ENERGY POVERTY, ECONOMIC GROWTH, AND ENVIRONMENTAL DEGRADATION IN SOUTH ASIA: A PANEL DATA ANALYSIS (1990-2022)

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by

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To God Be the Glory

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LIST OF ABBREVIATIONS

CO2	Carbon Dioxide
DOLS	Dynamic Ordinary Least Squires
EFP	Ecological Footprint
EKC	Environmental Kuznets Curve
EP	Energy Poverty
FMOLS	Fully-Modified Ordinary Least Squires
GDP	Gross Domestic Product
NRE	Nonrenewable Energy Consumption
PMG	Pooled Mean Group
RE	Renewable Energy
REP	Rural Energy Poverty
EP	Total Energy Poverty
UEP	Urban Energy Poverty
URB	Urbanization
USM	Universiti Sains Malaysia

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KEMISKINAN TENAGA, PERTUMBUHAN EKONOMI, DAN KEMEROSOTAN ALAM SEKITAR DI ASIA SELATAN: ANALISIS DATA PANEL (1990-2022)

ABSTRAK

Kemerosotan alam sekitar telah menjadi ancaman yang membimbangkan bagi penduduk seluruh dunia. Pihak berkepentingan alam sekitar juga mengambil berat mengenainya kerana kesannya yang berbahaya ke atas kawasan geografi yang berbeza di dunia. Tesis ini mengkaji kesan kemiskinan tenaga dan pertumbuhan ekonomi terhadap kemerosotan alam sekitar di negara-negara Asia Selatan dari tahun 1990 hingga 2022. Kajian ini menggunakan teknik ekonometrik, termasuk PMG-ARDL, *Fully Modified Ordinary Least Square, and Dynamic Ordinary Least Square.* Dalam fasa awal analisis, kajian ini mengkaji kesan berganda kemiskinan tenaga dan pertumbuhan ekonomi terhadap pencemaran. Selepas itu, ia akan menerokai dinamik melalui kemiskinan tenaga dan pertumbuhan ekonomi yang mempengaruhi kemerosotan alam sekitar. Akhir sekali, ia akan menyiasat peranan menyederhanakan kemiskinan tenaga dalam konteks pencemaran dan kemerosotan alam sekitar. Hasil kajian menunjukkan bahawa kemiskinan tenaga memburukkan lagi pencemaran alam sekitar dan kemerosotan alam sekitar, manakala penggunaan tenaga boleh diperbaharui mengurangkan pencemaran dan kemerosotan alam sekitar. Kemiskinan tenaga luar bandar dan bandar memberi kesan positif kepada pencemaran alam sekitar di Asia Selatan. Pertumbuhan ekonomi menyederhanakan dan mengurangkan kesan buruk kemiskinan tenaga terhadap pencemaran dan kemerosotan alam sekitar di negara Asia Selatan. Apabila ekonomi berkembang, pelaburan dalam teknologi tenaga yang lebih bersih dan lebih cekap meningkat, membawa kepada kemerosotan alam

sekitar yang rendah yang disebabkan oleh pelepasan karbon dan bahan pencemar lain. Kebergantungan mereka terhadap sumber tenaga yang tercemar seperti arang batu dan minyak berkurangan. Kajian ini tidak menyokong hipotesis EKC, menunjukkan bahawa pertumbuhan ekonomi secara langsung tidak menyelesaikan isu alam sekitar di Asia Selatan. Kajian ini mengesyorkan penggubalan dasar yang berkesan untuk mengurangkan kemerosotan alam sekitar dan menggalakkan penggunaan tenaga boleh diperbaharui dan teknologi yang cekap untuk meningkatkan pertumbuhan ekonomi mesra alam. Asia Selatan juga harus mengurangkan penggunaan bahan api fosil berbanding menggalakkan penggunaan tenaga boleh diperbaharui dan teknologi yang cekap untuk mencapai pertumbuhan ekonomi yang mesra alam. Akhir sekali, kajian ini mencadangkan bahawa negara-negara Asia Selatan harus menetapkan matlamat untuk menghapuskan kemiskinan tenaga dan mengurangkan pencemaran dan kemerosotan alam sekitar dengan memformat semula struktur pasaran, mengutamakan individu berpendapatan rendah dalam sektor tenaga, dan mengubah strategi pasaran daripada pembeli global kepada pembeli tempatan. Oleh kerana kuasa membeli yang terhad, orang berpendapatan rendah hanya boleh membeli produk pek kecil. Sistem rumah suria kecil, dan tanglung suria boleh memberikan alternatif kepada mereka yang miskin serta, membolehkan mereka beralih daripada sumber tenaga tradisional kepada sumber mesra alam.

ENERGY POVERTY, ECONOMIC GROWTH, AND ENVIRONMENTAL DEGRADATION IN SOUTH ASIA: A PANEL DATA ANALYSIS (1990-2022)

ABSTRACT

Environmental degradation has become an alarming threat to the population in the entire world. Environmental stakeholders are also concerned about it due to its hazardous effects on different geographical areas of the world. This thesis examines the impact of energy poverty and economic growth on environmental degradation in South Asian countries from 1990 to 2022. This study employs econometric techniques, including PMG-ARDL, Fully Modified Ordinary Least Squares, and Dynamic Ordinary Least Squares. In the initial phase of analysis, the study will examine the dual effects of energy poverty and economic growth on pollution. Subsequently, it will explore the dynamics through which energy poverty and economic growth exert influence on environmental degradation. Finally, it will investigate the moderating role of energy poverty in the context of environmental pollution and degradation. The findings show that energy poverty exacerbates environmental pollution and environmental degradation, while renewable energy consumption decreases pollution and environmental degradation. Rural and urban energy poverty positively impact environmental pollution in South Asia. Economic growth significantly moderates and mitigates the adverse effects of energy poverty on environmental pollution and degradation in South Asian nations. As economies grow, investment in cleaner and more efficient energy technologies increases, leading to low environmental degradation caused by carbon emissions and other pollutants. Their reliance on polluting energy sources such as coal and oil is reduced. The study does not support the EKC hypothesis, indicating that economic growth does not directly solve South

