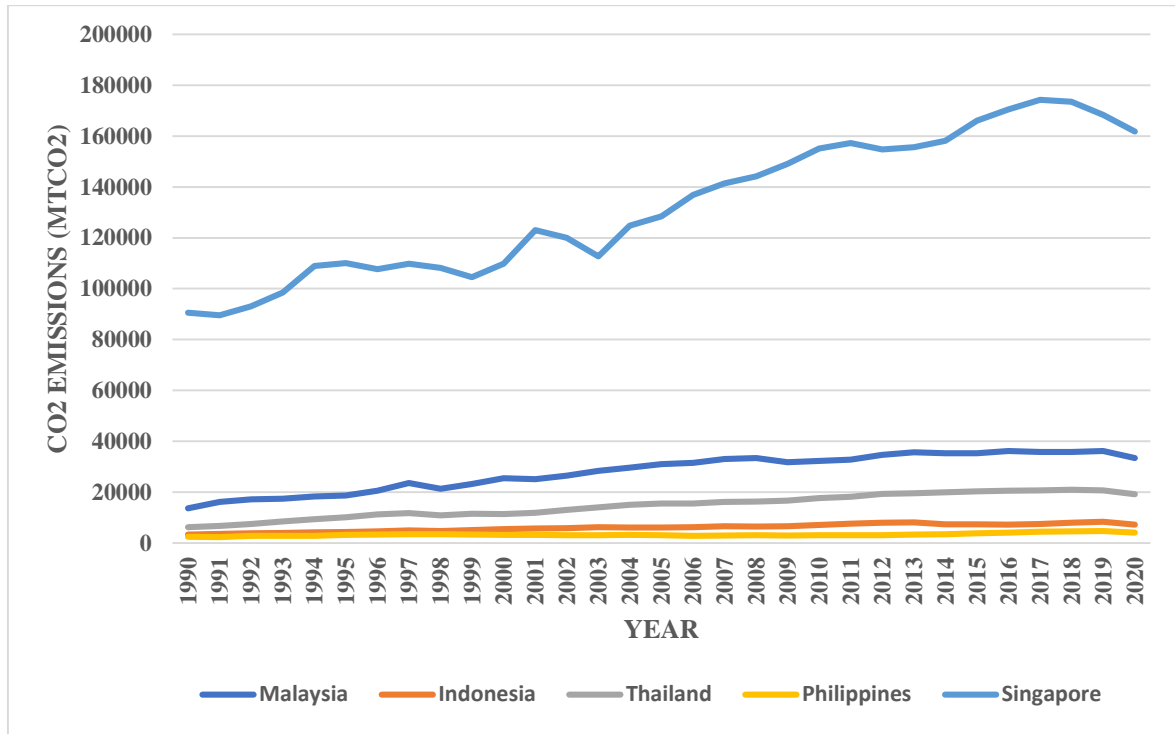


Figure 1.2: Non-Renewable Energy Consumption Per Capita of ASEAN-5 (1990-2020)

Source: Our World In Data (2022)

The reason behind Singapore recorded the highest non-renewable energy consumption due to recognize as the base of major oil companies in the country with ideal trading location and perceived safe environment, for instance the Exxon Mobil company. An analyses of energy tariff comparison platform depicts that most countries depend on fossil fuels and Singapore stand on top of the rank. According to the report from Power Engineering International (2021), Singapore relies on non-renewable energy more than other ASEAN-5 countries, with proximately 98% of total energy supply generated from traditional fuel sources. Singapore consumed large proportion of oil regarding on total energy supply, which the oil equivalent to 73% of energy supply. Increasing energy demand is crucial

towards economic growth as it contributes to GDP of the countries, but rapid increase in non-renewable energy consumption causes more environmental degradation such as rising in CO₂ emissions, as shown in Figure 1.1. As sequence, Singapore recorded highest non-renewable energy consumption among ASEAN-5 members, and followed by Malaysia, Thailand, Indonesia and Philippines.

