THE ROLE OF RENEWABLE ENERGY IN REDUCING GREENHOUSE GAS EMISSIONS IN SELECTED SOUTH ASIAN COUNTRIES: PANEL DATA ANALYSIS

A Thesis

Submitted to the Master of Finance in Sustainable Finance Study Program at the Faculty of Economics and Business in partial fulfillment of the requirements for the degree of

Master of Finance in Sustainable Finance (M.Fin.)

by:

Mohammad Sadiq Mohaqiq

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UNIVERSITAS ISLAM INTERNATIONAL INDONESIA
DEPOK
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ABSTRACT

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This quantitative study explores the effect of Renewable Energy on Greenhouse Gas Emissions (GHG) in the selected South Asian countries between 2003 and 2021. The research-study is based on secondary data. It utilizes panel data and analyzes the data using STATA, a robust statistical software. Therefore, it sheds light on the complex relationship between investments in renewable energy and GHG emissions across the region. By separating the impacts of important explanatory factors on the dependent variable, this study employs Fixed Effects (FE) estimation to account for time-invariant unobserved heterogeneity across nations, ensuring more impartial and accurate results. Empirical results also depict a negative relationship between the use of renewable energy and greenhouse gas emissions, hence indicating that in the past 22 years, GHG emissions in South Asia have dropped drastically as its investment in renewable energy sources grew. It reveals the importance of renewable energy in mitigating climate change in South Asian Countries. According to the study, more investments in sustainable energy will boost economic growth and assist South Asian nations in achieving their sustainable development goals (SDGs). South Asia can advance sustainable development, equitable economic growth, and the welfare of its people by lowering the cost and increasing the availability of renewable energy in both urban and rural areas.

Keywords*: Renewable energy, Greenhouse Gas, Sustainability, Sustainable Development Goal, Climate Change, Environment, Economic Development, Education, Policy Efficiency, Per Capita GDP, South Asia, Fossil Fuel, Economic Growth.*

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CHAPTER I
INTRODUCTION

1.1. Research Background

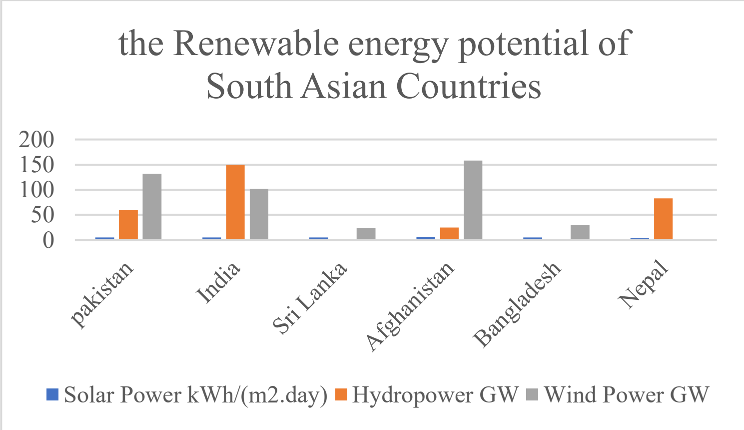
According to the National Renewable Energy Laboratory (NREL, 2001), Energy produced from naturally occurring resources that are continuously renewed and will never run out is referred to as renewable energy. These resources consist of biomass, geothermal heat, wind, water, and sunlight. Utilizing these resources, renewable energy technologies generate useful energy, mainly electricity but also heat, mechanical power, or chemicals. These technologies make it possible to meet energy needs without depleting the planet's resources by using nature's continuous processes in a sustainable manner. As highlighted by the International Renewable Energy Agency (IRENA, 2017), Renewable energies are more environmentally friendly and long-lasting than non-renewable energy sources like coal, oil, and natural gas. Technologies related to renewable energy efficiently convert the energy into electricity and heat. Utilizing renewable energies can solve major environmental challenges, enhance economic growth, and serve the betterment of society. In addition, renewable energies ensure a resilient, equitable, and sustainable utilization of energy sources, which provides us with the opportunity to take care of our future generation as well.

Insights from ERIA in 2023 emphasize that, in line with several regions across the globe, South Asian nations are progressively seeking methods to employ sustainable energy sources to tackle major issues involving energy security and sustainable development, and decreasing reliance on fossil fuels. In South Asia, the primary sources of renewable energy consist of hydropower, solar energy, wind energy, and, to a smaller extent, geothermal energy. Regions like Nepal and Bhutan take advantage of their ample water supply for hydropower generation, while India and Bangladesh are significantly allocating resources to solar power systems to utilize direct sunlight. Wind energy is increasingly becoming popular in India and Pakistan, taking advantage of favorable wind patterns. The varied geographical characteristics throughout the region, incorporating significant sunlight, wind, and water resources, afford considerable opportunities for South Asian countries to improve and extend their renewable energy sectors, encouraging a more eco-friendly and reliable energy future.

The economic, social, and environmental advantages of renewable energy are becoming more widely acknowledged in South Asian nations. According to the 2019–2020 report, 66,216 MW of South Asia's 1,53,888 MW renewable energy capacity comes from hydropower(Mitra et.al, 2023). A number of countries in the area, including Afghanistan, Pakistan, Nepal, and India, have made significant progress in implementing renewable energy sources like hydropower, wind, and solar. In a study which was done by Sahdev et. al (2023), Solar electricity in all the Indian states and union territories reached a 750 GWp yearly capacity during the period from 2017–18 to 2021–22, while its total capacity in 2021–2022 was 48087.83. Similarly, hydropower is crucial for Nepal and Bhutan, covering both their export earnings and meeting the local demand for energy. Whereas Bangladesh and Afghanistan focus on small projects for bringing electricity into the countryside with small-scale solar systems (Shukla et. all, 2017). The gradual move towards renewable energy sources reduces reliance on imported fossil fuels for energy-deficient countries like Bangladesh and Afghanistan, which are struggling with financial burden and economic instability. Long-term sustainability, reduction of air pollution, and improvement in the energy supplies are attempted by the nations through infrastructure development for renewable energies.

In a similar study by Rana and Gróf (2022), the potential of renewable energy in South Asian Countries has been explored. Based on the result of their studies, Afghanistan has the highest potential for solar energy with 6.5 kWh/(m^2.day), followed by Pakistan with 5.3 kWh/(m^2.day), preceded by India, Bangladesh, and Sri Lanka with 5 kWh/(m^2.day) for each, and Nepal with 4 kWh/(m^2.day). India, with 150 GW, Pakistan, with 59 GW, Nepal, with 83 GW, Afghanistan, with 25 GW, Sri Lanka, with 2 GW, and Bangladesh, with 0.3 GW, are considered ideal places for hydropower as well. In addition to solar and hydropower energy potentials, South Asian Countries are considered optimal places for the utilization of wind energy as well. Afghanistan holds the first position by holding 158 GW of potential for wind energy, followed by Pakistan with 132 GW, India with 102 GW, Bangladesh with 30 GW, and finally Sri Lanka with 24 GW as perfect places for wind energy. The potential of all South Asian countries for the utilization of renewable energy is depicted in the following chart.

Figure 1.1 The Renewable Energy Potential of South Asian Countries



Source: Author`s Creation using the result of a study by Rana and Gróf in 2022

This, in turn, can be used to accelerate economic growth within South Asia by creating more job opportunities within the renewable energy sector and increasing the supply of electricity in rural villages. subsequently, it will empower local communities and improve education, health, and the quality of life for the citizens of this region. Increased financing for renewable energy will also foster technological autonomy and innovation across the region.

The expanding importance of sustainable finance has a major impact on South Asian countries' shift to renewable energy. Green bonds, climate funds, and investment incentives are examples of financial products that support the growth of clean energy while maintaining long-term economic and environmental stability. For instance, India intends to boost green investments fivefold, with US$217.39 billion going toward renewable energy, reaching US$358.46 billion by 2030 (IBEF, Jan 2025). In addition, India is still resolute in its goal of achieving 500 GW of non-fossil power capacity by 2030. It declared in April 2023 that it would auction off 50 GW of new capacity every year in order to achieve this objective (IEA, 2024). In a similar vein, DFCC Bank of Sri Lanka showed growing investor trust in sustainable finance in December 2024 by issuing a green bond worth LKR 2.5 billion to promote solar energy projects. Reducing reliance on fossil fuels and speeding up South Asia's energy transition depend on these financial tools.

The growing recognition of green investment frameworks is further evident in the region's financial policies. In ASEAN, green bond issuance nearly doubled from USD 4.1 billion in 2018 to USD 7.8 billion in 2019, with two-thirds allocated to renewable energy and energy efficiency projects (ADB, 2020). South Asian governments and financial institutions are following a similar path, leveraging international climate funds, carbon pricing schemes, and public-private partnerships to expand solar, wind, and hydroelectric power. To ensure a just and affordable transition to a low-carbon economy, financial sustainability must be integrated into energy policies across the region.

The policymakers should be in line with the international agencies and regional stakeholders of private businesses in developing infrastructure policies and financial instruments that are necessary for the capacity utilization of renewable energy across South Asia. This could be a coordinated effort to realize a secure, sustainable energy transition with long-term economic stability, development of communities, and ecological protection for the region.

Although switching to renewable energy is thought to be a crucial way to lower greenhouse gas emissions and increase energy security, South Asian nations have not fully examined this relationship. Although renewable energy sources like solar, wind, and hydro help reduce carbon emissions, energy reliability may be impacted by their sporadic nature. This study investigates whether using renewable energy lowers emissions and improves energy security as determined by availability, cost, and dependability. Using a Panel Static model approach, Additionally, it additionally examines how switching from fossil fuels to renewable energy affects these results and evaluates the possible compromises necessary to maintain system stability and sustainability throughout the transition process.

In the final analysis, panel data from 2000 to 2021 have been investigated to assess the impact of renewable energies on lowering greenhouse gas (GHG) emissions across South Asian countries. The 2000–2021 timeframe was chosen because it illustrates how renewable energy was adopted in South Asian nations after 2000 and the COVID-19 pandemic's widespread economic effects in 2021, as well as political shifts in some countries, like Afghanistan, which all had an impact on the region's economic performance. This study intends to foster sustainability and offer perspectives on how the adoption of renewable energy can help promote environmental protection and climate change adaptation throughout the region and provide benefits to all contributing countries.

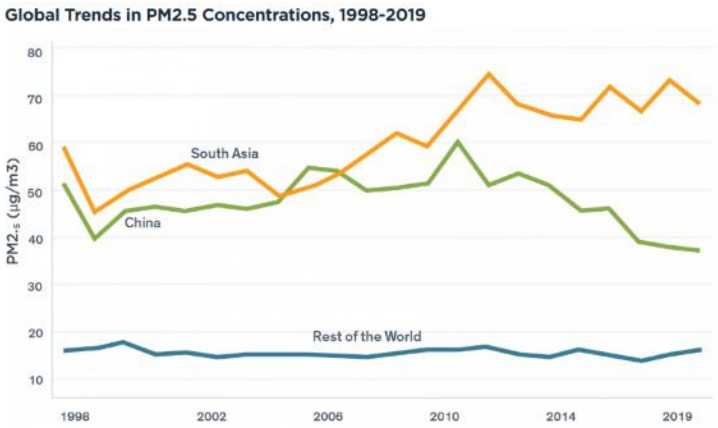
1.2. Problem Statement

As highlighted in a study by McMahon & Gray (2021), South Asian nations are particularly vulnerable to the impacts of climate change amidst severe environmental, economic, and social challenges in terms of extreme weather conditions, increased temperatures, and degradation of natural resources. According to estimates by the ADB, if the high-emission scenarios continue unabated in the South Asian Countries, by 2070, the

GDP of this region would fall by 17%. Besides, South Asian Countries have shown a tremendous rise in temperature. A study undertaken by Sivakumar & Stefanski in the year 2011 shows the increment of temperature in Bangladesh ranging from 0.5-1°C and India by an amount of 0.68°C per century during the period from 1985-1998. Nepal recorded an increase of 0.09°C per year, whereas Pakistan saw an escalation of 0.6 – 1.0°C in the temperature of coastal areas, and Sri Lanka encountered a 0.016°C surge in temperature from 1961 to 1990, which highlights the vulnerability of the region to climate change. This is further exacerbated by living in close proximity to China and India, two of the biggest polluters, whose industrial activities substantially increase the GHG emissions in the region. These cross-border emissions make South Asia's efforts to deal with climate change more knotty, raising the urgent need for viable solutions while at the same time posing great challenges to the mitigation strategies in the region.

The University of Chicago, Energy Policy Institute (EPIC) (2021), reveals serious environmental problems within the South Asian region. More precisely, Figure 2 shows an amazing increase in the level of PM2.5 within South Asia during a time bracket ranging from 1998 to 2019. Within these years, at the turn of the century, it shows South Asia accounted for an increasing average level of 35%, with much of the rest of the world fairly steady within these 20-odd years. With this increase, South Asia is now the most polluted region in the world and accounts for 38% of the global increase in pollution. The main contributors to these high levels of emission, expected to reach as high as 70 $\mu g/m^3$ in 2019, are heavy reliance on fossil fuels, uncontrolled urbanization, industrial emissions, vehicle emissions, and widespread burning of agricultural waste. The impacts are severe since emission levels in South Asia, which exceed the WHO Standards, account for 60% of all person-years lost throughout the world. If emission levels were reduced to meet these guidelines, residents of South Asia could live up to six years longer. That is a trend showing the dire need for the introduction of cleaner technologies and sustainable energy practices in the region.

Figure 1.2 PM2.5 Concentrations in South Asian Countries



Source: The University of Chicago, Energy Policy Institute (EPIC) (2021)

Additionally, based on the result of a study by Dialogue Earth in 2018, Bangladesh had the worst pollution in terms of PM2.5 emissions in South Asia, which was followed by Pakistan, India, Afghanistan, Nepal, Srilanka, and Iran, respectively.

Table 1.1 South Asian Countries by PM2.5 Emissions

Rank	Country	PM2.5 (µg/m³)
1	Bangladesh	**97.1**
2	Pakistan	**74.3**
3	India	**72.5**
4	Afghanistan	**61.8**
5	Nepal	**54.2**
6	Sri Lanka	**23**
7	Iran	**21.8**

Source: Dialogue Earth (2018)

In a similar study by Anadolu Agency (2021), on the air emission and environmental sustainability, it was an alarming situation as South Asian cities covered the entire top 10 in the most polluted cities of the world as of December 9, 2021. Among the cities with the worst air quality are three in China and India, two in Pakistan, and one in Afghanistan and Vietnam. This is indicative of South Asia's deteriorating air pollution situation, which is being caused by unchecked industrial expansion, automobile emissions, and fast urbanization. The number of South Asian cities on the list emphasizes how urgently hazardous emissions must be reduced, since they have a significant impact on environmental stability, public health, and sustainable development. three cities in China and India, two in Pakistan, and one in Afghanistan and Vietnam were chosen among the top nine in a chart of the cities with the worst air pollution. Such categorization exemplifies how the increasing environmental problems adversely affect South Asia, where there is growth in emissions, industrial outputs, and urbanization that compound the earlier issues. The high ranking of the South Asian cities has emphasized the urgent need that has to focus on overcoming pollution, which is threatening the health of the people, their living standards, and the lives of the entire region.

Table 1.2 Most Polluted Cities are Located in South Asia

No	City	Country
1	LAHORE	Pakistan
2	Wuhan	China
3	Hanoi	Vietnam
4	Kabul	Afghanistan
5	Beijing	China
6	Delhi	India
7	Kolkata	India
8	Karachi	Pakistan
9	Mumbai	India
10	Chungking	China

Source: Anadolu Agency for Environmental Research (2021)

Renewable energy is a primary pillar in the South Asian countries' energy policies; however, the ultimate aim of the policy is to mitigate greenhouse gas (GHG) emissions, achieve a low-carbon-based economy, and the achievement of energy security. However, due to the extended contacts with transboundary pollution, the achievement of these goals is hampered by this factor, which goes hand-in-hand with industrial and economic growth of the region. Therefore, renewable energy continues to be a critical policy in the chosen South Asian nations, but its effectiveness has continued to be handicapped by external pollutants, hindering regional industrialization and the expansion of their economies. It is not yet clear if the combined effects of local and external emissions can be reasonably prevented by relying on renewable sources of energy alone. Overcoming this challenge requires a better understanding of how renewable energy sources can be maximized to reduce greenhouse gas emissions significantly in spite of external influences.

1.3. The Objective of This Research

The main objective of this research paper is to study the impact of renewable energy resources on GHG emissions in South Asian countries. This vast and diverse region, with its diversified energy requirements and associated environmental issues, provides a unique opportunity to learn about and gauge the reduction in GHG emissions by the introduction of renewable energy alternatives like solar, wind, water, and biomass energy. This paper aims to follow a methodical approach in researching the viability of renewable energy in improving environmental sustainability and climate change in South Asia, and specifically on how significant the renewable resources are in addressing fossil-fuel-related emissions to a certain degree.

Among these goals, another significant objective is investigating the various reasons for adaptation to alternative sources of energy in South Asia, particularly for renewables. The current discussion collects the key constituents that influence the adoption of lean and the diffusion of renewable energy, which entail renewable forms of energy resource endowment, monetary incentive, technological development and innovation, socio-economic contextual and environmental regulations that prevail. The aim is to provide stakeholders, regulators, and policymakers with operational ideas through a clear study and assessment of these factors on how to strengthen renewable energy as the keystone of environmental protection and sustainable economic growth in the region.

The third aspect of the research involves aspects that determine the adoption of renewable energy from a South Asian perspective. Some of the determining factors include the availability of renewable sources of energy, the following of economic incentives, the advancement and enhancement of technology, the socio-economic conditions at hand, and the rule system that actually shapes the sector. By outlining these determinants, the research will proceed to offer practical recommendations that will strengthen the means to deploy and scale renewable technologies to make the energy source a cornerstone of ecologically and economically sustainable development in the region of South Asia.

At the same time, the review examines the main obstacles that limit the renewable-energy projects across the region. This is because barriers can be in the form of environmental boundaries, limitations on the use of technology, economic factors, as well as social-political forces that restrain growth and incorporation of green technologies. That is why it is critical to identify and resolve these obstacles to ensure the broader adoption of clean power and a sustainable, environmentally friendly South Asia.

The principal purposes of this research are articulated as follows:

1. To analyze the impact of renewable energy in relation to greenhouse gas emissions (GHG) in South Asian regions.

2. To explore the contributing factors, such as GDP per capita, Foreign Direct Investment (FDI), Education, and Policy Effectiveness on GHG emissions in South Asian countries.

In brief, this analysis aspires not only to underscore the possibilities of renewable energy in mitigating GHG emissions but also to furnish concrete suggestions for stakeholders throughout all sectors. By highlighting South Asia, this research strives to make a contribution regional symposium on sustainable energy strategies adaptation to climate change, ultimately backing the transition to a sustainable low-emission future for the whole region.

1.4. Research Questions

With the comprehensive background information that is provided above, the main research question of this study is to evaluate the impact of renewable energy on the GHG reduction in South Asian Countries in the study period. This involves analyzing the potential GHG reduction that is a result of utilizing renewable energy, such as solar, wind, hydro, and biomass, instead of fossil fuels. It aims to understand the efficiency of renewable energy sources on the environment in comparison to conventional fossil fuels. Understanding the correlation of renewable energy with GHG reduction is crucial to developing policies to contribute to the Sustainable Development Goals in the entire region.

The second question that this study aims to address is: What are the contributions of factors such as GDP per capita, FDI, education, and policy Effectiveness on GHG emissions in South Asian countries in the study period? To develop policies that can foster sustainable development, the following variables have to be analyzed and corrected: GDP per capita, Foreign Direct Investment, level of education, and policy performance. Identifying and addressing potential contributing factors like GDP per capita, FDI, Education, and Policy Effectiveness are crucial to developing policies in favor of sustainable development in this area.

In this regard, research questions of the study will be formulated as follows:

1- What effect did renewable energy sources have on South Asian countries' greenhouse gas emissions between 2000 and 2021?
2- What effects did variables like GDP per capita, foreign direct investment, education, and the efficacy of policies have on GHG emissions in South Asian nations throughout the study period?