Asia's environmental issues. The study recommends formulating effective policies to reduce environmental degradation and promoting renewable energy use and efficient technologies to boost environment-friendly economic growth. South Asia should also cut down the use of fossil fuels and instead promote renewable energy use and efficient technologies in order to achieve environment-friendly economic growth. Lastly, the study suggests that South Asian countries should set goals for eliminating energy poverty and reducing pollution and environmental degradation by reformatting the market structure, prioritizing low-income individuals in the energy sector, and changing market strategies from global to local customers. Due to limited purchasing power, low-income people can typically only purchase small-pack products. Small solar home systems and solar lanterns could provide an alternative for people experiencing poverty, enabling them to shift from traditional energy sources to environmentally friendly sources.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Environmental degradation and global warming represent two of the most pressing challenges facing the world, particularly as nations strive to meet the Sustainable Development Goals (SDGs). Over recent decades, the deterioration of environmental quality has become a central concern, with mounting evidence that the Earth's ecological balance is under threat. These environmental issues are no longer isolated phenomena but constitute interconnected global disasters that pose significant risks to sustainable development. Consequently, many countries are under immense pressure to maintain economic growth while addressing the environmental crisis (Dai et al., 2023; Munir et al., 2020).

It is widely accepted that human-induced activities, such as rapid industrialization, population growth, and excessive consumption of fossil fuels, are among the primary drivers of environmental degradation (Adebayo et al., 2023; Mohsin et al., 2021). These activities are most commonly linked to releasing carbon dioxide (CO_2) emissions, which are widely recognized as major contributors to environmental pollution and global warming (Castellanos et al., 2021; Ehigiamusoe et al., 2020). Consequently, CO_2 emissions are frequently used as a proxy to measure the intensity of human impact on the environment (Khan et al., 2021; Zhang et al., 2021).

As the global temperature continues to rise and air pollution intensifies, the frequency of natural disasters, such as floods, smog, and droughts, is also increasing, with consequences that directly threaten human health and biodiversity (Wang et al., 2019). Given these outcomes, policymakers worldwide are focused on reducing carbon emissions to prevent irreversible environmental damage. This has necessitated promoting low-carbon economies and exploring sustainable energy sources to alleviate the climate crisis.

Several global agreements and initiatives have been developed in response, including the Sustainable Development Goals (2015), the Paris Agreement (2015), the Millennium Development Goals (2000), and the Kyoto Protocol (1997). These efforts aim to curb greenhouse gas (GHG) emissions and mitigate climate change, while ensuring long-term economic and environmental sustainability (Ozturk et al., 2023; Wan et al., 2022).

However, CO_2 emissions alone do not capture the full extent of environmental degradation. A broader set of environmental issues, including water and soil pollution, deforestation, and biodiversity loss, also contribute significantly to ecological decline (Kanat et al., 2022; Usman & Makhdum, 2021). To provide a more comprehensive understanding of environmental sustainability, scholars have emphasized the importance of multidimensional indicators such as the ecological footprint (EFP) (Jahangir et al., 2022; Pata & Caglar, 2021; Sun et al., 2023).

The concept of ecological footprint, initially introduced by Rees (1992) and developed by Wackernagel and Rees (1996), offers a more holistic approach to environmental measurement. It quantifies the biological capacity required to produce the resources consumed and to absorb the waste generated by a population. The ecological footprint (EFP) comprises six components: cropland, grazing land, fishing grounds, forest land, built-up land, and carbon footprint. This multidimensional nature makes EFP a valuable tool for assessing the aggregate pressure human societies place on ecosystems (Global Footprint Network, 2023).

In this way, EFP measures the amount of biologically productive land and water required to sustain consumption and provides insight into resource depletion and environmental sustainability (Zhang et al., 2022). For instance, land is a critical ecological resource that serves as a base for agriculture, habitation, and forestry and as a sink for waste. Therefore, understanding land use within the EFP framework helps capture the long-term ecological consequences of unsustainable resource consumption (Ozcan et al., 2020; Mamghaderi et al., 2023).

Although frequently used CO_2 and EFP differ in the dimensions of environmental quality they assess. While CO_2 focuses narrowly on atmospheric emissions, EFP encompasses a broader range of environmental concerns, including pollution, natural resource depletion, and ecosystem services. Pollution results from human activity and industrial development, manifesting in various forms, such as air, water, soil, sound, and thermal pollution (Prabhat, 2016). In this study, air pollution is the focal point due to its critical role in environmental degradation and its direct link to rising CO_2 levels.

Environmental degradation, by contrast, is a broader process that encompasses not only pollution but also resource depletion, habitat destruction, deforestation, and biodiversity loss. It results from a persistent imbalance between resource extraction and environmental regeneration, primarily driven by anthropogenic factors (Brown et al., 1987; Mamghaderi et al., 2023). Its adverse effects are visible in declining soil fertility, deteriorating air and water quality, and extreme climate events (Maurya et al., 2020).

A key underlying driver of pollution and degradation is energy poverty, defined as the lack of access to reliable, affordable, and modern clean energy services. Energy poverty exacerbates environmental degradation due to poor infrastructure, limited economic resources, and inefficient energy policies (Churchill & Smyth, 2021; Middlemiss et al., 2019). The use of low-quality energy sources, such as coal and biomass, by energy-poor households significantly contributes to carbon emissions, air pollution, and health problems.

The causes of energy poverty are multidimensional, including the unavailability of infrastructure, limited access to energy, unaffordability, and poor energy efficiency in the face of global warming (Rodriguez et al., 2021; Chaudhry & Shafiullah, 2021). However, the consequences are even more far-reaching: diminished well-being, heightened inequality, and increased reliance on environmentally harmful energy sources such as firewood, coal, and kerosene.

Energy poverty presents differently across various geographical contexts, particularly in rural and urban settings. In rural areas, the lack of energy infrastructure means that communities heavily rely on biomass for cooking and heating practices, which degrade forest resources and release pollutants that contribute to both indoor and outdoor air pollution (IEA, 2022; Bonjour et al., 2013). Urban households, although generally connected to the grid, often face affordability and legal access challenges that compel them to use unsafe and polluting alternatives, such as diesel generators or illegal electricity connections (Bouzarovski & Petrova, 2015; Sovacool et al., 2012).