In contrast, Philippines recorded the lowest non-renewable energy consumption compared to other ASEAN-5 country. Since 1990s, Philippines had suffered electricity outages or shortages, particularly during summer months. Based on United Nations Framework Convention on Climate Change (2016) report, Philippines' electricity demand was rising 25.6 GWh in 1991 2003 to 77.3 GWh in 2014. The supply of primary energy forecasted to be double within 2011 to 2030. However, the energy scarcity has detrimental impacts towards the country's economic growth. According to Santos (2018), the recent challenges that faced by the energy sector related to supply-demand gap that characterized by the unfulfilled demand. Factors that causing unmet demand of energy in Philippines were because of high electricity prices, lack of investment in generation, reduction in self-sufficiency and lastly, expected increase rate in GHG emissions levels. Therefore, the Philippines has adopted a national renewable energy program to significantly increase the generation capacity of renewable energy technologies to achieve energy security in 2030, which also help to mitigating GHGs emissions from power sector.

1.2.3 Renewable Energy Consumption in ASEAN-5

Figure 1.3 shows the renewable energy consumption per capita (kWh) from 1990 to 2020 for the ASEAN-5 countries. According to Figure 1.3, most of the countries reveals that

renewable energy consumption per capita was increasing from 1990 to 2019 and decline in 2020 for Malaysia and Thailand.

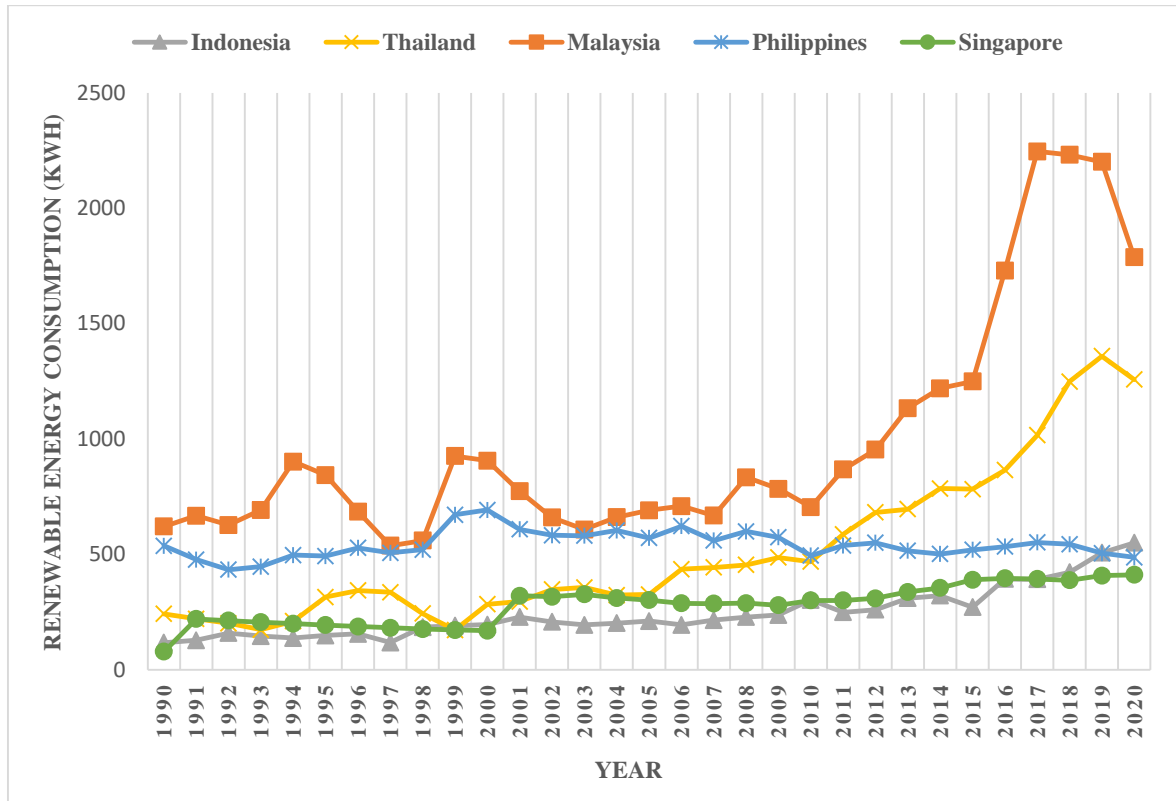


Figure 1.3: Renewable Energy Consumption Per Capita of ASEAN-5 (1990-2020)