1.5. Research Hypotheses

The given research topic explores the possibility of decreasing greenhouse gas (GHG) emissions in South Asian countries via renewable energy, and discusses the impact of the conversion of renewable energy on greenhouse gas reduction. The discussion is informed by relevant theoretical foundations, mostly the theory of Energy Transition, which explains the relationship between environmental deterioration and economic growth, among other elements.

The first hypothesis generates a correlation between the growth of renewable energy and the transition of greenhouse gases, that an increase in renewable energy installation will come along with bringing significant decrease in GHG emissions. At present, Fossil-fuel-based energy systems dominate South Asia's emissions profile; once these have given way to renewable sources, we should be able to see an overall downward trend. The second hypothesis continues in the argument that the influential determinants, namely, GDP per capita, educational attainment, foreign direct investment, and policy effectiveness, have a quantifiable impact on the GHG emissions in the region throughout the study period. Investment in and maintenance of physical infrastructure, renewable-energy technology, and an effective supporting policy environment tend to increase the effectiveness of efforts to reduce emissions.

H1: GHG emissions during this period are significantly impacted by renewable energy.

H2: During this period, GDP per capita, education, foreign direct investment, and policy effectiveness all significantly affect GHG.

1.6. The Significance of this Study

Power forms a fundamental factor of economic growth and sustainable development of South Asia. The growth patterns of the region are becoming more reliant on universal energy access, which in turn forms the foundation of innovation, job creation, and general development. The degree of reliable energy supply, especially of green nature, is positively correlated with GDP growth and an increase in employment. An increased amount of energy resources not only reinforces existing economic activities, but it also generates new jobs and leads to poverty alleviation. Especially relevant is the growth of renewable energy technologies, and in this regard, the use of solar, wind, and hydropower, as South Asia has many natural resources that are being poorly utilized.

Noticeable environmental and economic obstacles support the fact that renewable energy is a valid solution to impediments faced in South Asia. Chronic challenges such as air pollution, dust storms, and poor quality of air are endangering the health of people as well as the livability of society. These challenges can be addressed in integrating renewable energy in the region by reducing the dependence on fossil fuels, reducing greenhouse gases, and providing a power supply that is clean and renewable. With the current continued growth of renewable-energy investment, South Asia can set in motion an unprecedented transformational process that renders energy as a central pillar of economic development, thus making the economic activity in that region consistent with the goals of sustainable development. This would promote regional resilience and economic security, as well as a collaboration between the South Asian nations and an improvement in the reliability of power supply and stability in subsequent regional electricity systems.

In scholarly discourse of the renewable energy-sustainable finance nexus, the notion of policy effectiveness has received minimal focus, so far, compared to the claim that the shift away from fossil fuel to renewable energy is a dual agenda of greenhouse gas (GHG) reduction to using renewable energy, as well as sustainable development, especially in South Asian countries. Solar, wind, and hydro power may all play a role in the decarbonization of the energy systems; however, overall adoption of the technologies is typically limited by access to sustainable capital as well as the formulation of regulations that lead to favorable and effective adaptation. However, the majority of research has ignored this connection. Although Shukla et al. (2017) reviewed South Asian policies in controlling renewable energy, the authors failed to explore the synergy between policy implementation and financial instruments in the mitigation of emissions. Similarly, Tariq et al. (2021) failed to test the influence of the quality of governance on investment efficiency, but only attended to the green technologies. When exploring the sphere of commerce and renewable energy, Murshed et al. (2023) did not consider the policy environment that should be supportive of green finance and orderly transitions.

The paper challenges the claim of renewable energy uptake in South Asia to curtail emissions, especially in a situation where favorable governance setups and financially viable processes are projected. The authors check whether successful policy settings enhance the effect of the renewable investment plan, and thus boost decarbonization in societies. When supported by strong institutions, a swift transition away from fossil fuels might boost investor confidence and climate benefits. Even with greater RE capacity, however, poor legislative frameworks may lessen the benefit of financial assistance and impede emission reductions. In the context of decarbonization, examining the functions of renewable energy deployment and policy effectiveness offers valuable insights into the larger endeavors towards long-term climate goals and energy system resilience, especially in light of South Asian countries' developmental and regulatory limitations.

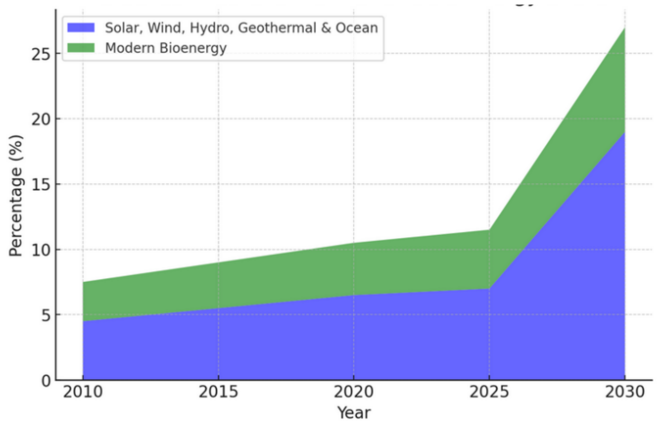
CHAPTER II
LITERATURE REVIEW

2.1. The Energy Transition Theory

Energy provision has been essential to human development. For cooking, heating, and construction, premodern communities relied on human and animal strength as well as biological energy sources, including wood, water, peat, and sun energy. Fossil fuels, especially coal, were increasingly employed in industrializing nations. The energy supply systems of today's modern societies are entirely dependent on electricity, gas, and oil, which are produced in a number of methods (Lagindijk & Verbong, 2012). In the past, shifts in cultural tastes, technological alternatives, and fuel shortages have prompted modifications to the supply system. Coal replaced wood in the eighteenth and nineteenth centuries. In the 20th century, this was followed by the switch to gas and oil, and after World War II, nuclear power was added. Wood shortages were a problem for pre-industrial society, but we now face almost insurmountable obstacles. We have developed a severe addiction to a steady supply of relatively inexpensive energy over the past century. However, it appears that coal and oil supplies are almost depleted, and the issue of global warming calls into question how humans are endangering the quality of life on Earth (Lagindijk & Verbong, 2012). There is no simple answer to the pressing need to alter our current energy system; historical research on energy transitions shows that these fuel shifts include protracted processes.

The shift to less carbon-intensive and more sustainable energy systems is centered on renewables, which include solar, wind, hydropower, biofuels, and others. Due to regulatory assistance and significant cost reductions for solar photovoltaics and wind power in particular, generating capacity has increased quickly in recent years. One of the key factors preventing the average global temperature from rising by more than 1.5°C is the use of renewable energy sources in the transportation, heating, and electricity sectors. Renewable energy sources enable nearly total decarbonization of electricity generation in the Net Zero Emissions by 2050 scenario. In the meantime, substantial emissions reductions in industry, buildings, and transportation are made possible by renewable heat and transportation fuels (IEA, 2024). The IEA report shows that the proportion of renewable energy in the overall supply has been rising consistently since 2010 and is expected to climb significantly by 2030, underscoring the speeding up of the global energy revolution (IEA, 2023).

Figure 2.1 Renewables' Share of Total Energy Supply in the Net Zero Scenario, 2010-2030



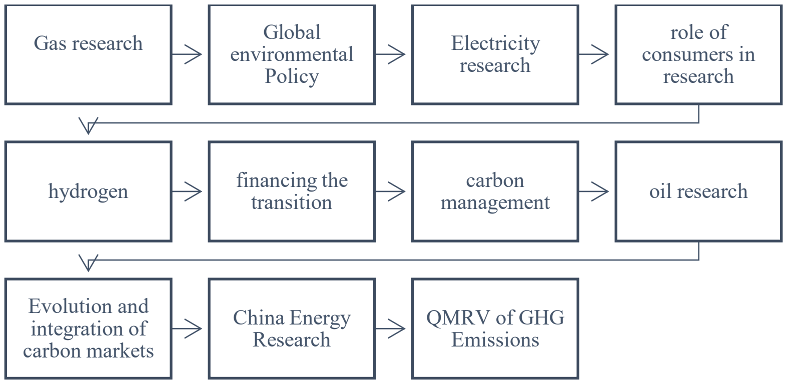
Source: IEA (2023)

The graph shows how, under the Net Zero Scenario, the proportion of renewable energy sources in the overall energy supply increased between 2010 and 2030. It displays a gradual rise from 2010 to 2020, then a notable uptick by 2030. This dramatic increase is a result of increased attempts to switch to sustainable energy. The significant increase in 2030 points to the need for extensive renewable energy projects and legislative actions to meet climate targets. All things considered, the data highlights the global energy sector's rapid transition to sustainability, which is consistent with net-zero emission ambitions.

A vast array of interrelated elements make up the energy transition, which aims to change the world's energy systems into ones that are lower in carbon and more sustainable. The development of renewable energy technologies like hydrogen, the growth and integration of carbon markets, and advances in gas and electricity research are important components. Global environmental regulations and efficient carbon management are essential, as is the requirement for funding plans to facilitate this shift. While regional efforts, such as China's energy research initiatives, emphasize the significance of localized approaches, consumer involvement—such as changing behavior and demand patterns—is crucial. These factors work together to propel the drastic change required for a sustainable energy future (Gitelman and Mikhail V. Kozhevnikov, 2023).

Figure 1 provides a clear and comprehensive overview of the crucial elements involved in the transition process by providing a thorough summary and visual representation of the necessary elements needed for an effective transition, including key considerations, tactics, and problems.

Figure 2.2 Key Themes Shaping the Energy System



Source: Oxford Institute for Energy Studies. (2023)

The efficiency with which present energy demands are satisfied is a natural topic for research and policy because the need for power in modern civilization is so obvious. New technology, including more renewable sources of generation, as well as new systems and institutions of provision, will undoubtedly be needed for a more sustainable future. They discovered that many communities today are working to replace finite fuel and coal-based energy sources with renewable energy sources. There are valid reasons to employ multi-level theories and models of socio-technical change in this context to demonstrate how and why technologies based on solar, biofuel, hydro, wave, or wind might endure and prosper in various configurations and at various scales (Lagindijk & Verbong, 2012). Alongside other bottom-up projects like local food sovereignty, green transportation, affordable smart housing, livable cities, cooperative social care, and more, several transition thinkers have been investigating grassroots low-carbon energy solutions in recent years. Several social scientists at Sitges gave inspiring examples of grassroots groups inspired by the goal of co-owning a renewable energy plant (Gismondi, 2018).

Academics, legislators, civil society activists, and business executives all agree that the shift to sustainable energy systems is a difficult task. Even if there is growing political and popular support for lowering the dangers connected to conventional energy systems, including resource depletion, geopolitical energy dependency, climate change, and environmental degradation, this complexity still exists. But there is hope thanks to the potential of renewable energy sources like solar, wind, hydro, and geothermal, as well as alternatives like nuclear, biomass, and even "clean" fossil fuels. These developments imply that, with combined effort and creativity, building a more resilient and sustainable energy future is not only desirable but also feasible (Pacala and Solocow, 2004).

Reliance on fossil fuels is still common despite tremendous attempts to diversify energy sources, lower energy usage, and create alternative technologies. It is anticipated that energy demand will increase dramatically, prolonging reliance on fossil fuels well into the twenty-first century. So why is this system so hard to change? (Verbong & Loorbach, 2012). Coal, oil, and gas are examples of fossil fuels that provide highly concentrated energy, which makes them effective for usage and transportation. On the other hand, because of their lower energy density, renewable energy sources like wind, sun, and biomass need far bigger regions to provide the same amounts of energy.

Energy transition in the transportation sector is another factor that contributes significantly to the transition process. According to the IEA report in 2023, between 2016 and 2021, the average yearly investment in road transportation, including spending on electric vehicles (EVs) and vehicle efficiency, was almost USD 40 billion in major emerging nations. Furthermore, this investment grew significantly in recent years, and by 2021, it was close to USD 60 billion. The roughly threefold increase in transportation electrification spending between 2019 and 2021 was a major contributor to this increase, whilst energy efficiency investments were mostly unchanged. Furthermore, a significant increase in yearly investment will be necessary to meet the climate goals established by the main emerging economies. Under the APS scenario, this investment needs to reach USD 150 billion annually between 2026 and 2030, eventually surpassing USD 230 billion annually by 2050. Such a large rise will require both international steps to guarantee more financial availability for low-carbon transportation in these nations and domestic efforts to improve the investment climate for clean energy (IEA, 2024).

Societal transitions are significant, wide-ranging changes that essentially change the structure of a society or its major components. These changes are the result of interrelated adjustments to institutions, policies, technologies, and personal habits. They call for close cooperation amongst stakeholders and involve a variety of actors. Systemic transitions are substantive reorganizations of socio-economic structures that act successively in causing shifts in actors between states of equilibrium. They develop at a slower pace and act by means of interconnectedness between networks, markets, and tendencies that emerge, proving the level of interdependence that is observed in modern society to be very high.

More recent system transformation scholarship has emphasized that transformative change requires a complete restructuring of economic, political, institutional, and socio-cultural spheres (Berkhout et al., 2009; Cohen et al., 2010; Stephens et al., 2008). In this regard, ethics should act as the yardstick that will guarantee that the technological advancements come with clear environmental motives. The level of influence that will be born within this framework must be long-term sincerity and in line with ethical imperatives that define a sustainable future (Jean-Louis Armand, 2019).

Major projects that are meant to shift to more renewable and cleaner sources of energy have gained increased significance in many states. The brightest example is the European Green Deal by the European Union, which outlined ambitious aims to reduce greenhouse gas emissions and become carbon-free by 2050. Some of these goals include the promotion of renewable energy, including hydropower, solar, and wind (European Commission, 2019). As it has already been outlined, the 13th Five-Year Plan of China in terms of ecological and environmental stewardship promotes structural investments in renewable-energy innovations, whereby, at the same time, the green-energy initiatives are being promoted and the use of coal is continuously being lessened (State Council of the People's Republic of China, 2016). In quest of the announced goal of generating 175 GW of green energy by 2022, as spelled out in the National Action Plan on Climate Change, India has committed itself towards increasing its solar and wind power capacities (Government of India, 2008).

2.2. Sustainable Finance's Role in the Transition Process

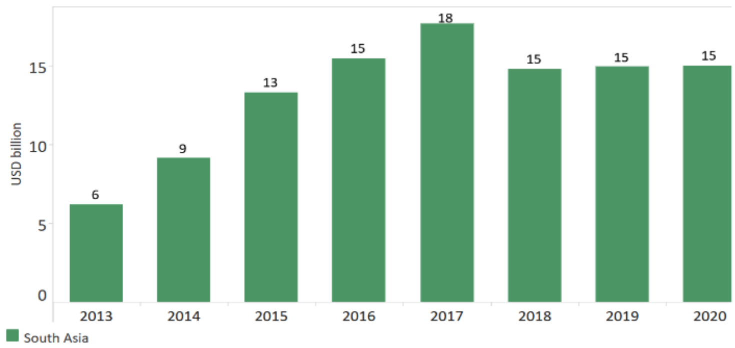
Sustainable finance plays a central role in the process of global energy transition and provides the capital required to produce clean energy. Despite the fact that, in marriage, the high initial investment and a risk that allow renewable energy implementation in certain countries in South Asia, innovative finance tools, such as green bonds, climate-specific funds, and specific investment incentives, enable the involvement of the private sector and project sustainability. Reduction of risks, encouragement of green innovation, and building the efficiency of policies altogether demonstrate how sustainable financing helps to shift the region towards a low-carbon economy.

Sustainable finance is an unavoidable tool that helps to reduce environmental risks and, at the same time, increase the pace of the switch to cleaner energy sources. As the analysis carried out by Sadiq et al. (2024) shows, green finance, especially green bonds, combined with long-term investments in research and development, can contribute to the diffusion of renewable-energy technologies and the economic sustainability of South Asia to a great extent. Although it indicates that increased expenditure on R&D is highly associated with the increase of access to green financing, the authors emphasize that these benefits entail some marginal trade-offs. In a similar vein, Kaewsaeng and Mehmood (2024) stress that the evolution of financial development dampens the level of environmental risk; properly planned policies may have the capability to reduce any risk to a wider range of consequences. These results further highlight how strong financial governance is key to pioneering a sustainable energy transition and reducing worldwide emissions.

In order to facilitate green economic growth in South Asia, sustainable finance is being recognized more and more as a fundamental instrument. Though South Asian countries have debated green growth on the global stage. Beekshan (2023) points out that Most countries have not shown decisive steps towards implementing good and environmentally sound policies, though India and Bhutan are known to be very good examples as exceptions. A good example is India, which is able to combine the concepts of sustainable development and economic growth and has attained high rates of growth, coupled with an air quality and health of the ecosystem that have remained high. As opposed to this, Bhutan has been in place as a role model of sustainable development with its Gross National Happiness framework as the foundation of its environmental governance. To attain long-term sustainability, South Asian economies have to rethink their existing predominant policy structures. According to Durrani et al. (2020), it is becoming more and more common that regional central banks become involved in facilitating sustainable finance. According to their survey of 18 central banks in the Asia-Pacific region, sustainability in central banks cannot be achieved without solid and strong legislation as well as the issuance of identified green financing incentives.

IRENA (2023) notes that the amount of green investment in South Asia has increased significantly during the past several years. It has gained momentum with the agglomerated figure soaring to an all-time high of 18 billion dollars in 2017, having previously been at 6 billion dollars in 2013, which represents a sharp determination towards growth in renewable energy. Although between 2018 and 2020, the allocation plateaued at around $15 billion, which implied consolidated-albeit slightly reduced- capital flow. The trend highlights a rising interest in this region in investing in renewable energy, an interest that is invaluable to long-term sustainability goals. This study is therefore valid to investigate the magnitude of sustainable finance to spur the move to renewable energy.

Figure 2-3 Annual Financial Commitments in Renewable Energy



Source: IRENA, 2023

2.3. Overview of Relevant Literature

The study by Mert and Bölük(2016) used a panel-based autoregressive distributed-lag (ARDL) approach to analyze the mutual relationship between foreign direct investment (FDI) and the use of renewable energy in Kyoto Annex countries, thus concluding that FDI enhances the diffusion of environmentally friendly technologies, which consequently puts the environment at par. The study also deduced that economic growth alone is not able to protect the environment and that renewable energy sources play an important role in carbon emissions reduction. In a subsequent study, Mert et al. (2019) examined FDI, renewable energy, and CO2 emissions in various groups of European countries. The empirical findings indicated that the 5th enlargement countries converged to EKC in the long run, while the 1st to 4th enlargement countries did not. Secondly, although the environmental regulations have not made much difference to PHH, they were quite crucial in establishing the validity of EKC for the EU. These works highlight that for the fulfillment of long-term environmental goals, the promotion of FDI and renewable energy is highly required; at the same time, it does not overlook the short-term regional discrepancies concerning the impacts of environmental policies.

Oyekale (2024) estimates the relationship between energy efficiency and GHG emissions by using a panel data analysis focused on the top five emitting countries in Africa. It can be seen from the study that most of the major African emitters are reconfiguring their production process to enhance energy efficiency. The research revealed that CO2 intensity and energy use intensity resulted in higher GHG, while the effect of GDP per capita and usage of renewable energy varies. The obtained results showed that, when moving to short-run analysis, the error correction mechanism was highly significant, with, for example, the case of Libya being significant for all emission proxies, and Algeria appeared to show significance in total GHG and CO2 per capita. The lower values of the reduced particulate emission damages in Libya and Nigeria contributed to lower GHG emissions, whereas the increased use of renewable energy increased the emissions in South Africa but reduced the emissions in Nigeria. The CO2 intensity has contributed much positively towards GHG emissions in South Africa, Egypt, Libya, and Nigeria. The loss in transmission of electricity is adding to the emissions in Libya and Algeria. The study shows the various impacts of energy efficiency measures on GHG emissions across different African nations.

Recent literature has analyzed the drivers of GHG emissions and environmental quality in South Asian countries, which are very complexly interrelated with energy sources, economic growth, and tourism. Rahman et al. (2023) studied that, in the long run, GHG emissions in selected South Asian countries are significantly influenced by renewable energy, fossil fuels, and nuclear energy, while population and GDP are not environmentally friendly factors for GHG emissions. In contrast, Mehmood et al. (2022) investigated the EKC hypothesis in South Asia and found that although CO2 initially increases with economic growth in countries like Pakistan and India, it may result in improved air quality after reaching some threshold. It also noted that there was a varying impact of tourism on CO2 emission across the region, depicting its positive environmental impact in both Pakistan and Nepal, while negative in the case of India. The findings thereby support customized environmental policies and the heterogeneity in the effect of tourism on environmental quality within the region.