These household and geographic differences in energy access and consumption directly influence patterns of environmental degradation. In rural contexts, deforestation, land degradation, and respiratory health risks are the primary contributors to the ecological footprint. Overburdened grids and fossil fuel-based backup systems increase carbon emissions, noise pollution, and safety hazards in urban settings. Consequently, energy poverty is not only a socioeconomic issue but also an environmental one. The inability to access clean energy forces households to adopt practices that degrade the environment and undermine long-term sustainability. Therefore, addressing energy poverty, especially in South Asian countries, is essential to mitigating environmental degradation and achieving equitable, sustainable development (Wang et al., 2023; Che et al., 2023).

The primary reason for energy poverty in some remote areas is the inadequate availability of infrastructure to access the energy supply. Furthermore, the causes of energy poverty are multifaceted: (1) people do not have access to energy, (2) there is a lack of available energy, and (3) they are unable to afford energy sources (Rodriguez et al., 2021; World Bank, 2017). Additional contributing factors include low income, high energy costs, and (4) unpredictable energy efficiency structures, often worsened by global warming (Chaudhry & Shafiullah, 2021; Ampofo & Mabefam, 2021). These structural and economic barriers exacerbate energy poverty, particularly in developing and underdeveloped nations. This situation is particularly critical in countries where energy production remains heavily dependent on fossil fuels. For instance, Streimikiene and Kyriakopoulos (2023) argue that transitioning to low-carbon energy sources can paradoxically lead to energy poverty due to issues with affordability and accessibility. Consequently, the interplay between energy systems and poverty remains a complex and pressing concern in development discourse.

In recent theoretical debates, climate factors such as extreme heat are also recognized as contributors to energy poverty. Hot temperatures can potentially intensify energy poverty in at least three specific ways. First, rising temperatures increase energy demand to meet cooling needs, as people rely on appliances like fans and air conditioners to adapt to the heat. This demand spike can strain fragile energy systems, particularly in low-income regions. Heutel et al. (2021) report that air conditioner usage during heat waves significantly lowers mortality in developed countries, underlining the necessity of energy access for climate adaptation. Thus, temperature adaptation strategies play a vital role in mitigating the consequences of global warming (Li et al., 2019; Zhang et al., 2022).

However, the increased energy consumption to combat high temperatures can come with environmental costs. When the additional energy demand is met through coal-based generation or other fossil fuels, air pollution worsens, contributing to climate change (Li et al., 2023). For example, the World Bank (2021) reported that South Asia, which comprises one-fourth of the world's population, consumes disproportionately high energy levels while experiencing poor air quality. Furthermore, in countries such as Bangladesh, Pakistan, and India, a high mortality rate is associated with indoor air pollution resulting from the reliance on polluting fuels (Dong et al., 2021). These findings underscore the consequences of energy poverty and highlight the urgent need to explore cleaner and more sustainable sources of energy production.

To understand these challenges, it is crucial to examine the types of energy available and their environmental implications. All living beings, including humans, require energy for sustainability, particularly for maintaining social and economic systems. There are two significant categories of energy sources: renewable and non-renewable. Renewable energy is derived from naturally replenished processes such as solar, wind, geothermal, biomass, and hydroelectric systems. While these sources are inexhaustible over time, they are often limited in output at a given moment (EIA, 2019). Non-renewable energy, by contrast, consists primarily of fossil fuels, including coal, oil, and natural gas, which cannot be replenished quickly after use. Historically, the global energy landscape has been dominated by fossil fuel consumption, a trend that significantly contributes to CO_2 emissions and exacerbates atmospheric and climatic imbalances (Lin & Agyeman, 2019; Wang et al., 2019). Ideally, countries that rely more on renewable energy sources should emit less CO_2. However, this outcome depends on policy choices, technological capabilities, and energy consumption patterns.

Both renewable and non-renewable energy sources are used to fulfill daily energy needs, which are essential for human development. Energy enables basic activities such as cooking, heating or cooling homes, lighting, operating appliances, maintaining healthcare and education infrastructure, and supporting transportation and communication systems (Foo et al., 2020). Despite its importance, the World Bank (2018) reports that nearly two billion people, mostly in rural parts of developing countries, still lack access to modern energy. Projections suggest that by 2030, about 2.7 billion people will be deprived of clean cooking energy, while over 1 billion will still lack access to electricity (Shell Foundation, 2014).

These alarming statistics indicate severe livelihoods and environmental sustainability consequences in developing regions, particularly South Asia. The scarcity of energy literature in the context of South Asian environmental challenges is notable, with most existing studies focusing on anthropogenic and natural factors such as population pressure (Iwejingi, 2012; Ogujiuba et al., 2013) and climate change (Odjugo, 2011). What remains largely underexplored is the role of energy poverty in exacerbating environmental degradation.

Furthermore, the impacts of energy poverty, energy types, and CO_2 emissions differ across South Asian countries. Each economy contributes differently to regional environmental degradation. Some scholars argue that economic growth offers a pathway to addressing environmental problems, but this relationship is not straightforward. The Environmental Kuznets Curve (EKC), introduced by Panayotou (1993), describes an inverted U-shaped relationship between environmental degradation and income: initially, environmental harm increases with economic growth, but it eventually declines after reaching a certain income threshold (Shahbaz et al., 2020).

This concept, grounded in early studies by Grossman and Krueger (1991) and Shafik and Bandyopadhyay (1992), suggests that economic development can initially cause environmental harm but later becomes a solution as wealth allows for investment in cleaner technologies and stronger policies (Kijima et al., 2010). However, the timing and extent of this turning point vary by country and stage of development. The World Bank data support this idea by linking economic growth to adverse environmental impacts such as pollution, biodiversity loss, and resource depletion. A key question emerges: how can economic growth continue without worsening environmental degradation? Researchers, including Shafik (1994) and Selden and Song (1994), estimate that environmental degradation declines once per capita income reaches $4,000. If accurate, this implies that many developing nations must endure environmental degradation until they achieve this income threshold. This underscores the urgency for policies to mitigate ecological harm while accelerating sustainable economic growth.

Nevertheless, the empirical literature on the EKC remains inconclusive. Besides income, energy consumption, particularly fossil fuel-based, drives rising CO_2

emissions (Nizetic et al., 2018). While reducing energy consumption may lower emissions, it also risks slowing economic growth (Danish et al., 2019). This is especially problematic in developing countries where energy use and economic development are tightly intertwined (Ehigiamusoe & Lean, 2019).