Source: Our World In Data (2022)

As shown in Figure 1.3 that Malaysia is among the highest renewable energy consumption as Malaysia considered the leader amongst the members. The renewable energy sector had gained momentum in pursuing the country’s National Renewable Energy Policy with Action Plan and the government’s feed-in tariff scheme. That is already accelerating the renewable energy consumption in the country. Additionally, both government and private corporations in Malaysia play their key roles in moving the country ahead to renewable and sustainable energy goals. Although Malaysia consists of legislation,

policies, and incentives in place for the renewable energy, however, the government still lack in convincing private companies or industries to make a shift in renewables.

In contrast, Figure 1.3 depicts that Philippines has the lowest rate of increasing in renewable energy consumption, although the country has reached substantial progress in lowering energy intensity of the economy. However, the potential CO₂ emissions reduction was exceeded by rising carbon intensity of energy sector, especially worrying in raising of coal in electricity supply. Philippines recorded lowest in percentage change of renewable energy because the share of renewables declined from 26% to 15% in 2000 and 2015, respectively, despite the current high-capacity additions, namely wind, solar and solid biomass, as stated in Philippines Country Profile (2019). In addition, the Philippines as fossil energy importer and rely heavily on imported oil for transportation industries and coal for energy sector. On the average, about half of Philippines primary energy depend on imported fossil fuels as it is cheaper than others. Thus, Philippines governments should reduce reliance on imported sources of energy to achieved the energy independences which are crucial for the Philippines economy.

1.2.4 Economic Growth in ASEAN-5

In addition, energy consumption exists in pursuit of the objective of economic sustainability. Based on Figure 1.4, all the ASEAN-5 countries demonstrate rising in GDP per capita throughout the three decades. In 1998, all the ASEAN-5 countries' GDP per capita experienced a sharp decline. According to Ba (2021), the reason was due to the financial crisis that hit the Thai baht currency to unpegged in Bangkok, that setting the currency devaluations and massive flights of capital.