Renewable energy helps economies separate economic progress from environmental damage. Therefore, it is essential to reach the utilization of renewable energy. The value of renewable energy as a means to reduce the anthropogenic impact on the emission of greenhouse gases has been accepted as a pivotal feature and has been empirically proved by the findings of Vasylieva et al. (2019), according to which the greater the share of renewables in the total energy consumption rate, the lower the carbon emissions. The cross-country comparative analysis by the authors that includes Ukraine, together with 27 EU member states, further highlights the importance of economic diversification and strong anti-corruption measures to succeed in the renewable-energy ambitions and reduce emissions. In their model, a reduction in emissions by 0.166103 % to 0.220551 % is associated with a 1% increase in the use of renewable energy. Such empirical observations affirm the claim that growing renewable energy does not contradict the direction of the Theory of Energy Transition, hence long-term sustainability.

The perturbation of the United Kingdom's centralized fossil-fuel reliant production and substitution, which allowed the development of the renewable energy distribution and decentralised systems (documented in Cheung and Butcher, 2019), highlights the essential role of leaders in legislation technology-wise. These advancements are geared to face eco-related pressures of the traditional dependence on fossil fuels, limit emissions, and strengthen energy independence. Another key pillar towards having a smooth transition is having modern renewable energy infrastructure throughout South Asia and other fast-developing areas. In addition to achieving sustainable development goals, such decentralization places economies in a position to enhance inclusive growth in an attempt to reduce ecological degradation in accordance with international demands. Compared to this, Shukla et al. (2023) reiterate the need to invest long-term in physical infrastructure and policy frameworks to tear down the barriers to the adoption of renewables in South Asia. In the sustainable development context, the authors argue that there should be specificity in the objectives and implementation of region-wide policy initiatives in the interest of enhancing the intended results. To this end, they propose assigning the elevated concern to the green-energy programs and accept the suggestion to propose the green-energy projects within the larger context of environmental sustainability.

The renewable energy transition paradigm has questioned quite stringently the correlation between greenhouse gas emissions and renewable energy implementation. It has been shown that with technological advancement in clean energy, environmental recovery is increasing faster, with the growth of economies. Ashiq et al. (2023) reveal that the increase in investment in green technology significantly reduces CO2 emissions, increases energy efficiency, and improves the performance of the economy in countries of the South Asian region. Corroborating this idea by Noor et al. (2023), renewable and non-renewable energies are equally endowed with critical significance as far as sustainable development is concerned. In their analysis, they end up concluding that a shift to renewable energy must become a necessity to reduce the long-run effects on ecology and preserve economic strengths despite the fact that the use of non-renewable power can accelerate growth in the short run. In conclusion, all these analyses support the transitional theory of renewable energy as they promote policy that embraces innovation to find a reasonable ground between environmental management and economic progress.

Rahman et al. (2023) support the assumption that increased urbanization in South Asia and developing economies harms the state of the environment due to the continued use of fossil fuels in the region. The authors stick to the idea that decoupling economic growth and environmental degradation may be addressed with the adoption of renewable energy, which is also supported by Sharma et al. (2023), who show that reliance on renewable energy significantly reduces the ecological footprint of emerging countries in Asia. Even though the currently observed factors of financial limitations and unstable infrastructure do not allow to implement sustainability-based energy technologies in the South Asian environment quickly, a range of bodies of knowledge formed in this area, as a whole, suggests that the principle of sustainable prosperity subject to environmental responsibility can indeed emerge as the force driving economic evolution because it allows sustaining the positive development of prosperity and the environment rather harmoniously.

The convergence of globalization, economic growth, and renewable energy projects in the process of implementation is a fertile, unstable ground on which an environmentally rich analysis of the possibility of sustainable growth can be evaluated. In South Asia, the agricultural sector has been serving as a linkage between ecological sustainability and economic growth. It is evident in the works by Wang et al. (2023) that unsustainable farming activities are the major contributors to increased levels of CO2 emissions, and the integration of renewable-energy technologies in farming activities would not only reduce these emissions but also contribute to environmentally friendly land-management activities. In line with these results, Tariq et al. (2023) stress the strategic value of energy efficiency and the incorporation of green technologies in reducing emissions and strengthening climate adaptability in the entire region. In their comparative analysis, it has been stated that South Asian nations stand a good chance to undertake a manageable change into a sustainable economic direction that minimizes greenhouse gas emissions and stabilizes the environment by redesigning their economic investments on clean technologies and renewable-source energy.

The empirical studies have raised a lot more questions about how Foreign Direct Investment (FDI) may affect environmental consequences. According to the study conducted by Mozahid et al. 2023, the states of South Asia show a two-way cause-and-effect relationship between FDI and carbon emissions: on the one hand, expanding FDI can drive economic growth; on the other, a FDI boom can increase environmental degradation due to channeling the investments in the options that are more carbon-intensive. The authors also stipulate that sustainable development may be achieved by focusing FDI on green technologies and renewable energy projects, and help the national economies to reach the “Green Technologies” threshold. At the same time, Murshed et al. (2023) assert that carbon emissions can be substantially trimmed down by regional economic integration and a gradual switch to renewable energy, in the case where trade regulations prioritize environmentally friendly forms of technology and align with overall environmental goals.

A refined understanding of the framework of energy transition can be gained through the consideration of the mutual interdependence between the social investment, i.e., spending in the fields of health and education, and environmental sustainability. Education investment, specifically, has some nuances of convergence towards environmental performance: Mehmood et al. (2023) show that further awareness on the part of the people and the implementation of the cleaner forms of energy sources are some of the less direct streams through which education expenditure may reduce emissions. At the same time, with the enhanced quantity of funds allocated to health care, which in turn is also connected to the reduced level of emissions, a feedback circle between the better production of environmental quality, enhanced human capital, and higher productivity gets initiated. This interconnected circle is in accordance with the environmental theory, which emphasizes far-reaching advantages of sustained policy interventions by demonstrating that the development not only reduces environmental degradation but also leads to improved societal welfare. The trend is supported by Khan et al. (2023), who outline the vitality of ISO 14001 certification and the availability of energy to citizens in the mitigation of emissions and the enhancement of the environment. The results of these studies collectively emphasize the importance of the multi-faceted approach that would combine the environmental and socioeconomic goals into the acceleration of energy transition.

Singh and Jana (2023) note, although globalization is mostly related to pollution and depletion of resources, the phenomena align themselves with strict environmental regulations and sustainable behavioral performance, which allows reducing the negative impact of globalization on the environment. Ikrama et al. (2023) continue to argue that food security and environmental sustainability are two sides to the same coin because enhanced renewable energy schemes and green certifications of agricultural products can unite countries behind the roadmap of sustainable development.

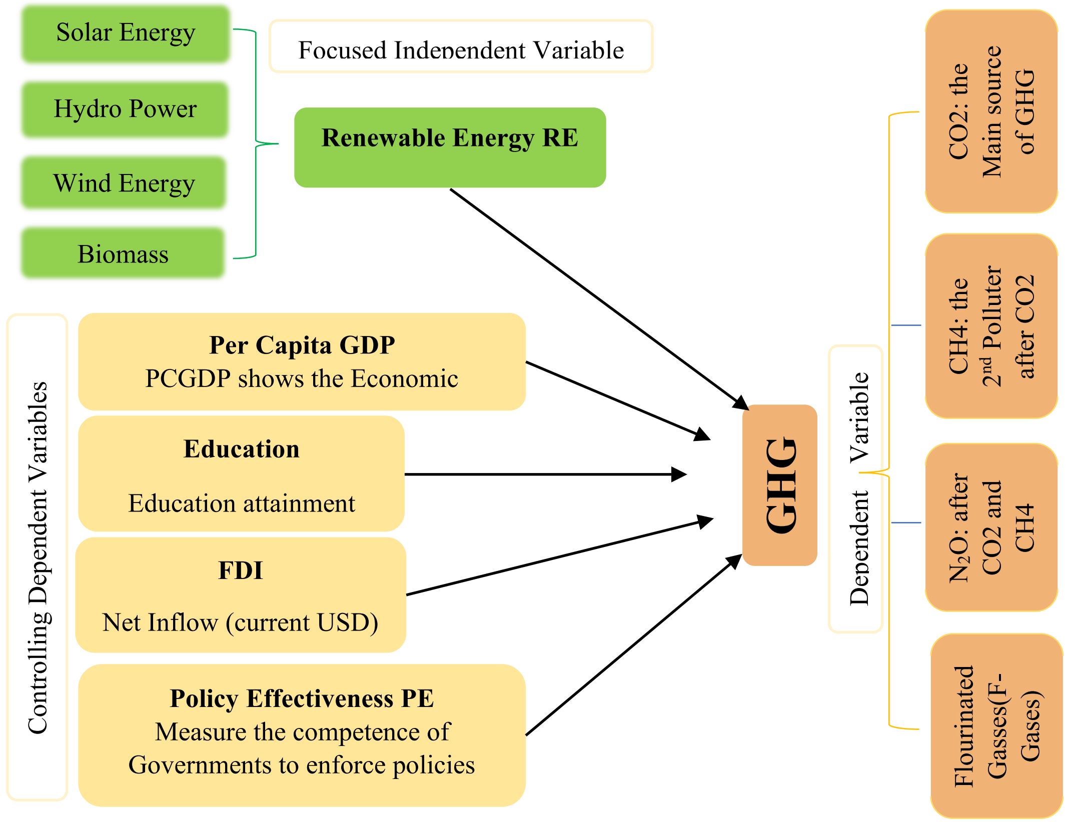
Renewable energy is one of the necessary systems that can help reduce carbon emissions and improve environmental sustainability in South Asia. Luni and Majeed (2020) emphasize the environmental benefits of renewable energy sources as compared to nonrenewable sources by showing that the shift in the proportion of the renewable energy share in total energy consumption by 4.51 % has a successful effect on mitigating carbon emissions. Simultaneously, Irfan, Mahapatra, and Ojha (2021) lay a long-term cointegration between the carbon emissions, energy efficiency, and renewable energy. Based on their findings, they state that on the one hand, renewable energy continues to reduce emissions, on the other hand, the impact of energy efficiency is not universal and depends on developing countries and the situation. What is more, Batool et al. (2022) examine the interaction between renewable energy, ICT, and financial development and indicate that renewable energy has both short-term and long-term positive effects on environmental quality. However, as the Environmental Kuznets Curve (EKC) theory predicts, economic development has two impacts: at first, an increase in emissions and then a decline in them. Comprehensively, these studies point out that specific actions and the extensive use of renewable energy sources are needed to enable South Asia to have sustainable development.

2.4. Conceptual Framework of the Study and the Variables' Explanation

In the current study, an energy transition framework within Energy Transition Theory that emphasizes a shift out of carbon-intensive energy systems to more sustainable ones is used. The main variables in this context are educational attainment, foreign direct investment, installations to harness renewable energy, effectiveness of policies, and per capita GDP, with each one of the variables representing or influencing the structural, economic, and technological changes needed to make GHG-mitigation feasible. The theoretical position, as informed by the previous research, is that renewable energy is the inevitable element to decrease greenhouse gas emissions, and the institutional, educational, and economic processes determine the environmental results together. There is a Panel Static Model that is applied as the empirical instrument to examine the impact of these variables. The framework advances knowledge of practical approaches to combating climate change by offering an organized viewpoint for investigating how these factors together affect GHG emissions in a subset of South Asian Countries.

Global warming and climate change are largely caused by greenhouse gas (GHG) emissions, which include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The main causes of these emissions include industrial processes, deforestation, agricultural practices, and energy generation (Gagnon & Doherty, 2012). Furthermore, according to a study by Afzal and Nishtar in 20203, due to South Asia's rapid urbanization, industrialization, and population growth, GHG emissions have increased significantly. The impact of significant emitters like China and India, which have economic and physical connections to other South Asian nations, exacerbates cross-border environmental issues and adds to the region's emissions.

Figure 2.4 Conceptual Framework of the Study



Source: Author Creation

The independent variable in this study is renewable energy, which comes from natural sources like sunlight, wind, hydropower, and geothermal heat. It is a vital component in reducing greenhouse gas (GHG) emissions because it is a sustainable substitute for fossil fuels. Renewable energy technologies are essential to the fight against climate change because, in contrast to non-renewable energy sources, they emit little or no carbon dioxide when in use. Adoption of renewable energy could help South Asian nations meet their expanding energy needs while also lessening the environmental damage caused by conventional energy sources (Paramati et al., 2017).

The per capita GDP has been accepted as a very important indicator of economic development and living standards; it represents the average income generated per individual in a country (Timmer & Zanden, 2014). In this paper, per capita GDP has been viewed from the perspective of an independent variable in order to assess its impact on

GHG emissions. It is acknowledged that with economic development comes higher energy consumption and industrialization, therefore increasing GHG emissions, particularly for developing countries whose economies rely heavily on fossil fuels (Ansuategi & Escapa, 2002). However, the trend of GDP and GHG is not consistent across the various stages of economic development. A previous study by Ansuategi and Escapa in 2002 has shown that in low-income countries, a rise in GDP is often accompanied by increased environmental degradation due to the expansion of industries and higher energy demand. In contrast, higher-income countries often show the decoupling of economic growth from environmental damage, where further economic development uses resources more efficiently, involves the adoption of renewable energy technologies, and follows more strict environmental regulations (Wu & Zhu, 2018). It is given that unless the national per capita GDP exceeds a certain level, governments in developing countries will tend to use green technologies, which tend to raise the energy efficiency in the country, and implement policies to cut emissions of GHG driven by the market. The intricacy of such a connection means that per capita GDP constitutes a very important explanatory variable in comprehending the association between economic growth and environmental sustainability.

Levels of education are an issue relative to sustainability and beyond the future of renewable-energy projects in South Asia, as we find that overall inequality in access to education and literacy prevails amongst the member states as well as South Asian subregions. Higher educational attainment augments the intensity of innovation in renewable-energy technologies, facilitates the implementation of the policy frameworks capable of assisting in reducing greenhouse-gas emissions, and provokes compliance with legislation practices that aid in attaining sustainability (Rahman et al., 2023).

Mahmood et al. (2022) show that sustainable energy technology adoption is drastically influenced by sound policy tools, namely carbon-pricing mechanisms, renewable-energy-project subsidies, and tight environmental laws. The countries that have more rigid policies are more likely to support the idea of public-private cooperation and drive investments towards renewable-energy technologies. On the other hand, the existence of a policy environment that is weakly enforced, with low levels of coordination or involving corruption, can deteriorate development and worsen environmental issues. In the current study, the dimensions of such policies are evaluated in relation to the effect on the correlation between renewable-energy deployment and the decrease in the emissions of greenhouse gases in the states of South Asia. The results found by Khokhar (2024) also contribute to the development of the idea that green bonds, tax incentives, and targeted subsidies are essential to the effectiveness of renewable-energy policies. He states that climate finance, especially the 40 billion dollars allocated to South Asia in 2015-2020, is essential to remove South Asian financial obstacles to renewables growth. Against this backdrop, India has already issued over ten billion dollars of green bonds, which have expanded renewable-energy projects, reduced investment-related risk, and mobilized the inflow of private money. Combined, the results suggest that the viability of renewable-energy policies greatly depends on the existence of sustainable financing systems, and this stronger adoption helps build a broader approach toward low-carbon energy systems and further emission reduction of greenhouse gases.

Foreign direct investment (FDI) and greenhouse gas (GHG) emissions are the two factors examined within the current model, and the special focus is on the emerging economies. The insights of the performed research, carried out by Abbas et al., in 2021 show that despite the common knowledge that FDI is linked to economic growth and transfer of technology, it may contribute to an increase in GHG emissions, should the capital be invested in an industry related to the production of goods, mining, or big infrastructure. In some countries of South and Southeast Asia, FDI is also used in the financing of industries that consume lots of fossil fuels, hence aggravating the emission of carbon. The paper hence contributes to understanding the environmental trade-offs that are associated with foreign investment and the nature of impacts of international capital flows to ecological outcomes by treating foreign direct investment as an independent variable. The use of the strategy provides a deeper insight into the factors of emissions other than those attributable to economic activity within the country or power production.

CHAPTER III
METHODOLOGY AND DATA

3.1. Methodology

The current study uses a panel data model with a static fixed-effects estimation to analyze the relationship between renewable energy consumption and emissions of greenhouse gas (GHG) in the South Asia countries from 2000-2021. Considering the formation of the linkage between the present outcomes of the dependent variable and contemporary values of the explanatory variables (renewable-energy use in this case), the usage of the static models, not involving any lagged variables, will be specifically appealing. The documentation of inter-country differences and changes over time is thus possible using these models since they incorporate both cross-sectional and time dimensions (Yafee 2003). Despite the possible underestimation of the effects of the unobserved, but not time-invariant determinants on the outcomes that can be produced by using such fixed specifications, they can be very useful when it comes to understanding relationships that are relevant at the same time; the issues in the underestimation of the results are also overcome when either of two strategies (introducing either fixed-effects or random-effects approach) are utilized (Seetaram et al., 2012). Fixed-effects method is especially appropriate in country-specific studies to explain the effect of economic and policy-related factors on the immediate environmental outcome.

In attempting to measure cross-sectional and temporal variations of GHG emissions, the paper utilizes a static panel-data framework to determine the impact of the cross-sectional aspect of renewable energy utilization, GDP per capita, and educational attainment, as well as FDI and policy efficiency, on the emissions. The framework, which assumes a contemporaneous relationship between independent and dependent variables, suggests that contemporary values of the regressors have a direct effect on the contemporary values of emissions. The panel design allows the researcher to control the heterogeneity not only in the time dimension but also country-wise, so as to mitigate the omitted-variable bias and accurately estimate the coefficients of the parameters. Considering the complications of environmental and developmental issues, and taking into account the complexity of the reality of most issues, the static panel models have continued to present a significant statistical tool to analyze the links between economic and policy-related determinants and the environmental outcomes over time and between countries.

Greenhouse gas emissions (GHG) represent the environmental variable, which is at the focal point of concern in the current empirical research, and is considered a central dependent variable. The first explanatory construct appears to be renewable energy (RE) proxied by either measure of installed capacity or energy consumption in the analysis. The other independent variables that will be introduced in the model were chosen deliberately to portray biological, economic, institutional, and social impact on energy transition. They are: GDP per capita (PC_GDP) as a proxy of economic development; education attainment (Edu) to indicate human capital and increased level of awareness in a society; foreign direct investment (FDI) as a proxy of inflow of capital across boundaries; and policy effectiveness (PE) as a proxy of effective environment governance. This selection of explanatory variables is in line with the theory of energy transition, which states that as nations transform their economies, over time they experience a gradual shift with regard to fossil fuel-intensive economies to renewable sources as one of the change through institutional and socio-economic transformation.

According to the energy transition theory, early economic growth is accompanied by increased emissions, but to a certain level of development, as soon as incomes increase, there is the development of cleaner methods of energy production (Gbadeyan et al., 2024). Education induces national advocacy of sustainable policy actions in that it makes society more conscious about the environment and increases demand for low-carbon development. Foreign direct investment (FDI) may bear either positive or negative results for the host country, depending on its institutional and legal framework. Therefore, Policy Effectiveness (PE), a statistic measuring the effectiveness of policy of government is considered to be central. Sound rules balance the ecological impact of the domestic and foreign economy and make economies more resilient to climate change by directing innovation, investment, and consumer behavior towards sustainability.

This empirical study converts into a stationary panel data model that covers the relationship of greenhouse-gas (GHG) emissions of countries with their contemporaneous covariations in the key independent variables, namely, GDP per capita, renewable-energy use, and policy frameworks. The panel structure thus incorporates the cross-country heterogeneity as well as time, and accordingly allows the analysis of the immediate dependence of macroeconomic outcomes on policy measures. In this respect, the role of static models is especially significant, since they explain the structurally meaningful factors of the level of emissions, which can explain the design of policy. In order to justify the specification of the model, a diagnostic test is put in place, like the Hausman test, to ascertain the model that is best fitted, which in this case is Random Effects or Fixed Effects estimation. By selecting the criteria that pass the statistically significant test outcome, one increases the validity of the findings and the reliability of further policy recommendations, as the model selected considers the possible correlation of the regressors and country-specific effects that cannot be observed.