The primary environmental culprits in South Asia are the high levels of fossil fuel combustion. Fossil fuels account for around 90% of commercial energy use in this region, and their usage directly correlates with increased CO_2 emissions (Karki et al., 2005). From 1990 to 2009, GHG emissions from South Asia's energy sector rose by 83%, representing the fastest growth among major emission sectors (ADB, 2009). Therefore, reducing fossil fuel dependence is crucial for mitigating environmental damage and promoting sustainable economic growth.

Moreover, energy poverty has environmental consequences, influencing the selection of energy sources, often leading people to choose cheap but environmentally harmful options, such as firewood or coal (Balaguer & Cantavella, 2018; Ek & Soderholm, 2008). This relationship is cyclical: energy poverty fuels environmental degradation, which in turn exacerbates poverty. Studies have shown that energy consumption has a positive correlation with economic growth (Acheampong et al., 2021), and many researchers confirm a constructive relationship between energy use and economic expansion (Rehman et al., 2021; Shahbaz et al., 2022). However, the nature of energy sources and consumption patterns determines the environmental outcomes of this growth.

In this context, exploring the dual and potentially moderating role of energy poverty on the environment and economic development is essential. The level of development in a country affects how energy poverty interacts with environmental outcomes. Therefore, investigating the direct and indirect (moderating) effects of energy poverty on the environment becomes crucial. This line of inquiry not only deepens our understanding of environmental degradation in the South Asian context but also helps identify viable pathways for promoting the use of sustainable energy sources that enhance environmental quality. Figure 1.1 presents the possible transmission mechanisms linking energy poverty, economic growth, and environmental degradation.

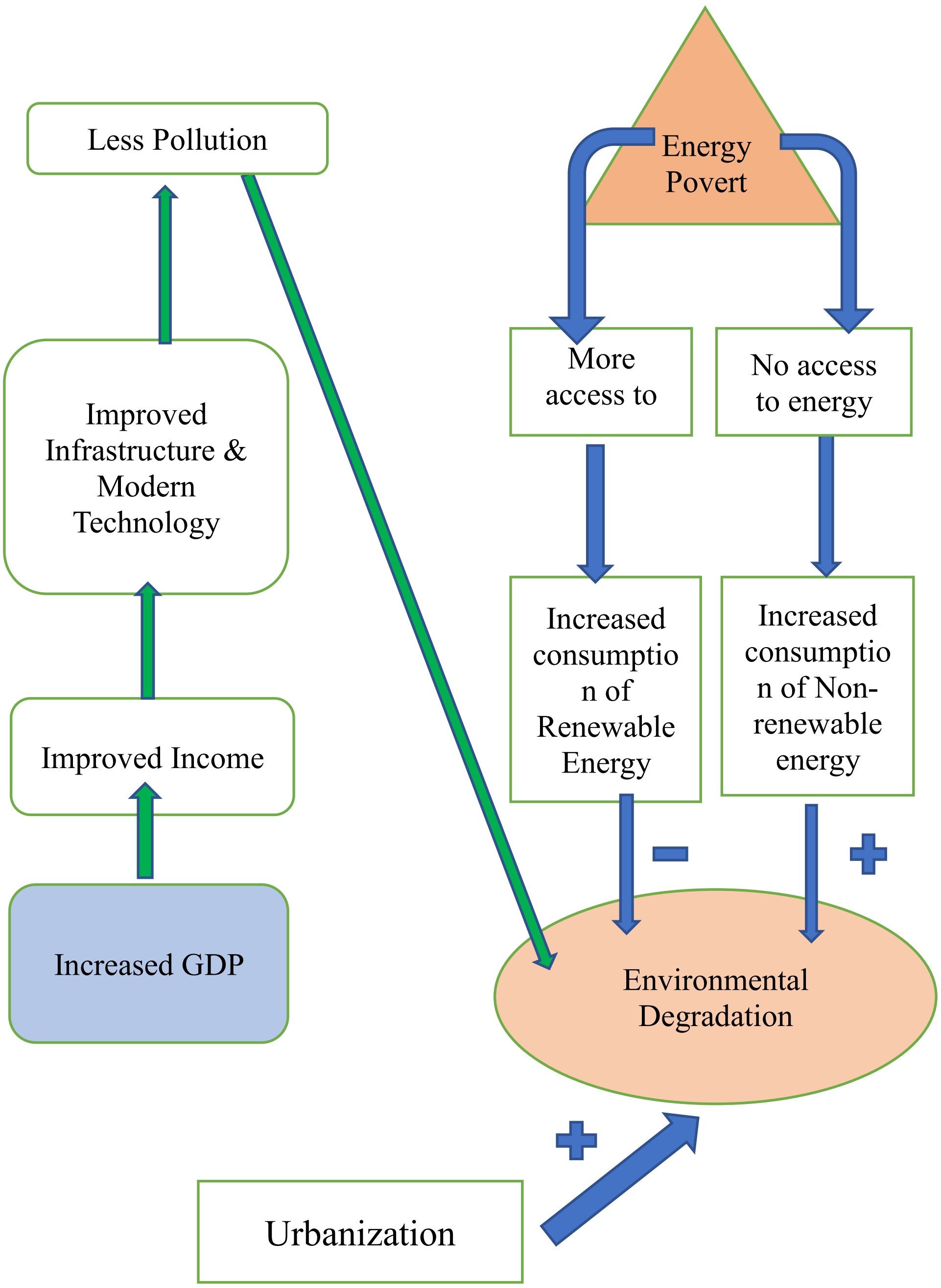


Figure 1.1 Possible transmission channels among the variables

Figure 1.1 illustrates the dual pathways through which economic growth and energy dynamics influence environmental degradation in South Asia, where environmental degradation is the dependent variable. On the left side, increased GDP positively (+) influences income levels, leading to improved infrastructure and adoption of modern technology. These advancements typically result in a negative (−) effect on pollution levels due to cleaner production methods and stricter environmental regulations (Lau et al., 2023; Wang et al., 2023). This pathway aligns with the Environmental Kuznets Curve (EKC) hypothesis, which posits that environmental degradation first increases with economic growth but eventually declines after surpassing a certain income threshold (Grossman & Krueger, 1995; Dinda, 2004). However, during the early stages of development, economic expansion often leads to a positive (+) relationship with environmental degradation due to higher industrial emissions and fossil fuel use (Ghazal et al., 2024; Murshed, 2024).