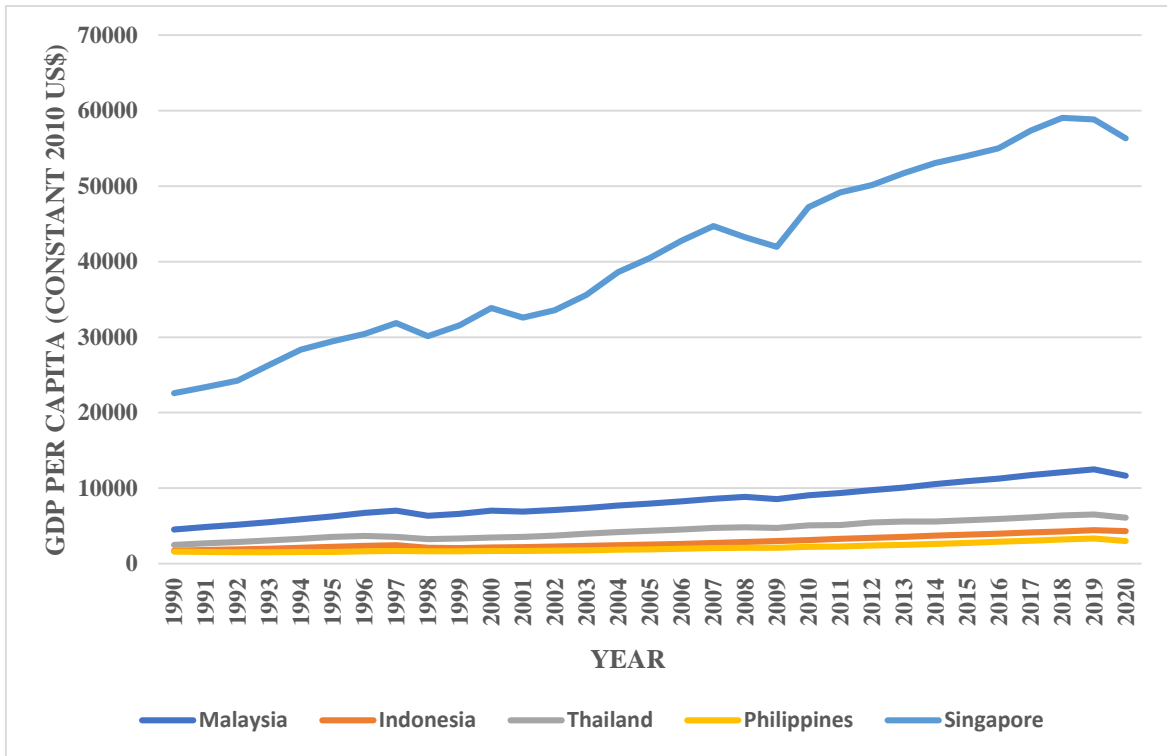


Figure 1.4: GDP per Capita of ASEAN-5 (1990-2020)

Source: World Development Indicator (2022)

Ba (2021) further mentioned that the value of Indonesia Rupiah was down by 80%, Thai baht exceed 50% decline and Malaysian ringgit own by 45%. Conjointly, the economies most affected saw a drop in capital inflows of greater than 100 billion US dollars in the year of crisis.

After the financial crisis event, all the ASEAN-5 countries' economy back to track, which the GDP per capita had been increase within two decades, until 2019, the GDP per capita swelling to 58829.63 US dollars Singapore, 12486.68 US dollars Malaysia, 6094.43 US dollars Thailand, 4312.35 US dollars Indonesia and 2980.02 US dollars Philippines. Towards the year 2020, where all ASEAN-5 countries are facing economic downturn due to Covid-19 pandemic. Based on the report of ASEAN Policy Brief (2020), the novel virus pandemic, Covid-19 had hit ASEAN countries that negatively impact on the economy. The

key sectors mainly affected by tourism, retail, and other services sectors, which almost all the sectors business operations and supply chained disrupted, employment and livelihood put on risk of infection, while the consumer confidence has declined. The Covid-19 outbreak has diminished the prospects of economic recovery from the broad global slowdown.

1.3 Problem Statement

Energy is an indispensable component of the ASEAN-5 economy. Conversely, as non-renewable energy sources, such as fossil fuels, are increasingly utilised, CO₂ emissions increase, giving rise to adverse externalities. Countries in this region, such as Malaysia, Indonesia, and the Philippines, heavily rely on coal consumption, while Singapore primarily uses natural gas, and Thailand utilizes both oil and gas. The energy sector in ASEAN-5 is recognized as the largest emitter of pollutants, posing one of the most pressing challenges faced by humanity. Approximately 90% of the ASEAN's total primary energy requirement is sustained by non-renewable sources like coal, oil, and gas. The demand for these non-renewable energies is projected to increase by 4.7% annually from 2013 to 2035. A significant portion of the oil requirements is imported from outside ASEAN countries, and consumption levels are expected to rise significantly with development and economic growth. Historically, ASEAN has imported around 60% of its oil requirements. According to IRENA and ACE (2016), CO₂ emissions from power generation are anticipated to increase by more than 84% annually, reaching 1 Gigaton each year. Coal is identified as the primary contributor to this growth. The second-largest source of CO₂ emissions is the combustion of oil products, while natural gas, though similar to oil, is projected to contribute less to overall emissions. These patterns underscore the escalating need for fossil fuels in the ASEAN-5 region, notwithstanding their progressive exhaustion, thereby exacerbating the escalation of carbon dioxide emissions.