The static panel data provide a perspicacious framework within which to have a multilayered association between the economic conditions, education, foreign investment, policy governance, and adoption of renewable energy as contributors to the emission of greenhouse gases in the context of South Asia. The empirical results demonstrate how much the policy tools could affect the course of decarbonization and, therefore, give practical evidence of developing regional and national policies that are necessary to hasten the switch to renewable energy sources. The explanatory ability of the current connections across several essential development variables and ecological outcomes transforms the static panel methodology into an advanced tool of analysis by policy makers interested in finding feasible ways of emission reduction. Also, the findings shed theoretical research into the scope of energy transition by investigating cross-national and time dependency. This study, therefore, makes a meaningful contribution to wider debates of climate resilience and sustainable development at a regional level.

3.2. Data and Sources

This study uses the databases generated by multilateral institutions, national statistical offices, and sectoral agencies. The main sources are the World Bank (WB) Development Indicators, International Renewable Energy Agency (IRENA), the Organization for Economic Cooperation and Development (OECD), the United Nations Development Programme (UNDP), the National Statistics and Information Association of Selected South Asian Countries, and different ministries of energy in South Asian countries. Such agencies provide standardized, tested data on renewable energy production, greenhouse-gas emissions, GDP per capita, educational achievement, government effectiveness, foreign direct investment, and other associated indicators. Though the study relies on assumptions underlying the dataset that can influence the output, the consensus and the scope of these reputable sources are useful in terms of analysis of the relationship between renewable energy and GHG emissions in the South Asian region.

This study uses panel-based data covering twenty-two years (2000 2021) to explore eight South Asian member countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. These are the countries that can be compared because of different economic regimes and policy frameworks, as well as the adoption of renewable energy. Using the period containing significant changes in energy policy, economic growth, education level attainment, and environmental regulation areas, as a period between 2000 to 2021, helps to provide a comprehensive evaluation of why renewable energy has a long-term effect on GHG emissions. Prolonging the duration helps identify tendencies and structural breaks, evaluate policy effectiveness, and, therefore, promotes the recommendations to the policies considering the region's priorities in achieving sustainable development goals (SDGs).

To accomplish the current research, a complex statistical analysis program of Stata was chosen as the main tool of the analysis. The ability of Stata to manage panel data, along with the feature that enables it to perform regression and econometric processes, helped to analyze the relationships at the level of variables comprehensively. Within this framework, the research team could gauge the causal structures, implement stringent regression specifications, and conclude on the effects of the use of renewable energy to reduce GHG emissions in the dynamic socio-economic landscape of South Asia.

3.3. The Econometric Model Equation

The available data that are considered in the given research can be used to find out how the implementation of renewable energy affects the greenhouse-gas (GHG) emissions in the countries of South Asia, and the main aim of the given research is to achieve the goals mentioned above with the help of panel-data methods, which have to be applied to a broad scale of data. The cross-national and temporal diversity used in this dataset makes the latter very appropriate to panel-data estimation. Taking into consideration the fact that unobserved country-specific factors are likely to covariate with explanatory variables, the Fixed Effects Model (FEM) could be chosen as the mode of estimation that would be preferred. The FE model reduces the probability of spurious relationships that would have otherwise occurred due to time-invariant non-observable heterogeneity across countries.

The assumption that any sovereign state has idiosyncratic, unchangeable features and characteristics such as institutional organizations, geographical environments, and regulatory regimes, among others, makes the utilization of fixed effects models (FEM) quite relevant. These models include nation-specific fixed effects that are usually confounded with the regressors, which makes them an ideal choice of parameters as they separate the inter-country variation over time (Asteriou & G. Hall, 2021). This research uses the framework of FE to delve into the impact that per capita GDP, education attainment, foreign direct investment, policy performance, and utilization of renewable energy have on lagged GHG emissions in South Asia. Such a research extension will escalate our understanding of the sustainable development trajectories in the region and provide more reliable information on the dynamically changing environmental behavior of South Asian countries. The model's general form is shown as follows:

$$GHG_{it}=\beta_0+\beta_1RE_{it}+\beta_2PC\_GDP_{it}+\beta_3Edu_{it}+\beta_4FDI_{it}+\beta_5PE_{it}+\mu_i+\varepsilon_{it}$$

Where:

a. GHG_{it}, which is in metric tons, denotes greenhouse gas emissions for country i in year t, serving as the dependent variable.
b. RE_{it}, which is the percentage of total energy consumption, is the main independent variable in this study.
c. PC_GDP_{it} represents per capita gross domestic product, indicating the income level.
d. Edu_{it} refers to educational attainment, reflecting awareness and environmental behavior.
e. FDI_{it} stands for foreign direct investment, the net inflow in current USD.
f. PE_{it} captures the overall effectiveness of national policy in achieving environmental outcomes. The system of laws is usually evaluated worldwide based on the World Bank Regulatory Quality Percentile Rank, a measurement that determines the ability of the state to forge and enforce sensible laws and regulations. However, the opposite is true regarding ranking and regulatory performance, where the higher the percentile, the better the regulatory performance, with the scale ranging between a value of 0-containing the minimal value of performance ever seen-and 100-Greatest performance.
g. μ_i is the country-specific intercept (fixed effect), accounting for unobserved heterogeneity across countries.
h. ε_{it} is the idiosyncratic error term that varies across both countries and time.

It is possible to link μ_i with the explanatory variables using the FE model. This is important in cross-country environmental analysis since the chosen regressors and GHG emissions may be influenced by unobserved country-level factors, including institutional quality, cultural norms, baseline environmental resources, and past industrial patterns. The FE transformation reduces omitted variable bias and yields consistent coefficient estimates under the rigorous exogeneity assumption by degrading the data (i.e., subtracting the within-country mean from each observation) and removing these time-invariant effects:

$$E[\varepsilon_{it}|X_{i1},X_{i2},...,X_{iT}]=0$$

This suggests that there is no correlation between the idiosyncratic error term ε_{it} and any explanatory variable over any period. Additionally, it is expected that future error words have no effect on the regressors, which is a prerequisite for causal interpretation. The marginal effects of each independent variable on GHG emissions over time within each nation are captured by the coefficients β_1 through β_5. In particular:

a. A negative sign indicates that greater adoption of renewable energy reduces environmental degradation. β1 measures the impact of renewable energy on emissions.
b. β2: Indicates the impact of economic expansion on emissions. Although a positive correlation between income levels and environmental deterioration is frequently seen in the early phases of economic growth, the degree and type of industrialization can have a substantial impact on this dynamic and change the anticipated results.
c. β3: argues that better education results in sustainable habits and environmental awareness, which are frequently linked to lower emissions.
d. β4: Indicates how much foreign direct investment contributes to emissions; the sign varies depending on whether the investment is going toward clean or polluting businesses.
e. β5: Assuming that better policy frameworks are associated with lower emissions, β5 takes into account the impact of domestic policy performance on environmental outcomes.

Both the inside transformation method and the inclusion of country-specific dummy variables (the Least Squares Dummy Variable, or LSDV approach) produce estimates that are quantitatively identical for the Fixed Effects estimator. With a reasonable number of entities and time periods, as in this study, the within estimator is computationally more efficient.

The study uses heteroskedasticity- and autocorrelation-consistent (HAC) standard errors grouped at the national level to guarantee robustness. Possible breaches of the classical assumptions, such as serial correlation and uneven variances across panels, which are frequent in macro-panel datasets, are corrected for by this modification. Additionally, the Fixed and Random Effects models are compared using pre-estimation diagnostics such as the Hausman test. The use of Fixed Effects is formally justified by a statistically significant Hausman test result, which verifies that the regressors are correlated with the individual effects (μi) (Gujarati & Porter, 2009).

With the use of this Fixed Effects specification, it is possible to estimate more accurately and internally how changes in a nation's income, human capital, foreign investment, policy enforcement, and deployment of renewable energy over time impact that nation's environmental performance. In the end, it backs up causal inference under tenable hypotheses and aids in identifying focused interventions to lower emissions and advance sustainability in the South Asian environment.

3.3.1 Greenhouse Gas Emissions(GHG)

In order to evaluate the effects of renewable energy on emissions reduction across South Asian countries, this study employs GHG emissions as the dependent variable. India plays the role of a pivot state in its region, and its sources of energy are largely in coal, whose emissions contribute significantly to the radiative balance is significant in neighboring regions. In addition, the geoeconomics of India, including the fuel imports, the manufactured goods, and raw materials flow, all capitalize on China's industrial output and its status as a leading global trading zone, consequently, further increasing GHG levels in the region. Any scientific, holistic approach towards reducing transboundary effects of climate should have a sufficient understanding of such interdependent dynamic states.

Maintaining economic growth and conceding at the same time, the undesirable environmental consequences caused by external sources of emissions are a twin mandate in South Asia. The lack of proportionality of the power exercised by China and India adds more hurdles to the issue of transitioning towards the use of renewable energy as a means of softening the effects of emissions. The current research highlights the complex interdependencies between regional emissions and reinforces the central role that renewable energy can play in reducing dependency on carbon-intensive activities by operationalizing GHG emissions as the dependent variable. Such a form of operation has a global resonance within the context of international climate and, at the same time, deals with local environmental problems.

3.3.2 Renewable Energy(RE)

Renewable energy acts as a separate explanatory variable to examine the changes in the modification of greenhouse gas (GHG) emissions paths in South Asia. Fossil fuel is the dominant energy mix in the area and continues to act as a significant source of GHG emissions (Salam et al., 2020). Institutional transition to renewable energy resources, especially hydropower, wind energy, and solar energy, is one of the key routes toward decarbonization. In addition, the wide availability of wind and solar in the region favors the incorporation of those sources into the domestic energy systems, and by doing so makes the overall emissions less, as well as reducing the dependency on coal and oil.

The economic sector and the community in society, along with the environment, are considerably impacted by renewable energy. It triggers socioeconomic growth since it fosters innovation, creates jobs, and increases access to electricity for the rural population. Evaluating the long-term and short-term impacts of renewable energy adoption on GHG emissions through the lens of policy implementation, technological improvement, and the current socioeconomic circumstances, this research paper seeks to do so. As the independent variable, the analysis highlights the vital role that renewable energy is playing in helping South Asian nations to realize a viable and green low-carbon future.

3.3.3 Per Capita GDP

The per capita gross domestic product (PCGDP) is a central indicator that can be used to judge the degree to which development processes in the South Asian states are balanced with sustainable resource management, since the two concepts (development and sustainability processes) have a reciprocal relationship. According to the data analysis provided by Timmer and Zanden (2014), due to the high volatility in PCGDP in the region, such differences could outline the different phases of the economic development of South Asia. In this way, the nations consisting of lower per capita incomes can raise the GDP rate higher than the environmental principle, but the monarchies with higher per capita incomes can invest in a renewable-energy paradigm and stricter environmental laws (Ansuategi & Escapa, 2002). Such a difference, in its turn, defines the potential of renewable-energy uptake in reducing greenhouse gas emissions. The current research is hence aimed at clarifying such pathways and assessing the mutual influences between economic prosperity and the implementation of sustainable-energy policies and, correspondingly, to environmental quality. Through the use of PCGDP as a causal variable, it interrogates the process in which development results affect the outcomes in the environment and the process in which a move towards sustainable energy transforms the region in terms of ecological factors.

3.3.4 Education

Education is one of the salient independent variables in the current investigation because it exerts significant effects on both individual and collective behavior, environmental sustainability, as is evident in this research by Rahman et al. (2023). Higher educational achievement, especially at the tertiary level, contributes to cognitive understanding of environmental problems, namely the adverse effects of greenhouse gas (GHG) air emission and the benefits of renewable energy. Professionals with high-level education are overly predisposed towards promoting and incorporating viable solutions, such as sustainable practices and cleaner technologies, in the individual decision-making process and group activities with regard to energy usage and environmental conservation. Besides, education provides scholars, corporate leaders, and policymakers with the necessary skills to develop and establish the appropriate strategies to mitigate GHG emissions and shift to green energy. It is on this basis that the current study also intensifies the importance of education in enhancing a more sustainable and environmentally friendly future in South Asia by examining its influence on the relationship between the adoption of renewable energy and decreasing GHG emissions.

3.3.5 Foreign Direct Investment(FDI)

The review of the role that foreign direct investment (FDI) plays in contributing to greenhouse gas (GHG) emissions requires the scope to treat FDI as an independent variable. The trend of delegitimizing the traditional fossil-based energy system in favor of cleaner and renewable sources of energy is enhanced by FDI. FDI can jump-start energy efficiency and usage of low-carbon technologies in the South Asian region, through funding innovative technology and renewable-energy infrastructure. The aspect to be highlighted by the current literature review is the ability of FDI to drive the energy transition, evaluating its relation to renewable-energy uptake and impending GHG emissions. The analysis proves that FDI promotes decarbonization and declines in the energy sector, correlating both results with increasing renewable-energy production (Tariq et al. 2022).

3.3.6 Policy Effectiveness (PE)

The current study establishes the fact that policy effectiveness (PE) yields a critical impact on environmental outcomes, especially on the management and suppression of greenhouse gases (GHG) emissions. In these terms, PE can be viewed as an independent variable denoting the quality and effectiveness of governance in terms of its application to the regulation of the environment, sustainable development, and ongoing energy transition. The Regulatory Quality (percentile rank) indicator included in the Worldwide Governance Indicators by the World Bank is the source of the corresponding variable. This indicator represents professional evaluations of the governmental ability to formulate and implement well-designed legislation and guidelines that promote the growth of the private sector (Mahmood et al., 2022). Annual data are available in most countries; data are reported as percentile ranks with a lowest of 0 and a highest of 100.

In the current analysis, the World Bank WGI Regulatory Quality (series GE.EST) stands as the main variable of influence in finding the Policy Effectiveness (PE). The WGI is a very established framework that has been updated every year since the late 1990s and measures governance in over 200 countries and territories. The governance instrument is based on the six composite characteristics, Voice and Accountability, Political Stability and Absence of Violence or Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption, which represent each of the distinct aspects of governance. The current study focuses on the Regulatory Quality, which measures perceptions of the government's ability to create and enforce consistent policies to promote the expansion of the business sector and support the achievement of increased sustainability goals.

The WGI (World Bank, 2023) uses more than thirty sources of data, and additional data are used in compiling it. Some of these sources include the World Bank, OECD, World Economic Forum, and regional development banks. These data incorporate enterprise surveys, household surveys, expert assessments, and business intelligence of the company. The Unobserved Components Model (UCM) is used to standardize and consolidate the heterogeneous governance indicators (i.e., survey questions and expert ratings) availed by the respective sources. This statistical model deals with the issue of measurement error, bias due to sources, in which measured measures are considered as imperfect indicators of an unobserved, underlying level of governance.

The UCM factors in the Regulatory Quality index as follows: regulatory burdens, market-unfriendly regulations, efficacy of licensing regimes, trade barriers, and government commitment to policy frameworks that foster development from the input that the UCM utilized in designing the Regulatory Quality index. The higher the scores, the better the regulatory regimes and extension-ranked policy efficacy. The score is then scaled on a standard normal distribution with a value of about -2.5 and 2.5. Each score has a margin of error given by the WGI to compensate for uncertainties caused by uneven data coverage and the reliability of the sources.

According to empirical evidence on regression analysis, policy intentions and carefully planned interventions are among the best ways through which environmental degradation can be mitigated to a great degree. This can be concluded by the negative and highly significant coefficient of PE that was obtained in this study. The examples of policy instruments, which have the ability to provide a measurable level of environmental gain, include the set of strict environmental policies, renewable energy incentives, and the promotion of clean technology development. The study uses the Fixed Effects estimator, which controls for key country-specific characteristics that would otherwise distort the PE coefficient; among them are geographic location and the cultural context of the country. Consequently, the research results confirm the need to fortify the institutions and governance to achieve sustainability in the long-term environmental desired goal(s) and economic growth, at the same time. Therefore, the PE indicator comes out as a central measure when governments are very concerned with tackling climate change successfully.

The variables used in the analysis are listed in this table along with their sources, units of measurement, and brief descriptions.

Table 3.1 Description of Variables and Data Sources

Variable	Indicator Used	Source	Unit of Measurement	Description
GHG Emissions	Total Greenhouse Gas Emissions	World Bank (WDI)	Metric tons of CO_2 equivalent	calculates a nation's total yearly GHG emissions. reflects the effects of climate change on the environment.
Foreign Direct Investment (FDI)	Current Net Inflows	World Bank (WDI)	USD (Current)	shows capital movement and investment patterns by representing the net inflows of investment from foreign companies.
Renewable Energy Usage	Renewable Energy Consumption (% of Total Final Energy Use)	IRENA	Percentage (%)	shows the proportion of renewable energy in a nation's overall energy mix.
Education	Population with at least some secondary education (aged 25+)	UNDP Human Development Reports	Percentage (%)	calculates the proportion of adults having at least a secondary education, which is a measure of awareness and human capital.
Policy Effectiveness (PE)	Regulatory Quality Percentile Rank	World Bank (WDI)	Percentile Rank (0–100)	captures the public's perception of the government's capacity to create and carry out sensible laws and policies. More effective governance is implied by higher values.

Source: Author`s compilation

Integrating sustainable finance methods to facilitate the shift to low-carbon energy sources is a critical component of policy Effectiveness in promoting renewable energy. Financial limitations frequently prevent the widespread use of renewable energy in South Asia; thus, government-supported green finance programs, tax breaks, and subsidies are crucial for getting beyond these obstacles (Sadiq et al. 2024). Between 2015 and 2020, South Asia got almost $40 billion in climate funding, with a large portion going toward renewable energy projects (CPI, 2021). Furthermore, green bonds have become a crucial instrument; by 2022, India alone issued more than $10 billion in green bonds to finance clean energy projects (Climate Bonds Initiative, 2022). Because these financial policies lower investment risks, draw in private resources, and guarantee long-term project viability, their efficacy has a direct impact on the success of renewable energy initiatives. As a result, this study views sustainable finance as a crucial element of effective policy in raising the use of renewable energy sources and lowering greenhouse gas emissions in South Asia.

3.4. Data Analysis

The current study examines the implications of renewable energy, gross domestic product per capita, formal education attainment, and foreign direct investment on greenhouse-gas (GHG) emissions in eight countries in the SAARC between the years 2000 and 2021. Early diagnostic tests reveal a prominent relation between the present explanatory variables and heterogeneity specific to nations, thus motivating the utilization of a fixed-effects (FE) estimation model instead of a random-effects (RE) analogue. Unlike in the RE model, the FE framework successfully soaks up any unobserved, permanent characteristics, which, otherwise, would somehow corrupt inference, making the estimation more accurate and resilient. Using intra-group time variation, the FE model provides a more distinct estimation of time-varying independent determinants on GHG emissions, and therefore, this makes it suitable for policy-related analyses because it can target distinct time changes in policy implications.

Even before estimating a Fixed-Effects model, a number of diagnostic procedures were carried out in order to ensure data quality and model validity. In particular, the heteroscedasticity, serial correlation, and cross-sectional dependence tests were computed to determine deviations of the accepted regression models. Since there was a sign of autocorrelation clustering and heteroscedasticity, robust standard errors were used, and the clustering level was at the year level. These adjustments have made the estimates represent real relationships as opposed to statistical noise or miscarried, which increases the statistical plausibility of the ensuing FE estimations.

The FE (Fixed Effects) employed in environmental economics can offer several benefits in times of analyzing the panel data. Replacing the between-country heterogeneity that is usually confounded by unobserved factors with within-country change over time makes the latter the target of inference. The orientation is especially useful in the environmental field of study, where major national differences in industrial composition, government or climate policy measures can significantly influence emissions levels, etc. Analysis confirms this advantage: F-tests and high inside R-squared demonstrate that the description of variation in lagged GHG emissions can be driven by the FE model to a significant extent. As a result, the FE model offers a more robust model to explain the time-varying, country-specific impacts of key economic and policy factors on the impact on the environment.