On the right side of the diagram, the energy poverty pathway highlights a crucial mechanism through which inadequate access to modern energy services contributes to environmental degradation in South Asian economies. In regions facing energy poverty, where large segments of the population lack access to reliable, affordable, and clean energy sources, households and communities often resort to using traditional biomass (such as wood, charcoal, and animal dung) or highly polluting fossil fuels like coal and kerosene for cooking, heating, and lighting. This heavy dependence on non-renewable energy sources leads to increased carbon dioxide (CO_2) and particulate emissions, accelerating environmental degradation. Hence, there is a positive (+) relationship between energy poverty and environmental harm: as energy poverty increases, so do pollution levels and ecological damage (Khurshid et al., 2024; Shahzad & Aruga, 2023). GDP influences energy poverty indirectly through its impact on income distribution, infrastructure, affordability, and the purchasing power of clean energy. In this context, a rising GDP can help reduce energy poverty by enhancing access to modern energy services and improving the socioeconomic conditions necessary for the adoption of clean energy. Households gain more access to clean energy services in contexts where energy poverty is decreased, creating a pathway for transitioning away from polluting fuels toward more sustainable energy solutions.

However, the environmental burden is reduced when energy poverty is alleviated, typically through policy efforts to expand electricity access and promote renewable energy technologies. The increased availability of clean energy options, such as solar, hydro, and wind power, can replace traditional fuels that are harmful to the environment, thereby lowering emissions and contributing to ecological sustainability. This shift produces a negative (−) relationship between renewable energy access and environmental degradation: as clean energy access increases, environmental harm decreases (Mahmood et al., 2023; Nguyen & Kakinaka, 2019). These dynamics highlight the importance of integrating energy equity into environmental policy frameworks, particularly in developing regions.

Urbanization is also a distinct driver of environmental degradation. Rapid and often unplanned urban expansion places significant pressure on natural resources through deforestation for land use, increased energy consumption for transportation and buildings, and elevated waste generation. These factors combine to form a positive (+) relationship between urbanization and environmental degradation (Sapkota &

Bastola, 2017; Sarkodie & Strezov, 2019). Thus, the environmental consequences can be severe in contexts where infrastructure improvements and sustainable energy policies do not match urban growth.

The association between GDP and energy poverty is positively significant, as highlighted by Bousnina and Gabsi (2023), indicating that improvements in economic performance can help reduce energy poverty by enhancing access to modern and reliable energy services. Similarly, Murshed et al. (2022) emphasized that economic growth facilitates infrastructural development and clean energy transitions, particularly in South Asian economies. However, when examining the broader environmental context, the relationship between GDP and environmental degradation appears more nuanced. According to Hameed et al. (2023) and Osuntuyi and Lean (2022), GDP has a negative impact on environmental degradation, suggesting that as economies grow, they may reach a stage consistent with the Environmental Kuznets Curve (EKC) where further growth contributes to environmental improvement through cleaner technologies, institutional reforms, and increased public awareness.

In contrast, several studies have found that energy poverty remains positively associated with environmental degradation. For example, Lan et al. (2022) argued that populations without access to clean energy alternatives tend to rely on biomass, kerosene, and coal, which contribute significantly to air pollution and ecological stress. This finding is further corroborated by Khan et al. (2022) and Acheampong et al. (2021), who found that energy poverty is correlated with higher household-level carbon footprints and lower adoption of green technologies in low-income settings.

Given these interrelationships, the current study introduces GDP as a moderating variable to explore how it influences the strength and direction of the relationship between energy poverty and environmental degradation. The underlying hypothesis is that while energy poverty on its own exacerbates environmental harm, rising GDP can act as a buffer by facilitating access to cleaner energy technologies, increasing environmental investments, and strengthening institutional and regulatory frameworks. Dogan and Seker (2020) also reported that economic prosperity plays a pivotal role in shaping national energy transitions, which in turn can offset the environmental externalities caused by traditional energy poverty.

In statistical modeling, this moderation is tested through an interaction effect (GDP × Energy Poverty) to capture conditional dynamics in environmental outcomes. Such an approach has been encouraged by scholars like Zhang et al. (2022), who suggest that nonlinear and interaction-based frameworks offer more accurate insights into sustainability policy design.

This line of inquiry is particularly crucial in South Asian countries, where populations are not only exposed to high levels of environmental degradation but also continue to face structural energy poverty. Countries like Pakistan, Bangladesh, and India face a dual challenge: achieving economic expansion while ensuring inclusive energy access. Adeleye et al. (2021) and Mughal et al. (2022) documented this phenomenon, highlighting that unless investments in sustainable energy systems accompany GDP growth, environmental degradation may persist or worsen. Understanding the moderating role of GDP is essential, as it can reveal how economic progress can be strategically leveraged to weaken the negative environmental effects of energy poverty, thus promoting long-term economic.

South Asia's temperature is above 50°C, more than the global average temperature (Karzani et al., 2022; Rashid et al., 2020; Zerafati et al., 2021). This study is timely, as it aims to explore the effects of energy poverty and the consumption of both non-renewable and renewable energy on environmental degradation, and to investigate the impact of economic growth on environmental degradation in South Asian regions.

1.2 The Rationale for Selecting the South Asian Region

This study examines the impact of energy poverty, economic growth, and various energy production sources on environmental degradation in South Asia, comprising countries such as Bangladesh, India, Nepal, Pakistan, and Sri Lanka. The South Asian region was selected for this study for several key reasons: increased pollution, economic growth, rising energy demand, availability of natural resources, climate conditions, geographical significance, and a growing population. All these are important reasons that make this area worth exploring.

According to IQAir (2021), South Asia is the most polluted region in the world, as most of the countries in the region are highly polluted. Bangladesh is the most polluted country, followed by Pakistan and India, with a difference of less than 10%. Nepal ranks 10th, while Afghanistan ranks 14th on the list. Increased air pollution has badly affected human health and tourism in this area. As a result, it has also affected the revenue generated by tourism and caused socio-economic shocks and spillovers (TERI, 2019).

Most environmental problems in the South Asian region are due to the transboundary character, as the burning of tropical rainforests in India has emitted CO2 that has severely polluted the environment of neighboring countries, including Pakistan, Bangladesh, and China. A collective response from all the neighboring countries is required to solve the issue of ever-increasing pollution in this area and to save the environment from further degradation.

