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Review

A Review and Analysis of Green Energy and the Environmental Policies in South Asia

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Abstract: This paper explores the challenges and opportunities for green energy and environment transition in South Asia, a region that faces the dilemma of meeting its growing energy demand while reducing its greenhouse gas emissions and environmental vulnerability. The region has rich renewable energy sources and potential for energy efficiency improvement, but it also relies heavily on fossil fuels and suffers from various barriers and constraints that hinder its green energy development. The region needs policies that can achieve economic growth, social welfare, and environmental sustainability coherently and effectively. Utilizing the thematic literature review approach, this paper examines the literature on four main topics: (1) the estimation of green energy resources potential and scenarios in South Asia; (2) the comparison of green energy targets and policies in the South Asian Association for Regional Cooperation (SAARC) countries; (3) the evaluation of green energy deployment and performance in different sectors; and (4) the identification of green energy transition challenges and opportunities in South Asia. This paper fills some research gaps in the literature by providing a comprehensive, comparative, holistic, and integrated analysis of green energy and environment policies in South Asia, using various data sources, methods, frameworks, criteria, indicators, scenarios, impacts, trade-offs, drivers, barriers, best practices, lessons learned, and policy recommendations. This paper also develops a conceptual model for the green energy transition in South Asia, which consists of five key variables: green energy potential, green energy policies, green energy deployment, green energy performance, and green energy transition. The main findings and implications of this paper are that South Asia has a huge opportunity to pursue a green energy and environment transition that can address its multiple challenges and aspirations, but this requires overcoming various obstacles and constraints that hinder its progress. This paper suggests some policy options and strategies to enhance the green energy and environment policies in South Asia, such as developing a clear and consistent policy framework, enhancing regional cooperation and collaboration, leveraging information technology and data analytics, emphasizing sustainability and resilience, and engaging with other stakeholders and partners.

Keywords: South Asia; renewable energy; green energy potential; green energy policies; green energy deployment; green energy performance; green energy transition

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1. Introduction: Pivotal Crossroads in South Asia's Energy and Environmental Landscape

In the contemporary milieu, South Asia finds itself at a critical juncture, confronted by a dynamic interplay of energy, climate, and sustainability imperatives. This region, composed of eight nations (Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka), grapples with a dual challenge—satisfying the mounting energy requirements of its burgeoning population and economy while concurrently striving to curtail greenhouse gas (GHG) emissions and fortify its environmental sustainability. At present, the region's energy framework remains tethered to fossil fuels, with coal comprising a substantial 44% of the total primary energy supply in 2018. Consequently, South Asia discharged a staggering 2.4 gigatonnes of carbon dioxide equivalent ($GtCO_2e$) from fuel

combustion in 2018, representing approximately 6% of the global aggregate. The region also grapples with formidable environmental predicaments, including air pollution, water pollution, land degradation, and biodiversity loss, all stemming from its energy production and consumption patterns.

A case in point is the highly unsustainable and inefficient modern industrial farming technologies prevalent in the region's agriculture sector, as underscored by [1]. These technologies not only incur excess energy and water consumption but also cast adverse ramifications on climate change, ecological integrity, and social equity. However, recent studies have shed light on the affirmative impacts of green energy initiatives and policies on socio-economic and environmental outcomes in various contexts, such as China [2–6] and the United States [7].

The principal objective of this paper is to furnish a comprehensive, comparative, holistic, and integrated analysis of green energy and environmental policies in South Asia, drawing from a multitude of data sources, methods, frameworks, criteria, indicators, scenarios, impacts, trade-offs, drivers, barriers, best practices, lessons learned, and policy recommendations. To this end, this paper endeavors to address the following research questions:

- What is the status and trajectory of energy and environment in South Asia?
- What green energy and environmental policies are currently in place or planned for implementation in South Asia?
- How effective, efficient, and sustainable are these policies in realizing their objectives and intended outcomes?
- What are the primary challenges and opportunities that underpin the transition towards green energy and environmental sustainability in South Asia?
- What policy options and strategies can be adopted to enhance green energy and environmental policies in South Asia?

This paper adeptly bridges several critical gaps in the existing literature. By providing a comprehensive, comparative, holistic, and integrated analysis of green energy and environmental policies in South Asia, leveraging a diverse array of data sources, methods, frameworks, criteria, indicators, scenarios, impacts, trade-offs, drivers, barriers, best practices, lessons learned, and policy recommendations, it fills a notable void. Additionally, this paper contributes to scholarship by introducing a novel conceptual model for the green energy transition in South Asia, comprising five pivotal variables: green energy potential, green energy policies, green energy deployment, green energy performance, and green energy transition.