3.5. Addressing Endogeneity and Model Specification in Panel Data

Endogeneity has formed the major econometric problem facing panel-data models. Omitted-variable bias, measurement error, and reverse causality all may trigger endogeneity to bias the estimate of coefficients and threaten statistical inferences. To offset these risks, the current study will make use of a robust estimation plan, including a Poised econometric plan and diagnostics that can be applied to strengthen the reliability and consistency of the outcomes.

High-dimensional fixed effects (HDFE) estimated fixed effects of the presented study allow controlling heterogeneity between nations, which is unobserved. In such a way, it deals with time-invariant country-specific factors that may otherwise skew the association between greenhouse-gas emissions and an explanatory variable of deploying renewable energy, the effectiveness of policy instruments, foreign direct investment, per capita GDP, and educational attainment. HDFE methodology increases the internal validity of the regression findings and decreases the possibility of the omitted variable bias likely to happen when the analysis neglects the latent country-based variables.

In the given scope of macro-panel studies, the current study utilizes Driscoll-Kraay standard errors and fixed effects, a combination that can help address three common problems that include: serial correlation, an issue of graphical dependency of cross sections, and heteroskedasticity (Asteriou & G. Hall, 2021). When typical OLS assumptions regarding error structure are probably broken in multi-country, multi-period datasets, these resilient standard errors are crucial for getting correct inference. The robustness of the analytical approach is further supported by the results' congruence between the fixed effects estimation and the Driscoll-Kraay corrected model.

In line with the study by Asteriou and G. Hall (2021), the study used a Variance Inflation Factor (VIF) analysis to evaluate the possible risk of multicollinearity. The approach ensures that explanatory variables are not overly correlated, guaranteeing accurate coefficient estimates and preserving the model's interpretability, even though the specific results of this study are provided in Chapter 4. The stability and independence of the chosen regressors are supported by the low VIF values discovered during diagnostics.

This study tackles endogeneity issues with methodological rigor, thorough diagnostic checks, and a theoretically based model structure instead of instrumental variables or dynamic specifications. The combination of fixed effects, strong standard errors, and meticulous model definition provides reliable and empirically supported insights into the relationship between GHG emissions and environmental, economic, and policy factors in South Asia, even though causal inference is still constrained.

CHAPTER IV
RESULTS AND DISCUSSIONS

4.1. Descriptive Statistics

This study contains 176 observations of institutional, environmental, and economic variables in eight countries over 22 22-year observation period. The dependent variable, the emissions of greenhouse gas (GHG), has a great portion of disparity, showing an average of 434.25 with a relatively high standard deviation of 925.35. The obtained values vary between 0.63 and 3679.87, and these results imply that there exist substantial differences between the countries that were sampled in terms of industrialization level, energy use, and environmental policies. Any data distribution that results suggests that the panel-data regression model would have certain substantive evidence, especially because cross-sectional and temporal dimensions have been included. An in-depth study of the role of aspects like renewable-energy implementation or policy efficacy on greenhouse-gas emissions in the long run would thus need to reflect such inter- and intra-national heterogeneity.

The standard deviation of renewable energy consumption (RE) of 27.66 and a mean of 47.16 % can be classified within the independent variables, and hence, its use indicates the level of heterogeneity of consumption of renewable resources among countries is quite high. The values are between the minimum of 1.2 % and the maximum of 92 % with marked variations in renewable-energy utilization. The average per capita gross domestic product (PC_GDP) stands at 2405.16 USD, but this may be considered a low-income as well as high-income country since the standard deviation is high at 2642.7, and the range runs between 277.12 USD and 11,263.19 USD. This type of heterogeneity sheds more light on how income and technology interact in the determination of the environmental outcomes. The existence of a wide range of income levels can enable the identification of non-linear or threshold effects within the relationship between the environment and the economy.

Empirical results show that the average inflow cross-nationally of foreign direct investment (FDI) per year is 4.17 billion USD, with a standard deviation of 11.2 billion and a minimum of -16.6 million USD, and the largest figure being 64.4 billion USD. This volatility highlights the heterogeneous nature of FDI across states and years impacted by differing levels of political stability, regulatory regime, as well as the scale of the market. In Bhutan, another country, the outward FDI is reported to be higher than the inward flow, meaning that the majority of companies invest in overseas markets instead of investing in their own country. This result can largely be explained by the limited new-investment opportunities as well as a sense of pessimism regarding the outside investors. The gradual integration of FDI, which is a critical process of globalization of the economy, cannot be excluded as part and parcel of assessing whether these inflows translate to the development of lower-carbon technologies or increase emissions through industrial growth. Due to the extensive range of FDI figures, the established framework of a panel model allows an analysis of the complicated interaction between FDI and environmental sustainability and economic development.

Table 4.1 Descriptive Statistics

Var	Description	Obs	Mean	Std. Dev.	Min	Max
GHG	Greenhouse Gas Emissions (metric tons)	176	434.25	925.35	0.63 Maldives	3679.86 India
RE	Renewable Energy Consumption (%)	176	47.16	27.66	1.2 Maldives	92 Bhutan
PC_GDP	Per Capita GDP (USD)	176	2405.16	2642.71	277.12 Afghanistan	11263.19 Maldives
FDI	Foreign Direct Investment (USD)	176	4170000000	11200000000	-16600000 Bhutan	64400000000 India
Edu	Education attainment	176	32.39	20.49	5.12 Bhutan	84.1 Sri-Lanka
PE	Policy Effectiveness in Percentile	176	30.38	16.12	1.63 Afghanistan	81.52 Maldives

Source: Author`s Compilation

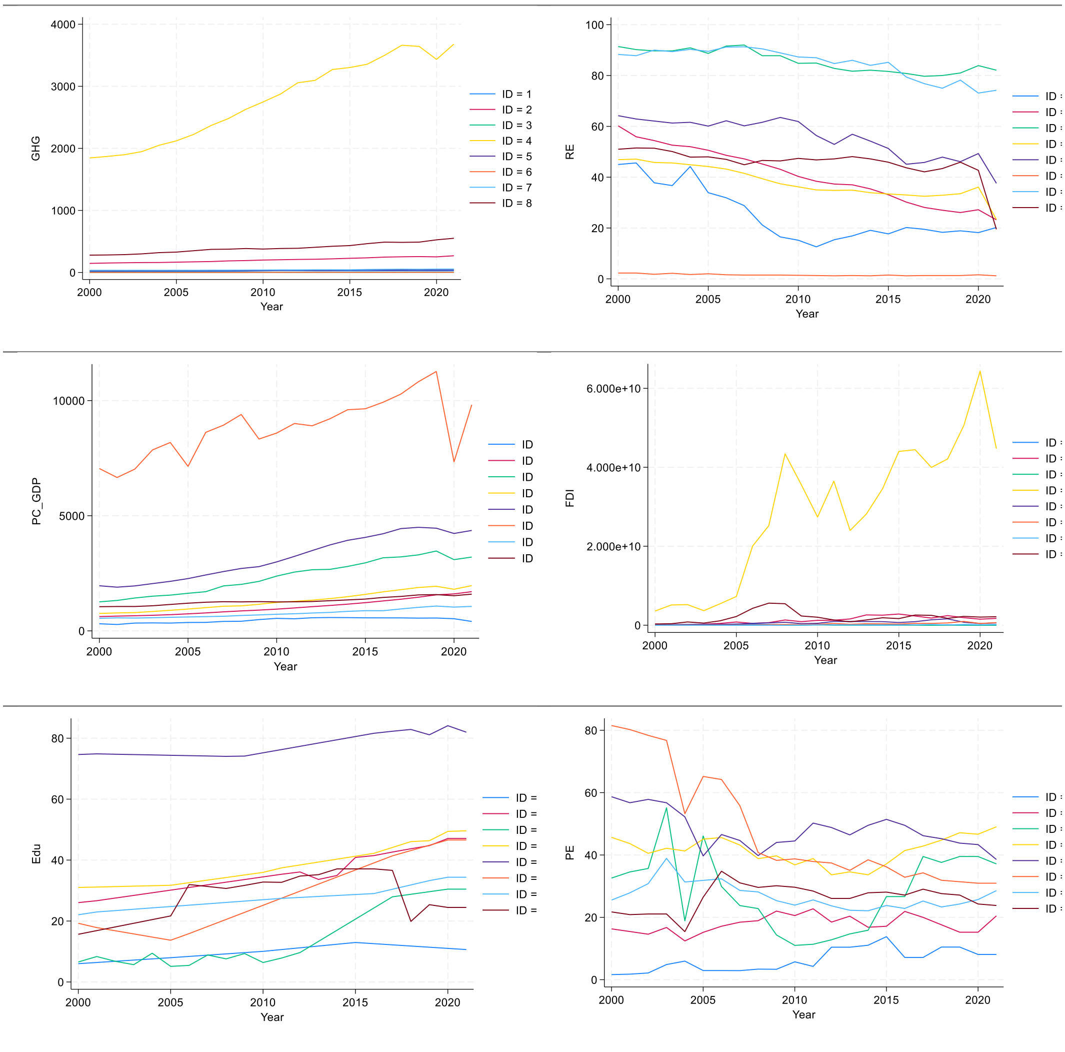
There is also notable diversity in the institutional and social elements. Education (Edu) ranges from 5.12% to 84.1%, with a mean of 32.38% and a standard deviation of 20.49. This suggests that public investments in human capital vary significantly among nations, which could have an indirect impact on emissions through environmental consciousness and technology uptake. Policy Effectiveness (PE) is limited to the scope of 1.63 to 81.52 with a mean value of 30.38 and a standard deviation of 16.11. These numbers help one to see the marked difference in the ability of governments to implement effective economic and environmental policies. Afghanistan ranks last with a score of 1.63, which describes a poor ability to contemplate and enact effective policies. On the other hand, the Maldives reports the highest PE value of 81.52, which shows better institutional capacity and strong governance in the country compared to the rest under study. The stark difference serves to underline the vast differences in the manner in which South Asian nations are interpreting administrative and economic agendas. Countries that have high values with regard to PE score are in a better position to support sustainable development and in the implementation of policy instruments, as compared to countries with low values, which may struggle with issues with regard to enforcement, coordination, and planning. Upon control of the non-market determinants of the emissions, the institutionalization of the factors would add significant components to the model. The descriptive statistics are, therefore, adequate support to implement fixed-effects regression to cater to the unobserved variability.

4.2. Graphical Analysis of Data

Here is an eight-year comparative visual review of various indicators of eight South Asian countries, 2000-2021. The greenhouse gas (GHG) emissions in India experience a sharp increase (ID 4), which denotes a significant contribution to the cumulative greenhouse emissions in the region. The GHG levels in comparison are very low in Bhutan (ID 3) and the Maldives (ID 6), which, on the other hand, continue to grow slowly in Pakistan (ID 8) and Bangladesh (ID 2). The utilization of renewable energy (RE) has been observed to decline on average across the region, with Bhutan (ID 3) and Nepal (ID 7) respectively maintaining the largest shares, though on a declining trend. Even though the Maldives shows a remarkably low use of RE consistently, India and Pakistan show small shares of RE. This contrasting trend of GHG emissions with the use of RE, hence, justifies additional econometric exploration.

There are notable differences in per capita GDP around the region. With steady economic growth, the Maldives (ID 6) stands out as having the highest income levels, followed by Sri Lanka (ID 5) and India (ID 4). Nepal (ID 7) and Afghanistan (ID 1), meanwhile, continue to be at the bottom. With notable oscillations and a sharp increase after 2005, FDI inflows are primarily centered in India. Most nations, including Bhutan and Sri Lanka, have steadily rising educational levels as shown by gross enrollment or literacy, whereas Afghanistan lags. While Sri Lanka and Bhutan exhibit greater stability, policy Effectiveness fluctuates, especially in Afghanistan and Pakistan. These variances highlight the structural distinctions across the nations and offer a starting point for investigating the relationship between emissions and renewable energy in the context of institutional and socioeconomic constraints.

Figure 4.1 Data Visualization of Key Variables by Country (2000–2021)



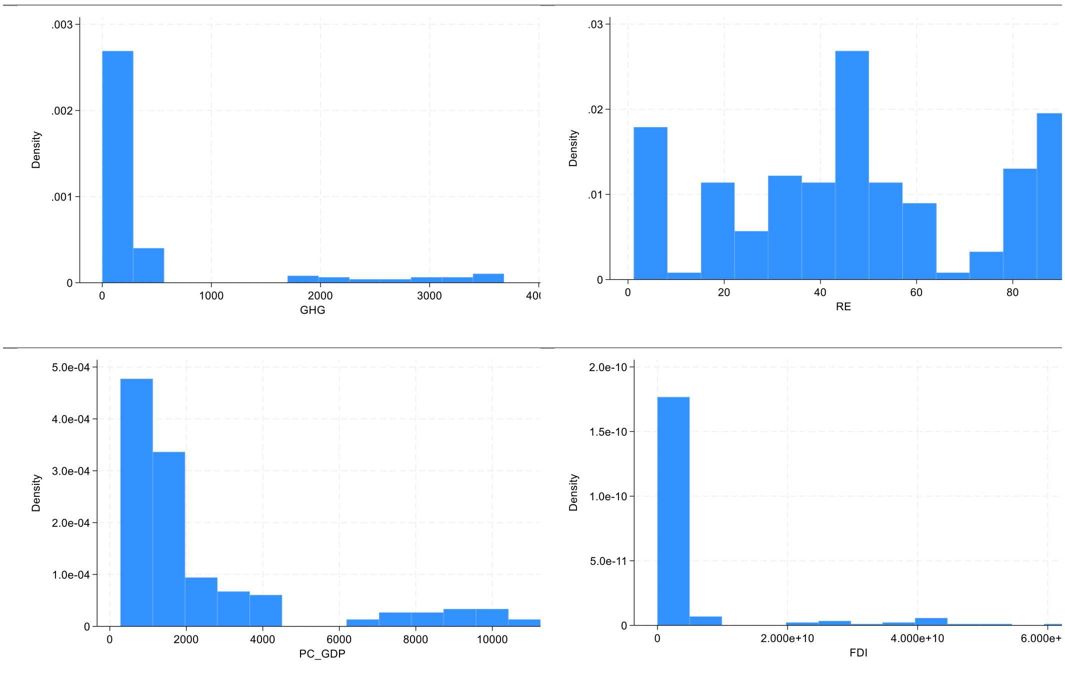
Source: Author`s Illustration

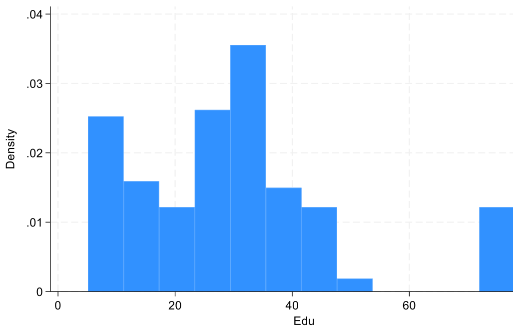
***Note**: ID1 stands for Afghanistan, ID2 for Bangladesh, ID3 for Bhutan, ID4 for India, ID5 for Sri Lanka, ID6 for Maldives, ID7 for Nepal, and ID8 for Pakistan*

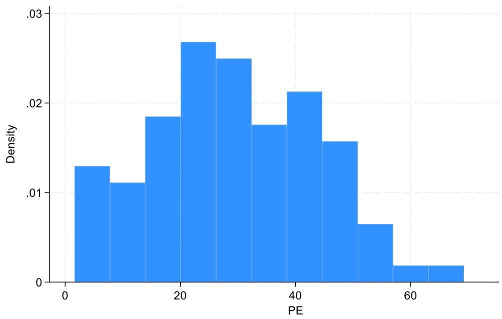
The distributions of the main variables utilized in this study are shown in the histograms, which provide a visual representation of their statistical properties. The multimodal structure of the logarithm of greenhouse gas emissions (GHG) distribution may be a reflection of structural variations in industrialization or environmental restrictions between nations. Emissions, for instance, are often higher in highly industrialized nations like the United States and China and lower in less industrialized nations and those with stringent environmental regulations, like Sweden. These variations contribute to the explanation of the distribution's several peaks. The renewable energy (RE) histogram indicates that different nations have adopted cleaner energy sources in different ways. The majority of nations are classified as middle-income, as indicated by the right-skewed distribution of the logarithm of per capita GDP (PC_GDP), which peaks at about 7. The trend analysis of foreign direct investment (FDI) over time would reveal a right-concentrated distribution with a majority of host economies receiving relatively small investments and a few jurisdictions receiving comparatively large investments than the average level.

The policy Effectiveness (PE) and education index (Edu) histograms highlight significant sociopolitical differences among the study countries. Although certain nations have attained noticeably high levels of educational development, the distribution of the education index is left-skewed, suggesting that a greater percentage of nations have comparatively lower levels. This disparity points to unequal access to high-quality education, which has a big impact on long-term economic growth and human capital. However, the distribution of policy Effectiveness (PE) is somewhat biased to the right, indicating that few countries have very effective governance institutions, while the majority function with moderate efficiency. Since development trajectories and environmental consequences are shaped by the effectiveness of both education and policy, it is imperative to capture these variances using reliable panel data analytic techniques.

Figure 4.1 Histogram Representation of Panel Data Variables (2000–2021)







Source: Author`s Illustration

4.3. Correlation Matrix

The links between the important variables employed in the study are shown by the correlation matrix. Foreign direct investment (FDI) and greenhouse gas emissions (GHG) have a strong positive correlation of 0.77775, indicating that higher levels of FDI are linked to higher emissions. This finding is in line with the studies by Shaikh et.al in 2024, which states that FDI contributes to the environmental degradation in South Asian countries. Even though this connection is somewhat large, multicollinearity is not always indicated by it. Other diagnostic tests, like the Variance Inflation Factor (VIF), were performed to evaluate this further. All independent variables, including FDI, had VIF values below the generally recognized cutoff (e.g., 5 or 10), suggesting that multicollinearity is not a significant problem in the model. The scale effect of investment-driven economic activity that fuels pollution may be seen in this connection. On the other hand, GHG and per capita GDP (PC_GDP) have a somewhat negative correlation (-0.4599), suggesting that emissions tend to decrease as economic development rises, perhaps as a result of better technology or stricter environmental laws. Policy Effectiveness (PE) and renewable energy (RE) have a weak or almost negligible connection, indicating that they do not significantly affect emissions in the short run but for the long term their impact will be remarkable in the long run.

In this context, renewable energy (RE) has a limited statistical link with the other economic and environmental aspects, as seen by its weak correlations with all other variables. Foreign direct investment (FDI) has the largest (although still moderate) negative correlation with it, at -0.3682. This could suggest that FDI is not primarily focused on the renewable energy industry. Similarly, the -0.3346 negative correlation between RE and per capita GDP (PC_GDP) may indicate that the switch to renewable energy sources is not yet having a major impact on the economies of the sample nations. It's almost zero connection with policy Effectiveness (PE) and education (Edu) suggests that environmental policies and education have not yet had a discernible effect on the uptake of renewable energy, or vice versa.

Per capita GDP (PC_GDP), a measure of economic development, has a strong positive connection with policy Effectiveness (PE) at 0.6449. This suggests that countries with higher levels of economic and environmental development likely to have more successful policies. Additionally, it has a modestly positive correlation with education (Edu) at 0.3854, indicating that economic progress is accompanied by the development of human capital. PC-GDP and foreign investment have a limited direct relationship, as seen by the modest positive correlation (0.0518) with FDI. This could be because FDI is sector-specific or influenced by institutional variables. The potential decoupling effect, in which economic expansion does not always translate into higher emissions—possibly as a result of cleaner technology or structural change—is highlighted by the negative association between PC_GDP and both GHG emissions and renewable energy.

A complementary relationship between these development indicators is indicated by the moderately positive correlations that education (Edu) and policy Effectiveness (PE) have with FDI and per capita GDP. Edu has a correlation of 0.4169 with FDI and 0.4773 with PE, indicating that nations with a workforce with greater levels of education may see bigger investment flows and that these nations are more likely to create and implement effective policies. The positive correlations suggest that institutional quality and education can raise a nation's appeal to foreign investors and promote long-term growth. On the other hand, their weak or negative relationships with GHG emissions and renewable energy imply that their environmental impact could not be immediately noticeable or might be influenced by outside factors like governance or industrial structure.