The second important reason for selecting this area for the current study is its economic growth. The World Bank (2021) declared it the fastest-growing region due to its consistently increasing economic growth year after year; the South Asian region's growth rate increased by 7.1% from 2021 to 2022. These countries also have diverse economic outlooks, which helps them boost their economies. According to the United Nations (2019) report, the economies of Bangladesh, Bhutan, and India have better GDP growth than Pakistan. Moreover, the economies of these countries have increased manifold in recent years, as the World Bank 2021 report declared that Maldives was on the first number in the list of countries having the best GDP growth rate in 2021; India was on the 2nd, Bangladesh was on the 3rd and Nepal was on the 4th, while, Bhutan was at 5th and Pakistan was on sixth. In contrast, Sri Lanka ranked last on that list (World Bank, Fall 2021).

Another important reason is that the South Asian region is unique due to its generously available natural resources. Many natural resources, including seas, rivers, lakes, vast rainforests, diverse flora, and abundant fauna, are abundant in this area, making it rich in natural wealth. The South Asian region was selected due to its climate conditions and geophysical importance. It is a vast region comprising several countries and their neighboring nations. However, the environment in this region is often degraded, negatively affecting all the countries and their neighboring countries. Healthy environmental conditions in the South Asian region are believed to benefit the global community. It highlights a pressing need for collective and cooperative efforts to address the environmental issues in this area.

That is why this study is necessary. Environmental degradation in the South Asian region is a pressing issue, and examining it in this study is crucial. This research employed panel data econometrics to gain a deeper understanding of the issue and examined the relationship between energy poverty, economic growth, and environmental degradation. A review of previous literature showed that previous research using panel data econometrics to explore the nexus between energy consumption and CO2 in the South Asian region is rare.

1.3 A Glance at South Asian Nations

The South Asian region is located on the South Asian continent. This region comprises seven countries: Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka. South Asian's total land area is 5.2 million square kilometers, which is almost 11.71% of the total continent of Asia and covers 3.5% of the world's land area. Its estimated population is nearly 1.891 billion, one-fourth of the world's population. It is 39.49% of the total Asian population. It is the most populated region in the world. Figure 1.2 shows the Seven Countries and their capital cities in the South Asian region.

Figure 1.2 Map of South Asian Countries

Source: https://www.google.com.my/search

Table 1.2 describes the South Asian countries' names with their capital cities, official languages, populations, and land areas.

Table 1.1 Land Areas, Population, and Official Languages of South Asian Countries

Countries	Capital cities	Official Language	Land Area (km2)	Population growth (%)	% of the Rural population
Afghanistan	Kabul	Pashto	652,867	2.3035	73.686
Bangladesh	Dhaka	Bengali English	148,460	0.9754	61.054
Bhutan	Thimphu	Dzongkha	38,394	1.0684	56.992

India	New Delhi	Hindi English	32,873	0.9667	64.607
Maldives	Male	Dhivehi English Arabic	300	0.5679	58.898
Nepal	Kathmandu	Nepali	147516	1.8299	78.992
Pakistan	Islamabad	Urdu English	881913	1.9314	62.56
Sri Lanka	Sri Jayawardenepura Kotte	Sinhala Tamil	65610	1.0755	81.14

Source: World Development Indicators (2022)

The output growth performance in the South Asian region shows that GDP growth rates are currently improving, which is related to economies in South Asian countries. Bangladesh's average GDP growth rate has been 6.9% since 2021, while the Maldives' economic growth was 30.9628% in 2021. This region is one of the fastest-growing economies in Asia. The GDP growth rates in South Asian countries are shown in Figure 1.2.

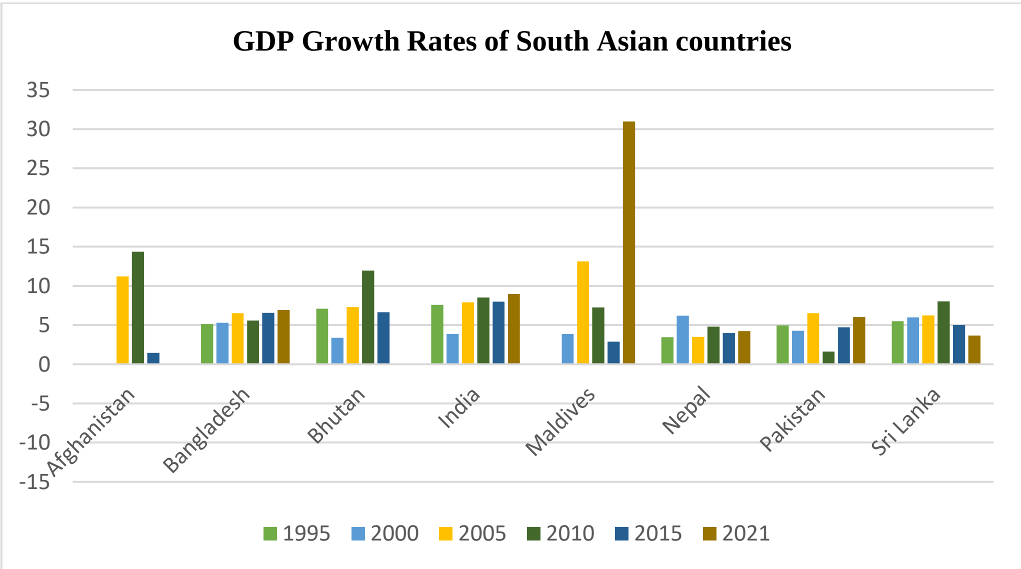


Figure 1.3 GDP Growth Rates of South Asian countries

Source: World Development Indicators (2021)