Table 4.2 Correlation Matrix

Variables	**LnGHG**	**RE**	**LNPC_GDP**	**LnFDI**	**Edu**	**PE**
LnGHG	1	-0.0143	-0.4599	0.7775	0.2574	-0.1046
RE	-0.0143	1	-0.3346	-0.3682	-0.0156	-0.0927
LnPC_GDP	-0.4599	-0.3346	1	0.0518	0.3854	0.6449
LnFDI	0.7775	-0.3682	0.0518	1	0.4169	0.1611
Edu	0.2574	-0.0156	0.3854	0.4169	1	0.4773
PE	-0.1046	-0.0927	0.6449	0.1611	0.4773	1

Source: Author`s Compilation

4.4. Some Diagnostic Tests

The current research study incorporated diagnostic practices to confirm that the empirical model is able to check robustness and reliability. To begin with, stationarity tests were conducted in order to determine that the variables were consistent across the period and thus would avoid spurious regression results. Multicollinearity was checked to identify high correlation among the explanatory variables that may skew coefficient estimates. The Breusch and Pagan LM test was then to be used to decide on which side is to be used: pooled OLS or random effects models, and the Hausman test on which of the two, random effects and fixed effects, best suited the specification. Tests of heteroskedasticity were also carried out in order to determine the non-constant variance of the residuals. Tests of panel correlation and cross-sectional dependence were used to test whether there was a correlation of a panel variable; they checked all the assumptions of the model and found that they were all met.

4.4.1. Checking for the Stationarity

To determine the stationarity of the variables that comprised part of the later regression presentation, panel unit root tests under the Im-Pesaran-Shin (IPS) procedure have been used. The results indicated that a huge proportion of the variables were not stationary at the level. The statistics of T-bar of GHG, RE, PC_GDP, Edu, and PE were greater than the statistically significant level of 5 % but their p-value was significantly higher than 0.05; thus, it is stochastic, and the mean and variance of the variables were not constant over time. FDI was the only variable that had stationarity at the level, and this was substantiated by the fact that the p-value was 0.0419, and this statistic was not significant as compared to a 5% critical value. Therefore, differencing of GHG, RE, PC_GDP, Edu, and PE is justified, but that of FDI is avoidable.

All variables that formed part of the non-stationary group were initially differenced once and then further examined to reduce the possible endogeneity effect of unit roots. Approaching the literature, the IPS test used at the first difference established stationarity of the differenced trend in the study of all the variables. D.LnGHG showed the highest signals of stationarity (T-bar = 4.9532; z-T-bar = 6.7591; $p = 0.0000$), whereas D.RE ($p < 0.01$) and D.LnPC_GDP ($p < 0.001$) exhibited stationarity signals. Such results support the use of the variables in differenced form in a regression treatment and demonstrate that it is integrated of order one, I(1).

The potential of comparability and methodological consistency is produced through the application of the IPS test with intercept-only specifications to all the variables. Since the time effects are already comprised in the data set plus the fixed effects design of the model, there is no necessity to exclude a time trend in the test of unit root. Statistical significance of T-bar was to be evaluated using the critical values of one percent, five percent, and 10 percent, namely -2.190, -1.990, and -1.880, respectively. The T-bar of every differenced variable lies below the 1 percent mark, hence cross-verifying the strength of stationarity. As such, first differencing makes all variables stationary.

Table 4.3 Checking for the Stationarity

Variable	t-bar Statistics	z-t-bar	P-Value	Critical Values (1%, 5%, 10%)	Stationarity
LnGHG	-0.3929	3.7048	0.9999	-2.190, -1.990, -1.880	Non-Stationary
D.LnGHG	-4.9532	-6.7591	0.0000	-2.190, -1.990, -1.880	Stationary
RE	-0.6711	2.8537	0.9978	-2.190, -1.990, -1.880	Non-Stationary
D.RE	-4.8640	-5.4102	0.0000	-2.190, -1.990, -1.880	Stationary
LnPC_GDP	-0.6601	2.7986	0.9974	-2.190, -1.990, -1.880	Non-Stationary
D.LnPC_GDP	-3.9621	-5.4589	0.0000	-2.190, -1.990, -1.880	Stationary
LnFD	-2.1261	-1.7291	0.0419	-2.190, -1.990, -1.880	Non-Stationary
Edu	0.1148	5.6101	1.0000	-2.190, -1.990, -1.880	Non-Stationary
D.Edu	-3.5513	-4.3048	0.0000	-2.190, -1.990, -1.880	Stationary
PE	-1.9200	-1.3830	0.0833	-2.190, -1.990, -1.880	Non-Stationary
D.PE	-5.4490	-7.2398	0.0000	-2.190, -1.990, -1.880	Stationary

Source: Author`s Compilation

According to the IPS unit root test, there exists a need that the non-stationary panel data must be pre-adjusted before it can be estimated. The findings show that all of the analysed variables, except FDI, cannot be considered stationary at the level. Unfortunately, without differencing, the presence of FDI would bring in a predominant influence in the regression and affect the tainting of the following results. After first-differencing, all the variables, except FDI, met the stationarity requirements, and the null of the existence of a unit-root on the rest of the time series was decisively rejected based on p-values. The dynamic panel analysis used in the research was, therefore, statistically valid. Differencing normalises the variance, weakens the trends, and reduces the effects of autocorrelation, promoting the trustworthiness of regression values and the validity of the drawn conclusions on the study.

4.4.2. Checking for the Multicollinearity

Another factor that is capable of skewing the regression coefficients and hence invalidating the inferences made on the basis of the model is known as multicollinearity, where there is a high pairwise correlation between the explanatory variables. He or she often deploys the Variance Inflation Factor (VIF) test to determine this problem. When VIF is above 5, then multicollinearity is potentially problematic; when the VIFs go above 10, the problem is usually severe. In the current application, all VIF values, the greatest of which is 2.24 for PC_GDP, are highly below the critical values, implying that multicollinearity is insignificant.

The exploratory variables run through the regression analysis, which were PC_GDP, Policy Effectiveness (PE), Education (Edu), Foreign Direct Investment (LnFDI), and Renewable Energy (RE), have VIF scores of PC_GDP 2.24, PE 1.98, Edu 1.72, LnFDI 1.62, and RE 1.53. Since all these VIF values are reasonably low, there is no significant linear relationship among the independent variables. Computed VIF scores have all centered around a mean of 1.82, which ascertains that multicollinearity does not present a convincing topic in the dataset. The model will therefore render credible and strong coefficient estimates.

Lack of multicollinearity in the given analysis is supported by the inverse VIF estimates (1/VIF), which range between 0.44 and 0.65. The findings, therefore, imply that there is an acceptable level of independence between and among the independent variables, which in turn makes the interpretability of the regression results beneficial. The lack of multicollinearity in this study, which examines the relationship between renewable energy consumption and greenhouse gas emissions, guarantees that the estimated effects of each independent variable—particularly RE—are not muddled by linear relationships with other predictors. This strengthens the econometric analysis that follows and the model's policy implications.

Table 4.4 Variance Inflation Factor (VIF) Results

Variable	VIF	1/VIF
LnPC_GDP	2.24	0.446656
PE	1.98	0.506282
Edu	1.72	0.581631
LnFDI	1.62	0.617661

Variable	VIF	1/VIF
RE	1.53	0.651963
Mean VIF	**1.82**	

Source: Author`s Compilation

4.4.3. Burech and Pagan Lagrangian Multiplier (LM) Test

The suitability of employing a random effects model instead of a straightforward pooled OLS regression is assessed using the Breusch and Pagan Lagrangian Multiplier (LM) test for random effects. The null hypothesis in this test states that there is no panel impact, and thus, pooled OLS would be suitable since variances between entities are assumed to be zero. The test result indicates that the null hypothesis is strongly rejected, with a chi-squared value of 95.53 and a p-value of 0.0000. This implies that a random/Fixed effects model is better than pooled OLS and that there is substantial variation among cross-sectional units (i.e., countries). Therefore, to generate objective and effective estimates, the model must take unobserved variability into account.

Additionally, the estimated results indicate that the individual-specific effect (u) has a variance component of 0.2624701 with a standard deviation of roughly 0.5123184. The variance of the idiosyncratic error term (e), on the other hand, is only 0.0116362, suggesting that unobserved individual effects, rather than random noise, account for a significant amount of the error variation. The significance of capturing cross-sectional heterogeneity is confirmed by the significant difference between the two error components, especially in panel data spanning several South Asian nations. The empirical result supports the use of the advanced modelling methods, namely, the random effects or fixed effects model, in order to provide a more accurate measurement of the determinants of greenhouse-gas emissions, especially focusing on the influence of the renewable energy technologies, and to validate the panel structure of the data used.

Table 4.5 Breusch and Pagan LM Test for Random Effects

Component	Variance (Var)	Standard Deviation (SD = √Var)
LnGHG	5.868061	2.422408
e (idiosyncratic error)	0.0116362	0.1078713
u (panel-level effect)	0.2624701	0.5123184
Test; Var(u) = 0		
Chibar2(01) = 95.53		
Prob > Chibar2 = 0.0000		

Source: Author`s Compilation

Test Hypothesis:

- H_0: Var(u) = 0 (No panel-level variance; pooled OLS is appropriate)
- H_1: Var(u) ≠ 0 (Panel-level variance exists; random effects model is preferred)

4.4.4. Hausman Specification Test

The suitability of the fixed impacts (FE) or random impacts (RE) model was tested by use of the Hausman specification test, whose aim is to contrast the precision of the RE estimates with the consistency of FE estimating. The p -p-value of 0.0000 and Chi2 value of 85.77 make the null hypothesis, which asserts that the differences in the coefficients are not systematic, unsustainable. Since this model, which includes the fixed effects, addresses unobserved heterogeneity between countries that correlates with or relates to the explanatory variables, the finding implies that the most suitable option available to such a panel data analysis is the use of this fixed effect model. As a result, the fixed effects model is the underlying basis of the interpretation of the results of the study, which is more accurate and consistent in terms of the coefficient estimations.

The extra analysis of the Hausman test on the compatibility of the effects confirms the Hausman test results since the estimates of parameters between the fixed-effects (FE) and random-effects (RE) regression differ significantly. Take an example of PC_GDP: the coefficient of its fixed effect is 0.1640958, and the coefficient of its random effect is 0.0112375. The fixed-effects estimation has a standard error value of 0.0326266, which makes the difference between the two coefficients significant at $p < 0.0001$ value with a magnitude of 0.1753333. Such strength attests to the extent to which country-specific influences left out in the RE model take a critical bearing on growth in terms of per-capita GDP. When analyzing the relationship between GDP and greenhouse gas emissions, it is crucial to account for unobserved variability, as evidenced by the larger size under the fixed effects model.

Likewise, there is a noticeable difference between the FE and RE models in FDI. The random effects model displays a positive value of 0.0100211, but the fixed effects model estimates a negative coefficient of -0.0052362. With a standard error of 0.0017622 and a difference of -0.0152573, the RE model's bias from missing variable correlation is further supported. This implies that, based on unknown, nation-specific characteristics, foreign direct investment may have varying environmental effects. When country-specific characteristics are taken into consideration, the fixed effects model's negative sign can suggest that FDI is sometimes focused on cleaner or less polluting industries.

Though the magnitude varies, other variables also exhibit significant differences between the two models. For example, there is a negligible difference of 0.0000527 in the coefficient for PE between FE (-0.0082) and RE (-0.00816). Even though they are minor, consistency and direction are important when choosing a model. In addition, the variable RE displays a 0.0029853 difference between FE and RE, whereas Edu only varies by a negligible -0.0023501. The Hausman test's main conclusion—that fixed effects offer a more robust and consistent framework for interpreting panel data, capturing the unobserved heterogeneity essential for trustworthy inference—is supported by the cumulative evidence, even though these variables exhibit less noticeable variations.

Table 4.6 Hausman Test – Fixed vs Random Effects

Variable	Fixed Effects (b)	Random Effects (B)	Difference (b − B)	Std. Error
RE	-0.0099961	-0.0129814	0.0029853	0.009852
LnPC_GDP	0.1640958	0.0112375	0.1753333	0.0326266
LnFDI	-0.0052362	0.0100211	-0.0152573	0.0017622
Edu	0.0218999	0.0242499	-0.0023501	0.0004462
PE	-0.0082163	-0.0081636	0.0000527	0.0002068

Test of H_0: Difference in coefficients not systematic

- $Chi^2(5) = 85.77$
- p-value = 0.0000

Source: Author`s Compilation

4.4.5. Test for Heteroskedasticity

The Modified Wald test for groupwise heteroskedasticity was used to determine whether heteroskedasticity existed in the fixed effects panel regression model. This test determines if the variance of the residuals is constant across all cross-sectional units and is especially intended for panel data models with fixed effects. Homoskedasticity, or the idea that the error variance is the same for every group (σi2=σ2 for all i), is the null hypothesis of the test. With a p-value of 0.0000 and a chi-squared value of 672.41, the results demonstrate great statistical significance. Groupwise heteroskedasticity may be present in the model as a result of the null hypothesis being rejected at the 1% level. Because of this breach of the homoskedasticity assumption, standard errors could be skewed and inconsistent, which could result in inaccurate conclusions. Heteroskedasticity-consistent estimators or robust standard errors should be used to solve this problem and guarantee the accuracy of coefficient estimations and hypothesis testing in the fixed effects framework.

Table 4.7 Modified Wald Test for Heteroskedasticity

Test Type	Statistic	Degrees of Freedom	p-value
Modified Wald Test for Heteroskedasticity	672.41	Chi^2 (8)	0.0000
Null Hypothesis (H_0): Groupwise homoskedasticity: $\sigma_i^2 = \sigma^2$ for all *i*			

Source: Author`s Compilation

4.4.6. Testing for Panel Correlation

To determine if residuals across cross-sectional units are independent, panel data analysis uses the Breusch-Pagan LM (Lagrange Multiplier) Test of Independence. With 28 degrees of freedom and a p-value of 0.0000, the test in this investigation produced a Chi2 statistic of 116.218. There is no cross-sectional dependence in the error terms, according to the test's null hypothesis, which states that the residuals are independent across entities. The incredibly low p-value, however, offers compelling evidence that refutes this null hypothesis. This implies that there may be substantial cross-sectional dependence among the panel's units, which would violate the concept of independence since unnoticed shocks or missing variables that affect one unit may also affect others.

In panel data, cross-sectional dependence may result from shared causes, spillover effects, or worldwide shocks that impact several nations or businesses at once (Asteriou & G. Hall, 2021). The presence of cross-sectional dependency suggests that if the dependence is not taken into consideration, conventional estimation methods, such as fixed or random effects models, may produce biased and ineffective findings. The above-mentioned empirical observation supports the view that panel-corrected standard errors (PCSE), Driscoll-Kraay standard errors, or spatial econometric techniques should be used when examining endogenous variables. The irrepressible effect of a globalisation process and orchestration in policy-making structures acts globally to create uniform ordering in the system of various national economies in the macroeconomic enquiry. Based on this, interdependence should form part of any suitable study.

The model must be modified to account for the cross-sectional dependence in light of the Breusch-Pagan LM Test results. Failing to do so may jeopardize the accuracy of coefficient estimations and the dependability of hypothesis testing. The robustness of the methodology used in this study is demonstrated by the inclusion of this diagnostic test in the model selection and validation procedure. It also emphasizes how crucial it is to test for both cross-sectional dependence and heteroskedasticity in panel data sets, particularly when working with environmental and economic variables that are probably impacted by regional and global dynamics. In order to guarantee consistent and trustworthy results, additional empirical estimations will employ techniques that can handle these interdependencies.

Table 4.8 Residual Correlation Matrix Test

Test Type	Chi² Statistic	Degrees of Freedom	p-value
Breusch-Pagan LM Test of Independence	116.218	28	0.0000

Source: Author`s Compilation

4.4.7. Cross-Sectional Dependence Analysis

Pesaran's test for cross-sectional dependence assesses the correlation between residuals across panel units. The p-value in this analysis is 0.0681, and the test statistic is -1.824. Cross-sectional independence is assumed by the null hypothesis, which states that the residuals from one panel unit are unaffected by those from other panels. The p-value is greater than the significance level, indicating no evidence of cross-sectional dependence, since it is above the traditional 5% threshold. As is typical in macroeconomic or environmental datasets, this finding suggests that panel units—such as nations or businesses—may not be independent and may be impacted by common unobserved characteristics or external shocks.

Furthermore, the average absolute off-diagonal correlation of 0.354 indicates a moderate level of dependency among the panel units. The comparatively high average correlation suggests possible practical significance, even if the Pesaran test for cross-sectional dependency returns a statistic of −1.824 with a p-value of 0.0681, meaning that the null hypothesis of cross-sectional independence cannot be rejected. Biased standard errors and ineffective estimates could still result from ignoring these interdependencies. Therefore, even in the absence of strong statistical support, it is wise to take into account estimation methods that are resistant to cross-sectional dependency. Addressing cross-sectional dependence improves the validity and reliability of the regression results, which is especially important in studies using globally related variables like greenhouse gas emissions, foreign direct investment, or policy indicators.

Table 4.9 Pesaran's Test for Cross-Sectional Dependence

Test Statistic	Value
Pesaran CD Statistic	-1.824
p-value	0.0681
Avg. absolute off-diagonal correlation	0.354

Source: Author`s Compilation

4.5. The Result of Driscoll-Kraay Standard Error Regression

By using the natural log of GHG emissions (LnGHG), the fixed-effects regression model examines how certain independent factors affect greenhouse gas emissions. The within R2 value of 0.8552, which shows a significant explanatory power with 176 data across 8 groups, shows that the included predictors account for 85.52% of the within-group variation in GHG emissions. With a p-value of 0.0000 and an F-statistic of 401.23, the model as a whole is highly significant, rejecting the null hypothesis that all of the coefficients are jointly equal to zero. This suggests that the dependent variable is statistically significantly impacted by the variables that were chosen. Across the panel units, the model offers solid insights into how economic, educational, and policy-related issues affect the environment.

Table 4.10 Fixed Effects Regression with Driscoll-Kraay Standard Errors

Dependent variable: LnGHG

Observations: 176 Groups: 8 Within $R^2 = 0.8552$

Variable	Coefficient	Std. Error	t	p-value	95% Confidence Interval
RE	-0.0099***	0.0026	-3.82	0.001	[-0.0154, -0.0046]
LnPC_GDP	0.1640**	0.0882	1.86	0.077	[-0.01932, 0.3475]
LnFDI	-0.0052	0.0066	-0.79	0.436	[-0.0189, 0.00849]
Edu	0.0218***	0.0019	11.26	0.000	[0.01785, 0.02594]
PE	-0.0082***	0.0009	-8.84	0.000	[-0.01015, -0.00628]
_cons	2.7174***	0.7115	3.82	0.001	[1.2378, 4.1972]

F(5, 21) = 401.23 Prob > F = 0.0000

Source: Author`s Compilation

***Note**: Statistical significance levels are indicated by the asterisk notation: *** denotes significant at 1%, ** at 5%, and * at 10%. Stronger evidence against the null hypothesis is indicated by more asterisks, indicating that the data are more likely to reflect a true effect than to be the result of chance.*

It agrees with the results of previous research by Rahman et al. (2023) and Tariq et al. (2022) that examined the clash between renewable energy and greenhouse gas emissions. The significance indicated by the statistically significant negative coefficient of -0.00999 and p-value of 0.001 states that an increase in the use of renewables is related to a corresponding decrease in the emission of greenhouse gas. This is the kind of evidence that would mark the validity of the energy Transition theory that the levels of pollution can be reduced with the help of solar and wind, as well as other forms of renewable energy. The theoretical implications are further illustrated by the fact that the confidence interval is 95; however, the range of this interval is from a wide 0.0154 to 0.0046. To countries that are keen on avoiding mowing down their carbon footprints at the expense of economic prosperity, the study highlights the tactical importance of investing in renewable-energy infrastructures to reduce environmental degradation.