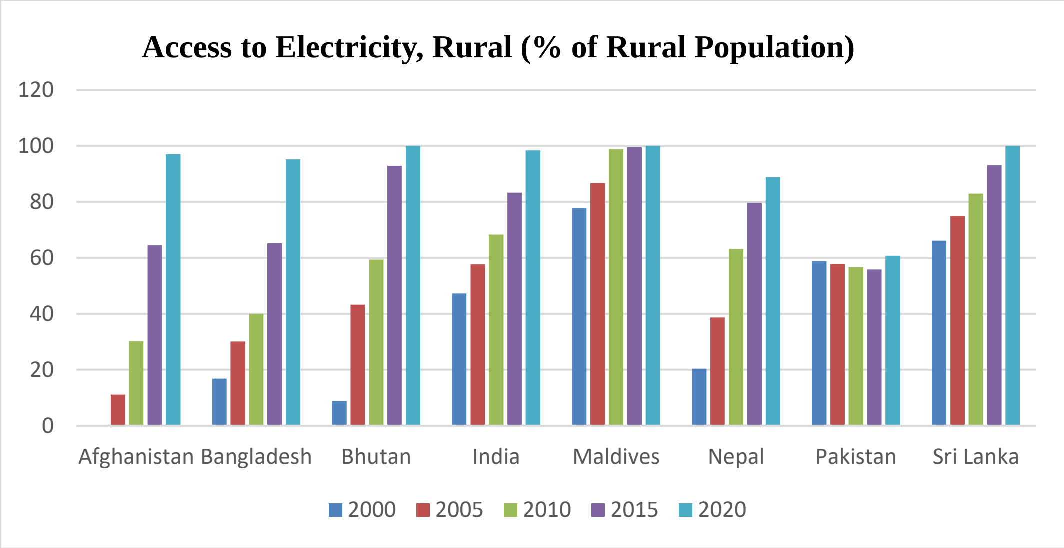
Table 1.2 indicates the population in terms of the percentage who have access to electricity. According to the World Bank (2021) report, access to electricity increased in South Asian countries between 2000 and 2020. In Afghanistan, India, and Bangladesh, 97.7%, 99%, and 96.2% of the population, respectively, had access to electricity in 2020. In Nepal and Pakistan, the population had access to electricity at rates of 89.9% and 75.379%, respectively. In Bhutan, the Maldives, and Sri Lanka, 100% of the population has access to electricity.

Table 1.2 Access to electricity (% of the Population)

Country Name	**2000**	**2010**	**2015**	**2019**	**2020**
Afghanistan	1.6135	….	71.5	97.7	97.7
Bangladesh	32	55.259	74.903	92.2	96.2
Bhutan	31.15	73.282	95.530	100	100
India	58.721	76.300	88	97.308	99
Maldives	83.8	99.156	99.706	100	100
Nepal	29.046	68.599	82.523	89.9	89.9
Pakistan	70.310	70.768	71.381	74.127	75.379
Sri Lanka	70.262	85.300	94.351	99.758	100

Source: World Development Indicators (2022)

Most households in rural areas use wood, straw, vegetables, or animal dung as energy sources for cooking, but these pollutants have a negative effect on people (Rasheed & Anser, 2017; Xu et al., 2020; Ahmad et al., 2020).



Source: World Development Indicators (2022)

Figure 1.4 Access to electricity, rural (% of rural population)

Although South Asian countries report high national electricity access rates ranging from 70% to nearly 100% as illustrated in Figure 1.4 and Table 1.2, this access remains insufficient to meet the population's actual energy needs. This insufficiency is mainly due to persistent regional disparities, particularly in rural and remote areas, where affordability and infrastructure limitations undermine consistent supply. Even in urban centers, many households experience frequent load shedding, electricity shortages, and poor-quality power, especially during peak summer and winter seasons. As a result, communities are compelled to rely on oil, gas, and coal to supplement their energy needs, a trend reflected in the increasing share of non-renewable energy use depicted in Figure 1.5. Over time, the consumption of non-renewable energy has risen not only due to inadequate electricity supply but also because of rapid population growth and expanding energy demands. Moreover, non-renewable sources continue to be widely used due to their traditional availability and relatively low cost in the South Asian energy landscape.

The need for high-quality energy access has forced poor people to pay a higher cost per unit of energy services. People with limited incomes are often compelled to use traditional energy sources, such as wood, animal dung, and crop residues, which are non-commercial and collected at no cost, rather than purchasing them. The increasing population has led to a shortage of resources, and women are primarily responsible for collecting these traditional resources for household use (Nawaz, 2021).

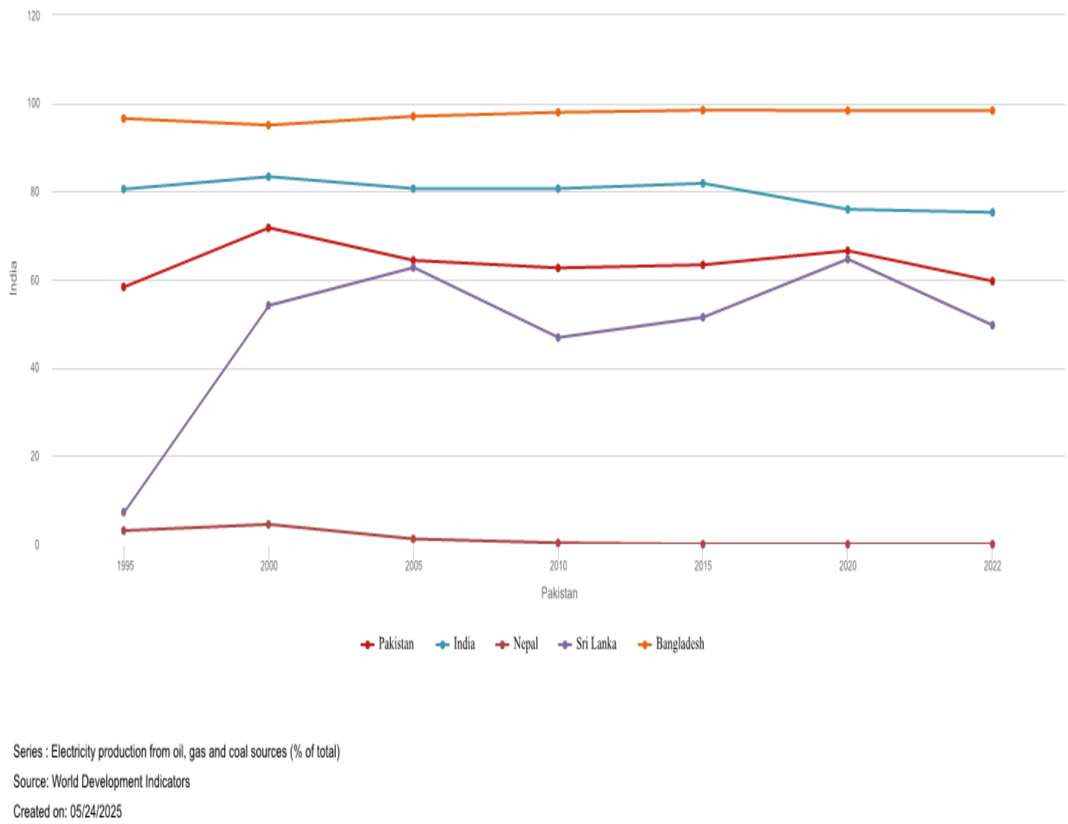


Figure 1.5 Electricity production from oil, gas, and coal sources (% of total)

Source: World Development Indicators (2022)

Figure 1.6 shows the percentage of final renewable energy consumption. Renewable energy is a costly way to produce energy; due to poor financial conditions, people cannot afford to use it in South Asia. Figure 1.6 shows a slight increase in renewable energy from 1990 to 2019.