In log log-linear model, the coefficient log per capita Gross Domestic Product (LnPC_GDP) is estimated as 0.1641 with a p-value of 0.077, indicating that there is a relationship between the variables in question, and it is statistically significant as well. This finding agrees with Saleem et al. (2021) and corroborates previous empirical evidence. The 95 percent confidence interval on LnPC_GDP is the range, 0.0193 to 0.3475, which further supports the strength of the estimation output. Simply put, the results validate the fact that economic growth, as proxied by per capita income across countries, is positively correlated to higher levels of GHG emissions and thus painting a picture of the costs of economic growth on the environment. The same can be said of the study results: it adheres to the first parts of the Environmental Kuznets Curves, where emissions grow as income develops until they reach a turning point. Therefore, green technologies and sustainable practices as a part of development strategies have to be embedded by policymakers striving to decouple growth and ecological degradation.

The study fulfils the p-value of 0.436 to assert that foreign direct investment (FDI) is not significant at the conventional levels, but has a negative sign of -0.052. The confidence interval is very broad (-0.0189 to 0.0085), showing that inflows of FDI do not always influence GHG emissions in the panel it is observed on. This adverse finding could be because FDI cuts across activities in carbon-intensive industries and also clean energy ventures, as it is pointed out that its environmental impact varies in different sectors and countries. The findings imply that FDI by itself does not achieve environmental gains and emphasize the necessity of specific laws to guarantee that foreign investments support sustainable development objectives.

Based on the study, Sarwar et al. (2020) establish that, whereas past studies indicate otherwise, education (Edu) has a very significant and positive impact on the GHG emissions, where the coefficient estimate is 0.219 and the significance is p = 0 (000). This is a surprising result, but it does show that the present schooling practices in particularly in the emerging and Southeast Asian settings, do not enable emission cuts at the moment. Rather than enhancing theoretical material and standardized testing, these systems give only slight consideration to environmental considerations, thus contributing to rising levels of energy consumption among higher-educated citizens, and ultimately, causing greater rates of resource usage as a result of physical infrastructure expansion. This finding has a high degree of precision, which is supported by a confidence interval of 0.01785-0.02594. The real environmental impact of education, however, depends on the content of the curriculum and modalities of that teaching. Whilst education systems do seek to extend environmental consciousness, Climate-related themes tend to be sprinkled in at the side as often being taught only as part of science studies or geography studies. Therefore, the education environment needs to inculcate climate issues by incorporating environmental literacy, experiential sustainability programs, and interdisciplinary teaching to make education instigate sustainability. According to Sarwar et al. (2020), it is adequate, therefore, to say that the successful provision of the instruction process, how and what to teach, is crucial and not the sheer growth of official education.

With a coefficient of -0.0082 and a p-value of 0.000, policy Effectiveness (PE) is found to significantly reduce GHG emissions. The high level of reliability is indicated by the narrow confidence interval between -0.01015 and -0.0063. This suggests that fewer emissions are linked to more effective environmental regulations. The outcome demonstrates how important institutional quality and governance are in tackling environmental issues. Standards, incentives, and enforcement tools are examples of effective policies that can promote the structural and behavioral changes required to reduce emissions. This study highlights that environmental gains are heavily reliant on the effectiveness and strength of policies that are put into place, even in the face of economic and educational expansion. As a result, good governance is essential to sustainability.

The model's constant term (_cons), which has a p-value of 0.001 and a coefficient of 2.7175, is statistically significant. The dependability of this estimate is confirmed by the confidence interval (1.2378 to 4.1971). The positive and substantial intercept indicates that unobserved factors or fixed traits specific to each nation or group would continue to influence GHG emissions even if the independent variables remained unchanged. In addition to reflecting structural elements not explicitly modeled, such as geographic geography, industry makeup, or long-term institutional legacies, this intercept records baseline emission levels. Understanding the constant term's importance puts other variables in perspective and serves as a reminder that quantifiable economic or policy factors are not the only factors influencing environmental outcomes.

4.6. The Result of Fixed-Effect Regression

The HDFE regression model uses robust standard errors clustered by year to examine the factors influencing greenhouse gas emissions (LnGHG). The within R-squared value of 0.8552, which shows that the independent variables account for around 85.52% of the within-group variance in greenhouse gas emissions, indicates the model's good explanatory power. Furthermore, the overall R-squared value is 0.9982, indicating a very good fit for the model. The joint importance of the independent variables is confirmed by the F-statistic, which is significant at the 1% level ($F = 355.93$, $p < 0.001$). These findings imply that the model is well-defined and that the selected predictors successfully account for changes in emissions over time and between nations. Additionally, unobserved heterogeneity among the nation units is controlled for with the use of high-dimensional fixed effects (HDFE).

Table 4.11 HDFE Regression Results (Dependent Variable: LnGHG)

Robust standard errors clustered by year (N = 176, Groups = 8, Clusters = 22)

F(5, 21) = 355.93 Prob > F = 0.0000

R-squared = 0.9982 Adjusted R-squared = 0.9980 Within R-squared = 0.8552

Variable	Coefficient	Std. Error	t-Statistic	p-Value	95% Confidence Interval
RE	-0.0099***	0.0022	-4.55	0.000	[-0.01456, -0.005422]
LnPC_GDP	0.1640**	0.08879	1.85	0.079	[-0.02056, 0.348759]
LnFDI	-0.0052	0.00632	-0.83	0.416	[-0.01837, 0.0079]
Edu	0.0219***	0.00172	12.73	0.000	[0.01832, 0.02548]
PE	-0.0082***	0.0008	-9.53	0.000	[-0.010009, -0.006423]
_cons	2.7174***	0.6902	3.94	0.001	[1.282029, 4.152906]

Root MSE = 0.1079

Fixed Effects Absorbed: 8 (ID)

Source: Author`s Compilation

With a coefficient of -0.009996 ($p = 0.000$), the regression findings demonstrate that the use of renewable energy has a statistically significant and adverse impact on greenhouse gas emissions. This suggests that there is a 0.99% decrease in emissions for every 1% rise in the percentage of renewable energy use. This result is in line with Ahmad and Majeed's (2019) study, which likewise found a negative correlation between carbon emissions and the adoption of renewable energy. This relationship's tenacity, even after taking institutional and financial restraints into consideration, demonstrates how strong the environmental advantages of renewable energy are. This research paper supports policy efforts aimed at hastening the moves to fossil-free energy systems within developing countries and the use of renewable energy as a form of energy that plays a pivotal role in terms of limiting environmental erosion.

As the current analysis shows, per capita GDP (LnPC_GDP) has a positive and significant effect on the emissions, with the estimated coefficient of 0.1640 and the p-value of 0.079 at the 10 % significance level. The finding suggests that economic growth is becoming conjoined with the high rates of environmental pollution in modern society. The present finding is in line with the findings of Bilal Khan et al. (2021), who demonstrate that there is a positive correlation between economic growth and GHG emissions, especially in the short run. This was the pattern of the energy transition theory, according to which, at the onset of growth processes, carbon-intensive energy consumption is frequently the most common, called predominant. However, it is anticipated that the economy will eventually meet the requirements for a successful energy transition as it develops and embraces cleaner technologies, renewable energy, and more effective systems. This emphasizes the necessity of proactive policies that sustain economic growth while facilitating the slow transition to low-carbon development.

In this model, FDI has no significant immediate effect on emissions, as indicated by the foreign direct investment (LnFDI) coefficient, which is negative (-0.0052) but not statistically significant ($p = 0.416$). This could imply that the sectoral allocation of FDI—whether it is allocated to polluting industries or clean technology—has a significant impact on its environmental implications. The negligible results also suggest that more disaggregation or dynamic modeling is required to fully depict the intricate relationship between FDI and environmental effects. Furthermore, the lack of statistical significance in this case may be explained by the absence of institutional elements and regulatory quality in the host nations, which may mitigate the association between FDI and emissions.

There is a highly significant positive correlation between emissions and education (Edu) (coefficient = 0.0219, $p < 0.001$). This analysis confirms the results given by Hamed, Ayers, and Ashraf (2023). Though the positive relationship between educational attainment and CO2 emissions might seem counterintuitive, several explanations explain such a fetishism. Developing environments, such as examples, often face a faster pace of industrialization and energy use after their knowledge levels have climbed, causing such development patterns to drive up carbon emissions unless matched with infrastructure in a sustainable way. In addition, the rise of both education levels and the growth of energy use, especially in urban areas, gives the impression that higher capital stock in human capital leads to a greater need for urban services. The findings, therefore, stress the necessity to correct the discrepancy between the lack of sustainability and environmental literacy in formal educational curricula to mitigate the indirect environmental impacts of the further increase in educational levels.

The current paper illustrates the significant and negative relationship between policy effectiveness (PE) and emissions (coefficient = -0.0082, $p < 0.001$), indicating that a stronger policy application will result in a reduction of greenhouse gas emissions. The results confirm the centrality of the regulatory good performance and the institutional robustness in the development of the environmental results and the direction to become sustainable. Governments that formulate and enforce effective environmental standards have higher chances of recording quantifiable reduction in emissions, thus confirming the argument that quality of governance is one of the primary determinants of environmental performance, irrespective of the financial resources or the advance of technology in influencing it. In turn, the reinforcement of policy implementation and institutions strengthening turns out as beneficial measures to develop climate goals and move towards sustainability.

At all other explanatory variables held constant, the constant value representing the baseline value of emissions is shown to be positive, as well as statistically significant (2.7174, $p = 0.001$). The result of its effect is the existence of unmeasured factors affecting emissions. These may involve climate processes, industrial development patterns that were in the past, or maybe culturally oriented practices. Because this otherwise baseline heterogeneity was included, a significant intercept also enhances the fixed-effects model structure. The outcome illustrates the complexity of the ecosystems and the need to consider the structural effects when conducting studies on the emission level.

The high-dimensional finite-element (HDFE) regressions reviewed in this research paper present empirical evidence that economic activity, education, the efficiency of policies, and renewable energy have a substantial impact on greenhouse gas emissions. The large coefficients and high values of R-squared areas verify the statistical strength of the results. These outcomes are very relevant to policymakers who aim to undertake specific strategies aimed at reducing emissions. Enhancing green innovation in education systems, increasing the application of renewable energy technologies, and improving the effectiveness of environmental policies seem to be the key spheres of intervention. Future analyses of greenhouse-gas dynamics and chemical dynamics are to consider dynamic models or nonlinear formulations of environmental processes and economy in order to better capture the long-term vibration of these systems.

4.7. Individual (ID) Effect Analysis

The fixed-effects estimates shown in the bar graph reveal that there is substantial unobserved heterogeneity in GHG emissions across national jurisdiction once observing renewable energy consumed (RE), Per-capita GDP, foreign direct investment (FDI), education (EDU), and the effectiveness of policies (PE). Such country effects include the institutional frameworks, the industrial organization, environmental regulation, and geographical factors, thus providing a floor that cannot be one hundred percent explained by the empirical model. India exhibits the biggest positive fixed effect of 4.03, and it is an acceptable notion that the intrinsic country-specific features are linked to significantly higher GHG emissions when the rest of the variables are held constant. Its extensive industrialization, strong reliance on coal, and comparatively high energy use may be the cause of this.

On the other hand, nations with negative fixed effects, such as Sri Lanka (-1.19), Bhutan (-2.38), and the Maldives (-3.92), show lower-than-expected emissions after controlling for the primary explanatory factors. In the empirical environmental-economic analysis, structural attributes, i.e., the use of low-emission-generating sources of energy, positive and strict environmental regulations, and reduced industrial activities, may present a negative baseline, or fixed effect, in carbon emissions. Akbar et al. (2024) illustrate the connection between these two facets in the case of Bhutan, where massively produced hydropower, preservation of forestation, and the interrelation of these associations have ultimately made the state carbon-negative. Another assumption made in the study suggests that the relatively low emission intensity in Sri Lanka could be explained by active environmental governance and policy-making, whereas the geographical size of the Maldives and the unimportance of the industrial sector of the country are the natural limiting factors to emissions. Regional climate policies should recognize that certain nations seem to enjoy institutional or structural advantages that reduce baseline emissions levels.

Afghanistan (-0.46) and Nepal (0.48) have fixed effect values that are almost zero, meaning that their GHG emission levels are roughly in line with what would be expected based on RE, GDP, FDI, EDU, and PE. The relatively positive fixed effects of Bangladesh (1.33) and Pakistan (2.24), on the other hand, raise the possibility that higher emissions are caused by unmeasured factors such as urbanization trends, energy inefficiency, or laxer enforcement of environmental regulations (Zainordin & Zahra, 2020). These differences highlight the significance of adjusting climate policies to national contexts because standard policy recommendations might not be sufficient to address the distinct institutional and structural challenges that every nation faces. All things considered, the fixed effects study emphasizes how important unobserved country-specific characteristics are in determining emission results and reaffirms the necessity of both national-level initiatives and more extensive regional collaboration.

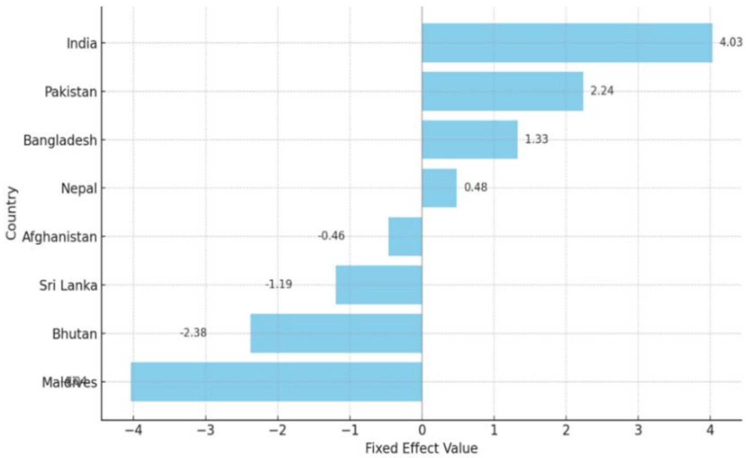
Table 4.12 Country Fixed Effect on GHG Emission

Country Code	AFG	BGD	BTN	IND	LKA	MDV	NPL	PAK
Fixed Effect	-0.465	1.3289	-2.37	4.027	-1.193	-4.042	0.482	2.24

Source: Author`s Compilation

Figure 4.3 Country Fixed Effects on GHG Emissions

(Controlling for RE, PCGDP, FDI, Edu, PE)



Source: Author`s Illustration

4.8. Assessment of Time Impact

In order to capture the temporal dynamics of greenhouse gas emissions over the sample period, the fixed effects regression model incorporates year dummies. The model explains around 89.7% of the variation in GHG emissions within nations, according to the inside R-squared value of 0.8972. The joint relevance of the predictors is confirmed by the overall F-statistic ($F = 47.66$, $p < 0.001$), which shows that time is a key factor in determining emission trends. Notably, we reject the null hypothesis that all year coefficients are jointly zero based on the testparm result ($F(26,142) = 47.66$, $p = 0.0000$). This highlights the structural evolution of emissions across the research period and validates the inclusion of time fixed effects in the regression, confirming that year effects are statistically significant.

The low amplitude and high p-values of the estimated year coefficients in the fixed effects model show that there was no statistically significant fluctuation in emissions during the first few years of the study period (2001–2004). But starting in 2005, the coefficients start to show statistical significance and continue to increase steadily until 2019. For example, almost all year dummies from 2005 onward are significant at the 1% level, and the coefficient increases from 0.1097 in 2005 to 0.4976 in 2019. The trend of increasing levels of greenhouse gas (GHG) emissions over time remains positive in line with the constant industrialization and energy demands that have been witnessed in South Asian countries, as identified by Sivakumar & Stefanski (2010). The cumulative increase of such coefficients is indicative of the growing environmental footprint, most probably caused by regional changes in the structure, namely, growth in population, infrastructural growth, and changing consumption patterns.

Coefficients in 2020 (0.4418), 2021 (0.4539) show a slight decrease reaching its peak in 2019, but statistics are not zero, but positive, which means that pressure on emission increase is not released completely, and yet decreased. This little decline might be the result of temporary disturbances like the COVID-19 pandemic, which had an impact on global industrial and economic activities. However, the fact that year dummies continue to be significant until 2021 suggests that the structural drivers of emissions are still mostly in place. These findings highlight how urgent it is to put in place strong and efficient environmental regulations that go beyond band-aid fixes and instead work to reverse the region's long-term trend of increasing emissions.

All things considered, the year impacts draw attention to a time-dependent aspect of emissions rise that needs to be taken into consideration in any meaningful analysis of climate policy. The temporal dummies' combined relevance indicates that global changes and cumulative environmental effects, rather than only country-specific or economic factors, influence emission trajectories. As a result, including time fixed effects increases model accuracy and aids in identifying variables that are important for policy. Furthermore, the noticeable rise in emissions over time emphasizes how urgently long-term mitigation measures are needed. Beyond short-term economic indicators, policymakers must take into account how structural developments, such as changes in global energy systems and technological advancements, impact emissions trajectories. The regression results support the idea that time is important for understanding environmental impacts, both statistically and substantively.

Table 4.13 The Impact of Year on LnGHG

Year Impact on LnGHG (Fixed-effects (within) regression)

Dependent Variable: LnGHG

Model: Fixed Effects (Within) Regression

Number of Observations: 176 Groups: 8

Within R^2: 0.8972 $F(26, 142) = 47.66$ Prob > F = 0.0000

Year	Coefficient	Std. Error	t	p-value	95% Confidence Interval
2001	-0.0391331	0.0487453	-0.80	0.423	[-0.1354, 0.0572]
2002	0.02109	0.0488	0.43	0.667	[-0.0755, 0.1177]
2003	0.0659101	0.0493	1.33	0.184	[-0.0317, 0.1635]
2004	0.0440769	0.0505	0.87	0.385	[-0.0559, 0.1441]
2005	0.1097011**	0.0509	2.15	0.033	[0.0090, 0.2103]
2006	0.1388475***	0.0525	2.64	0.009	[0.0349, 0.2427]
2007	0.15649***	0.0555	2.82	0.006	[0.0467, 0.2662]
2008	0.17715***	0.0569	3.11	0.002	[0.0646, 0.2897]
2009	0.20132***	0.0585	3.44	0.001	[0.0855, 0.3171]
2010	0.25272***	0.0617	4.09	0.000	[0.1307, 0.3747]
2011	0.30497***	0.0634	4.81	0.000	[0.1796, 0.4303]
2012	0.3142***	0.0656	4.78	0.000	[0.1843, 0.4440]
2013	0.3333***	0.0675	4.94	0.000	[0.1998, 0.46685]
2014	0.3760***	0.0699	5.37	0.000	[0.2376, 0.5143]
2015	0.3597***	0.0722	4.98	0.000	[0.2168, 0.5025]
2016	0.3854***	0.0755	5.10	0.000	[0.2361, 0.5347]
2017	0.4007***	0.0773	5.18	0.000	[0.2477, 0.55367]
2018	0.4781***	0.0790	6.05	0.000	[0.3218, 0.6344]
2019	0.4976***	0.08109	6.14	0.000	[0.33736, 0.65797]
2020	0.4418***	0.0774	5.71	0.000	[0.2888, 0.5948]
2021	0.4539***	0.0819	5.54	0.000	[0.2918, 0.6160]

Source: Author`s Compilation

Statistically significant at the 5% level ($p < 0.05$)

Table 4.14 The Test Parameter of Time Impact on GHG

Test Description	Deg of Fr	F-Stat	p-v	Interpretation
H_0: All year dummy coefficients = 0	(21, 142)	2.76	0.0002	Reject H_0: Year effects are jointly significant

2002.Year	2003.Year	2004.Year	2005.Year	2006.Year	2007.Year	2008.Year
0	0	0	0	0	0	0
2009.Year	2010.Year	2011.Year	2012.Year	2013.Year	2014.Year	2015.Year
0	0	0	0	0	0	0
2016.Year	2017.Year	2018.Year	2019.Year	2020.Year	2021.Year	
0	0	0	0	0	0	

Source: Author`s Compilation

4.9. Diagnostic Evaluation and Empirical Evidence of Endogeneity Control

A number of issues, including measurement error, omitted variable bias, and reverse causation, can lead to endogeneity in panel data models. This can skew the predicted coefficients and render statistical inference erroneous. Lagged variables, which are frequently included in dynamic models but were purposefully excluded in this work to maintain sample size and model simplicity, were one of several measures taken to reduce potential endogeneity. Instead, to account for unobservable time-invariant traits across nations, the study used a fixed effects technique with high-dimensional fixed effects (HDFE). The relationship between greenhouse gas emissions (LnGHG) and important explanatory factors like renewable energy use (RE), per capita GDP (LnPC_GDP), foreign direct investment (LnFDI), education (Edu), and policy Effectiveness (PE) could otherwise be complicated by country-specific heterogeneity, which these fixed effects mitigate.