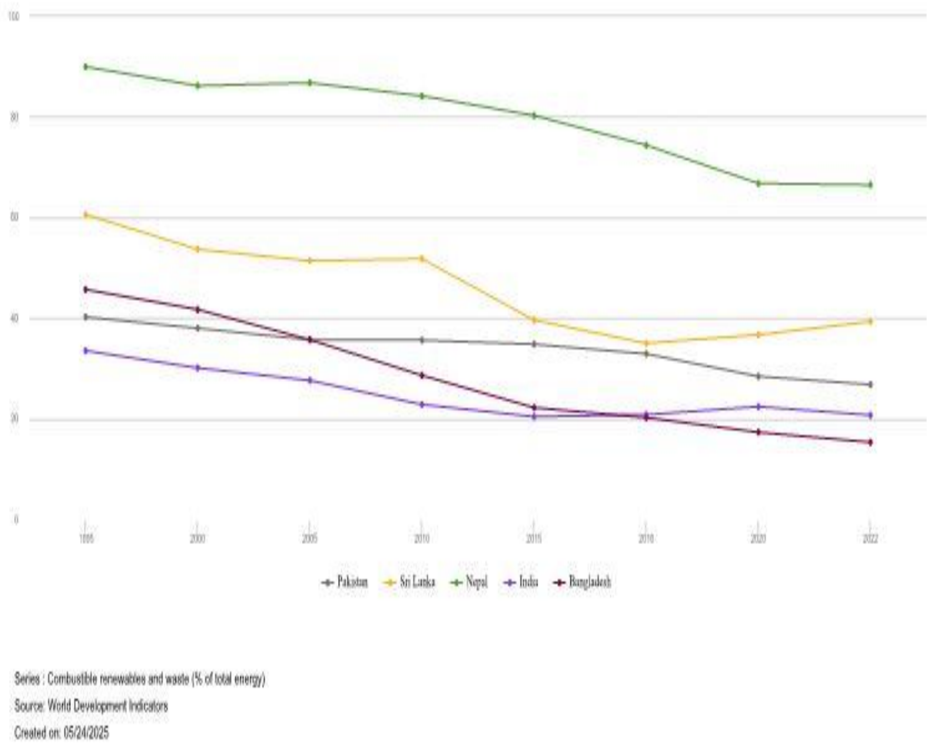


Figure 1.6 Renewable energy consumption

Source: World Development Indicators (2022)

CO2 emissions have increased steadily, and according to the World Development Indicator (WDI) database of the World Bank, South Asian countries have contributed to exacerbating the climate change problem by increasing CO2 emissions. Figure 1.7 illustrates that in 2022, global CO_2 emissions were dominated by a few key regions. The East Asia and Pacific region led approximately 31.5% of total global emissions, followed by North America (14.7%) and Europe and Central Asia (11.4%). In comparison, South Asia accounted for about 8.4% of global CO_2 emissions, translating to roughly 3.2 billion metric tonnes. Within South Asia, India was the primary contributor, emitting around 2.7 billion tonnes**,** approximately 7.1% of the global total, making it the third-largest emitter. Other South Asian countries, including Pakistan, Bangladesh, Nepal, and Sri Lanka, had much lower emission shares (e.g., Pakistan 0.6%, Bangladesh 0.3%).

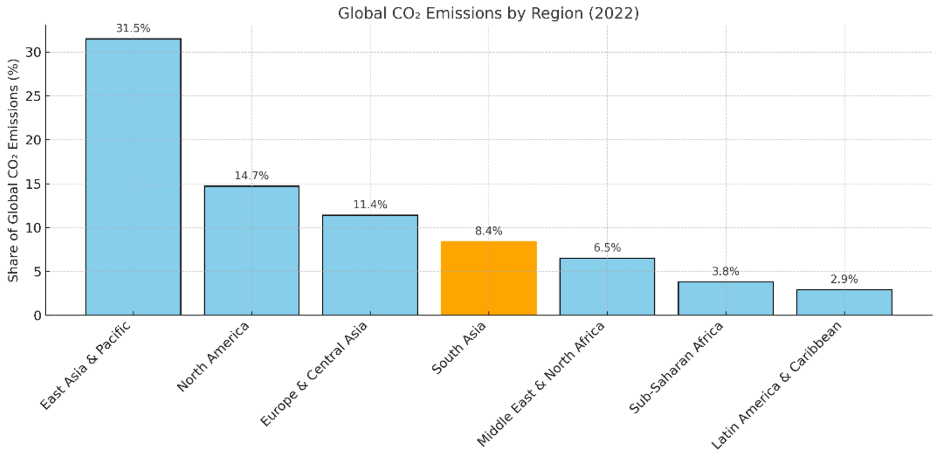


Figure 1.7 Global CO_2 Emissions by Region (2022)

Source: World Development Indicators (2022)

Despite this increasing contribution, South Asia's historical emissions and per capita contributions remain comparatively low. For instance, India's cumulative emissions from 1850 to 2022 account for only about 3.4% of total global emissions, while the United States and the European Union are responsible for approximately 25% and 22%**,** respectively (Our World in Data, 2023). Furthermore, per capita emissions in South Asian countries are among the lowest worldwide, with India emitting around 1.9 tonnes, Pakistan 0.9 tonnes, and Bangladesh 0.5 tonnes per person in 2022, compared to 14.9 tonnes in the United States and 8.2 tonnes in China.

While South Asia, particularly India, is emerging as a significant contributor to CO_2 emissions in 2022, its historical responsibility and per capita emissions remain considerably lower than those of more developed regions. This complexity highlights