Panel-level variance decomposition further supported the fixed effects model selection by confirming that variation in greenhouse gas emissions was significantly explained by unobserved variability across nations. The panel-level effect of u's variance was statistically significant ($Chibar^2(01) = 95.53$, $p < 0.001$), specifically showing that individual country effects are not zero and should be taken into consideration. Furthermore, the null hypothesis that there are no systematic differences between fixed and random effects estimators was strongly rejected by the Hausman test comparing them ($Chi^2(5) = 85.77$, $p < 0.0000$). Because it yields reliable estimates in cases when regressors are correlated with unobserved heterogeneity, this result supports the adoption of the fixed effects estimator. As anticipated by the high-dimensional fixed effects (HDFE) specification, attempts to include country or time dummy variables resulted in 100% collinearity. This demonstrates that the model effectively accounts for all absorbed and time-invariant fixed effects, lowering the possibility of omitted variable bias, a major cause of endogeneity.

Diagnostic tests were performed to assess the structure of the explanatory factors in order to further guarantee the estimation's output. A Variance Inflation Factor (VIF) test showed the average VIF of 1.82, and the range of variable-specific scores was VIF = 1.53; VIF = 2.24. This suggests well-conducted behaviour of the regression model since all VIF values were very low below the recommended thresholds. Lack of large collinearity reduces possible biases in coefficient estimation and overestimation of standard errors. The small values of the VIF also improve the internal consistency of the outcomes of the fixed-effects regression model and indicate that the coefficient estimates provide the required confidence in the accuracy of the estimations.

To address typical econometric problems, i.e., serial correlation, heteroskedasticity, and cross-sectional dependency, this empirical research has taken the so-called Driscoll-Kraay approach that is a compromise between standard error robustness and fixed-effects model all of which tend to bedevil macro-panel data. Being based on robust standard errors, the validity of the estimates is improved when dealing with these challenges, though inference is made complicated. The results indicate the presence of a reasonable amount of consistency between the two estimation approaches: the DriscollKraay and the heteroskedasticity and autocorrelation corrected (HDFE) methods. Across all the models, they had found a more significant relationship with low greenhouse-gas emissions on both higher levels of policy effectiveness (PE; -0.0082, $p < 0.001$) and increased use of renewable energy consumption (RE; -0.0099, $p < 0.001$). The correlations were found to be robust, meaning that through cleaner energy sources and better governmental policies, it is possible that they can collectively lead to a positive environmental assessment. Additionally, a within R2 of 0.8552 suggests that the model's explanatory power is high.

Furthermore, the null hypothesis of homoskedasticity was rejected at a high level of significance ($Chi^2(8) = 672.41$, $p < 0.0000$) in the Modified Wald test for groupwise heteroskedasticity, further confirming the necessity of robust error correction. Therefore, considering the heteroskedastic nature of the panel data, using robust standard errors was both methodologically sound and empirically required. When combined, these diagnostics increase the fixed effects and Driscoll-Kraay estimation strategy's dependability in producing accurate and consistent estimates even when faced with typical econometric difficulties.

To sum up, this study addresses potential endogeneity issues that are frequently encountered in panel data analysis using a methodologically informed approach. Using a fixed effects framework with high-dimensional country-specific controls, robust error correction methods, and diagnostic tests, the estimator aims to reduce major sources of bias such as autocorrelation, omitted variable bias, and unobserved heterogeneity. But it's crucial to recognize that, as Gujarati (2003) points out, fixed effects estimators don't completely address endogeneity problems, especially those brought on by measurement mistakes or reverse causality. As a result, even while this method increases the validity of the predicted correlations between greenhouse gas emissions and factors like the usage of renewable energy, the effectiveness of policies, and economic indicators, residual endogeneity cannot be completely wiped out.

CHAPTER V
CONCLUSION

5.1. Conclusion

This study uses panel data analysis to examine the dynamic link between greenhouse gas (GHG) emissions and the utilization of renewable energy in South Asian nations between 2000 and 2021. GHG emissions, expressed in megatons of CO_2-equivalent, are the dependent variable. The main independent variable that directly affects emissions levels is renewable energy, which is represented as a proportion of total final energy consumption. Furthermore, a number of control variables are included to fortify the model and distinguish the overall impact of renewable energy. These include education (as measured by school enrollment rates), foreign direct investment (FDI) to capture international capital flows, GDP per capita to reflect economic growth, and Policy Effectiveness (PE), which measures the efficacy of climate-related policy frameworks. When viewed as an integrated structure, the variables considered herein provide a full picture of institutional and socioeconomic drivers of GHG emissions in the territory considered.

This study is based on two main research questions, namely: (1) to identify how direct use of renewable energy is associated with global warming potential emissions in the South Asian countries; and (2) to validate how socio economic and institutional factors such as the gross domestic product (GDP) per capita, foreign direct investment (FDI), educational attainment, and policy effectiveness of a country moderate national emission patterns over the period between 2000 and 2021. In answering these questions, the study contributes to a glaring research vacuum, as highlighted by examining the effectiveness of policy in the context of the larger environmental policy environment of greenhouse-gas emission mitigation in renewable-energy adoption. Though prior research studies like Shukla et al. (2017), Tariq et al. (2021), and Murshed et al. (2023) have touched on discrete elements of effective green-technology integration or renewable-energy deployment, all of them have consistently overlooked the institutional and policy structures that permit or hinder adequate decarbonization. This hence makes the current analysis unique in its approach as policy effectiveness is embedded in an empirical study of the results of renewable energy in South Asia.

The conceptual approach applied in this study is the Energy Transition Theory, as it enables a structured approach to the analysis of the structural transformation of the transition to a dependence on renewable energy as opposed to fossil-based systems. As stated by the literature of Bergh and Bruinsma (2008), the shift towards low-carbon energy can be realized through the dynamic relationships among the three drivers of favourable institutional environments, socio-economic flexibility, and technological advancement. When referring to South Asia, where coal and petroleum-derived sources of energy have been the prevalent source of energy for many years, the shift towards renewable sources of energy is, therefore, both a technical issue and a socio-political shift. In that regard, the hypothesis suggests that this transition can be hastened through the facilitation of variables like good governance, inflow of investments, and educational progress. Using the Energy Transition Theory, it is possible to investigate to what extent renewable energy sources can mitigate emissions and point out which institutional and developmental structures play a critical role in the long-term energy transition of the region.

Regression analysis explains the connection between greenhouse gas emissions and renewable energy with economic growth in South Asia. When considering a negative relationship between the renewable energy use (RE) and emissions, the coefficient, which is statistically significant at the 1 % level ($p = 0.001$), has been estimated at -0.0099. This finding can be compared with global preparations for sustainable energy transitions and supports the claim that an increased use of renewable energy decreases emissions. Simultaneously, the GDP per capita coefficient (LnPC_GDP) is 0.1640, and significantly so ($p = 0.079$). This indicates that levels of economic development correlate with increased emissions, and the most probable reason behind this aspect is the rising industrial production and energy-related demands. This observation highlights the importance of creating a process that can uncouple economic growth and carbon intensity by explaining the environmental consequences of a growing economy without the adoption of clean energy at large.

Education (Edu) and policy Effectiveness (PE) are two of the control variables that show significant statistical significance and practical consequences. With a p-value of 0.000 and a coefficient of 0.0219 for education, it appears that, in contrast to predictions, higher levels of education are currently linked to higher GHG emissions. This could indicate a lag between improvements in legislation or behavior toward environmental stewardship and educational achievement. However, the negative coefficient of -0.0082 for policy Effectiveness is extremely significant ($p = 0.000$), underscoring the critical role that good governance and policy implementation play in cutting emissions. In the South Asian context, where governance quality varies greatly among nations, this study emphasizes the significance of institutional capacity and regulatory enforcement in accomplishing environmental goals.

FDI has no appreciable direct effect on GHG emissions within the timeframe and scope of the model, as indicated by the negative but statistically insignificant coefficient (-0.0052, $p = 0.416$) displayed by Foreign Direct Investment (LnFDI). This could be because the many types of investments—some that are eco-friendly, some that aren't—dilute the overall impact. With an R-squared of 0.9982 and an adjusted R-squared of 0.9980, the model exhibits good explanatory power overall, explaining nearly all of the variation in the dependent variable. The joint significance of the regressors is confirmed by the F-statistic (355.93, $p < 0.0000$), and the inside R-squared value of 0.8552 shows a high level of explanatory strength across time within specific countries. With robust standard errors grouped by year, these results confirm the fixed effects model's robustness against serial correlation and heteroskedasticity. These findings support specific reforms that increase investments in renewable energy, strengthen the way policies are implemented, and match educational initiatives with sustainable development objectives. Achieving long-term climatic resilience and environmental sustainability in the area requires sustained dedication to these tactics.

5.2. Policy Implications

The study's conclusions highlight how important renewable energy is to lowering GHG emissions in South Asian nations. However, the widespread adoption of clean energy technology would continue to be difficult if sustainable finance structures like green bonds, concessional loans, and ESG-compliant investment vehicles are not integrated(Mahadevan, 2018). The creation of strong financial structures that draw sustained investment in renewable energy infrastructure ought to be a top priority for policymakers. This involves facilitating public-private partnerships (PPPs) and providing incentives for private sector participation. Through specialized financing programs, regional banks and financial institutions must also be encouraged to finance renewable energy projects. In contemporary research, the intersection of energy transition goals and mechanisms of sustainable finance has been marked as crucial towards the active promotion of energy security, furthering decarbonization, and strengthening investor confidence in green development projects. This form of alignment forms a self-reinforcing cycle of innovation and investment, without which long-term climate resilience is impossible.

The findings of this paper provide strong reasons for why policy effectiveness in reducing emissions is vital, a factor that makes it highly significant to ensure implementation of more explicit, enforceable, and internally-consistent regulatory frameworks. It is, therefore, incumbent upon the governments in South Asia to strengthen institutional capabilities in the drafting and implementation of policies that are economically efficient and at the same time environmentally competent. Policymakers are recommended to set up mechanisms that de-risk investment in renewable energy, as well as guarantee regulatory predictability to attract foreign direct investment (FDI) that is consistent with the principles of sustainable finance. Moreover, policy instruments which deal with the policy targets, like clear reporting criteria, fast-tracked regulation methodology, etc., need to be supplemented with incentives in the form of feed-in tariffs, tax credits, and carbon pricing vehicles. In addition, national climate finance measures ought to be in line with existing international standards so as to be harmonious with international green capital movements. When properly executed, these policies have the potential to greatly increase the impact of scarce domestic resources while promoting a sustainable, low-carbon economy.

Given the strong link between education and greenhouse gas emissions, raising awareness and promoting climate action requires institutional knowledge, training, and awareness. Climate finance literacy at all levels—public administration, financial institutions, and the general public—must be given top priority by governments and multilateral organizations (Mahmood et.al, 2022). Both technical and higher education curricula should include modules on environmental economics, green technologies, and sustainable financing as part of educational reform. Initiatives to increase capacity can also enable regional financial organizations and institutions to efficiently evaluate, oversee, and fund low-carbon projects. By investing in human capital, a competent ecosystem is produced that can mobilize and guide long-term financial flows. The possibility of effective, responsible, and influential policy implementation rises sharply as more experts and decision-makers acquire the skills necessary to comprehend and apply green investment principles.

More access to regional and global climate finance structures like the Green Climate Fund (GCF), Climate Investment Funds (CIFs), and the Sustainable Development Investment Partnership (SDIP) is necessary for South Asian countries, many of which are developing economies (Fatica & Panzica, 2021). Multilateral development banks (MDBs) and governments should collaborate closely to develop the institutional preparedness needed to efficiently access and manage such funding. Broader participation will be promoted by streamlining application processes, enhancing transparency, and enhancing project monitoring systems. Furthermore, cross-border investments in clean energy infrastructure, such as shared solar grids or hydropower projects, might be strengthened by regional collaboration on climate finance, whether through South Asia or other multilateral forums. Sustainable financing must be a key component of economic development and climate diplomacy plans, not an afterthought (Faridi & Nazar, 2023). A much-needed flow of climate-aligned investments can be unlocked by utilizing global capital markets in this way.

A lack of sound green taxonomies and extensive disclosure standards is one of the core barriers to sustainable finance development in South Asia (Fatica & Panzica, 2021). Cooperation between government agencies and financial regulators is essential to define what in a certain domestic environment is considered to be a green initiative. This task is associated with the development of investment-screening criteria, climate-consistent standards, and environmental performance metrics that provide transparency in the information and limit greenwashing. Such taxonomies should be aligned to international standards, e.g., as expressed by the European Union or the Association of Southeast Asian Nations, in order to encourage foreign investment. Moreover, the requirement to report on climate risk by financial institutions and companies will probably encourage environmentally friendly activities and will drive capital into climate-friendly sectors. In the end, these steps should contribute to the improvement of investor confidence and financial market transparency, which can then be directed to the renewable-energy use and sustainability in general.

Factoring in equity and inclusion issues in the financing of sustainability is are critical facet, especially in situations in South Asia and poor-servicing locations. Financial mechanisms in decentralized systems of revitalizing energy, such as mini-grids, household installations of solar power, and biogas systems, are the ones that have to satisfy their specific requirements (Azhgaliyeva et al., 2020). When microfinance institutions, cooperatives, and local banks become part of the climate finance system, the empowered representative is able to give full engagement to underserved communities. When equitable finance is supported, community cooperatives, women-owned businesses, and owners of small companies can fund investments in renewable technologies through policy interventions. These approaches reduce emission levels and increase energy supply, rural growth, and the generation of jobs all at once. The term inclusive sustainable finance is used to indicate that equity in energy transition is fast-tracked using more inclusive approaches, as it is concerned with social equality and the environment.

South Asian states should ensure that effective institution of monitoring and evaluation (M&E) is systematically placed so as to ensure accountability in checking the effectiveness of climate-related investments in sustainable finance policies. These systems ought to include the monitoring of not only their financial outflows but also the environmental and social impacts, especially the creation of employment, energy saved, as well as GHG reduction (Mehrotra, 2013). The cost-effectiveness and scalability of green initiatives can be determined by policymakers upon a collection of information regarding organizations like the World Bank, IRENA, and national ministries. Transparent M&E reinforces policy-making and gives empirical evidence that can sustain the clean-energy investment. Moreover, it creates responsibility and protects the wise use of the financial resources. When it is incorporated within sustainable finance structures, M&E would become a long-term financing mechanism rather than a short-term one.

5.3. Limitations

Although it possesses its contributions, the current study has a few methodological and contextual limitations that are worth taking into account when situating the findings in the context of wider applicability. The authors are themselves aware of the fact that the South Asia region, with its changing institutional landscapes and policy regimes and varying coverage of data, is a complicated scenario in the case of quantitative analysis. The region is also relatively belated into the world of sustainable finance, which is still at the exploratory stage and indicates significant differences in the levels of market development, regulations, and other existing financial architectures. It can be helpful to frame the results more cautiously and provide guidance for future study by acknowledging these limitations.

Constraints on data availability: Robust longitudinal analysis was hindered by incomplete or inconsistent renewable energy and GHG data across South Asian nations from 2000–2021, which may have affected the accuracy and comparability of regression results.

a. Lack of specific sustainable finance data: A thorough evaluation of the true impact of sustainable finance on reducing emissions was hampered by the lack of comprehensive data on green bonds, ESG investments, and climate funds.
b. Heterogeneity among nations: The panel study may have masked country-specific effects due to economic, political, and institutional variations among the eight South Asian nations.
c. Simplified Policy Effectiveness Metric: The Policy Effectiveness proxy might not accurately represent a variety of factors, including the region's real implementation effectiveness, governance quality, and legal enforcement.
d. Underdeveloped sustainable finance ecosystems: In many South Asian nations, inadequate or inexperienced regulatory frameworks restrict the efficient

application and oversight of sustainable finance, hence diminishing its potential influence.

e. The lack of participation in the private sector is one of the basic limitations to the conversion to a sustainable economy and the overall economic development. Empirical evidence highlights the fact that although they claim to be sustainable in their operations, the private firms have performed vastly below their capacity in investing in green endeavors, technological development, and infrastructure. Long-term undermining of competition and, therefore, the development of the circular economy model.

f. Possible endogeneity concerns: Despite the use of panel data methodologies in this study, problems such as omitted variable bias or reverse causation could still lead to endogeneity. For example, although FDI might raise emissions, it's also feasible that nations with high emissions draw more FDI to particular industries. The estimated connections may also be skewed by unobserved factors that affect both the independent variables and greenhouse gas (GHG) emissions, such as regulatory strictness or technological innovation.

g. Undifferentiated renewable sources: When all renewable sources were combined, differences in the financial needs and environmental effects of solar, wind, hydro, and other clean energy technologies were not taken into account.

5.4. Recommendations

This study has identified two important variables that are strongly linked to lower greenhouse gas (GHG) emissions in South Asian nations: the efficacy of policies and the utilization of renewable energy. These results highlight how important clean energy development and high-quality institutions are in influencing regional environmental outcomes. According to the findings, nations that rely more heavily on renewable energy sources and implement policies more effectively are better positioned to reduce emissions. Even while factors like economic growth and education exhibit complex or mixed correlations, their policy relevance should not be disregarded. These realizations lay the groundwork for practical, research-based tactics. While adhering to the parameters of this study, the following suggestions aim to improve policy frameworks and encourage the use of renewable energy. Their objective is to assist South Asian policymakers in promoting low-emission development paths and more efficient environmental governance.

a. It is important to further turn up the dial of renewable energy integration into national development agendas. Empirical evidence shows that by placing solar, wind and hydro energy at the center stage in macroeconomic planning, it would enhance the realization of the climate goals by reducing greenhouse gas emissions. As a result, national-level players ought to allocate resources, i.e., financial resources, technical support, and policy incentives, to these energy sectors to achieve complete decarbonization.

b. The other requirement on the path to the achievement of the goals of environmental and energy governance is related to the strengthened institutional capacity. This makes it necessary to invest in the operational infrastructure and human capital. Increasing institutional effectiveness may be implemented by approaching it with specific training practices, introducing advanced electronic mechanisms of monitoring, and implementing an interagency cooperation system. Empirical findings indicate that emissions reductions rest on the quality of the policy design, which further requires strong institutional capacity (Tabash et.al, 2024).
c. The paper at hand demonstrates that understanding of policy coordination requires development of institutional mechanisms that help establish collaboration between the Ministries of Planning, Finance, Environment, and Energy. Such mechanisms include task forces or interministerial committees that are supposed to achieve continuity in policy formulation as well as implementation. The empirical evidence of the research paper reveals that when governance is coordinated, it has better results in the mitigation of pollution, but when regulations are divided, there is less success in the effectiveness of the policy.
d. The current argument goes further to suggest that implementing enforcement of environmental policy, at the national and subnational levels, should be strengthened by investing in the structural determinants of the enforcement practice. In particular, it is claimed that regulatory agencies should have sufficient personnel working at them, sanctions against non-cooperation should be regularly or systematically applied, and compliance testing must be a regular requirement that is institutionalized. The empirical literature emphasizes that there is a very important linkage between strong enforcement and policy efficacy; strong enforcement not only legitimates the environmental policy instrument but also proves its ability to reduce its emission level.
e. Integrate environmental goals into educational outreach: Long-term attitudes toward sustainability can be shaped by including environmental topics in school curricula and starting awareness programs that connect individual conduct to national climate goals. According to the model, education is important because it increases the

likelihood that knowledgeable citizens will support and embrace low-carbon behaviors, which will have a multiplier effect on reducing emissions.

f. Encourage the moderate incorporation of sustainable finance tools: Although this study did not evaluate the causative relationship between emissions and sustainable finance, policymakers may nonetheless carefully consider complementary financial techniques such as climate risk assessments and green budgeting. In keeping with the necessity for cautious interpretation of the study's scope, they can help the development of renewable energy projects and emission-reducing policies without exaggerating their direct influence.

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