While our work represents a significant stride in advancing the knowledge of green energy and environmental policies in South Asia, it is not immune to limitations. Chief among these are data availability and quality constraints, the inherent uncertainty and variability of assumptions and parameters, the risk of oversimplification and overgeneralization within models and frameworks, the potential for subjectivity and bias in criteria and indicators, and the feasibility and acceptability of policy options and strategies. With these limitations in mind, we set the stage for future research directions. These avenues include the deployment of innovative data sources, methods, tools, and techniques such as big data, artificial intelligence, machine learning, and blockchain. Further exploration involves the development of dynamic, interactive scenarios and simulations based on our conceptual model, integrating diverse and inclusive perspectives and stakeholders into policy processes and outcomes, and undertaking the evaluation of specific, tailor-made policy interventions and experiments guided by our conceptual model.

2. Methodology

This study adopts the thematic literature review approach to examine the dynamics of green energy and environmental policies in Southeast Asia. This approach is a systematic and rigorous method of literature review that classifies and synthesizes the existing literature based on the main themes or topics that are relevant to the research question or objective [8,9]. The purpose of this approach is to provide a comprehensive and critical

overview of the current state of knowledge and research on a specific field or topic, as well as to identify the main research gaps, challenges, and opportunities for future research. Thematic literature reviews are suitable for exploring complex or interdisciplinary topics that have not been adequately defined or addressed by previous literature reviews [9,10].

3. Exploring Green Energy and Environmental Policies in South Asia: A Thematic Review

The sphere of green energy and environmental policies in South Asia has been a focal point of extensive scholarly investigations, comprehensive reports, and insightful articles. These collective efforts delve into the underlying forces, impediments, consequences, and future trajectories of policies in this region. Organizing this multifaceted literature, a thematic review approach reveals four overarching themes:

3.1. Assessment of Green Energy Resources Potential in South Asia

In this section, we delve into the meticulous assessment of green energy resource potential and the creation of scenarios within the context of South Asia. Numerous studies have taken a deep dive into the estimation of potential across various green energy sources in the region, encompassing renewable electricity generation (REG), renewable heat generation (RHG), renewable transport fuels (RTF), and energy efficiency (EE). The following studies apply diverse criteria to gauge these potentials, categorizing them into technical, economic, and social dimensions, as outlined in Table 1.

Table 1. A summary of methods, criteria, and scenarios of various studies.

Methods	Criteria Used for Policy Assessment	Scenarios *	Studies
Potential assessment	Technical, economic, and social	--	[11,12]
System dynamics	Policy support and public awareness	BAU, MRED, HRED, and VHRED	[13,14]
Scenario analysis	Effective implementation and consumer adoption	BAU, MEEI, and HEEI	[15]
Cost–benefit analysis	Environmental, resource availability, resource quality, land use, water consumption, grid integration, reliability, social acceptance, and equity	--	[16]
Multi-criteria analysis	Technical, economic, environmental, and social	--	[17]
Rebound effect analysis	Energy savings and emissions reduction	--	[18]

* BAU: business as usual; MRED: minimum (5%) renewable energy deployment; HRED: high (10%) renewable energy deployment, and VHRED: very high (15%) renewable energy development; MEEI: moderate energy efficiency improvement (a 10% reduction in the energy intensity of the industrial sector by 2030); HEEI: high energy efficiency improvement (a 20% reduction).

For instance, [12] examined the technical potential of REG in South Asia, which quantifies the maximum renewable electricity generation achievable based on the physical availability of renewable energy resources. Their findings unveiled a staggering total technical potential of approximately 3000 Gigawatt (GW) across solar Photovoltaic (PV), solar thermal, wind power, hydropower, biomass power, and geothermal power.

On the economic front, [19] assessed the economic potential of REG in South Asia, signifying the amount of renewable electricity that can be generated competitively when compared to conventional sources. They arrived at a cumulative economic potential of 1500 GW from the same sources.

Moreover, [17] ventured into the social potential of REG, considering the societal and environmental implications of RES. Their analysis suggested an aggregate social potential of about 800 GW from the same sources.

These assessments are complemented by scenarios that envision green energy development in South Asia under varying assumptions and conditions. These scenarios are a reflection of various levels of ambition and policy support. For instance, [14] constructed four scenarios for REG development in South Asia by 2030, spanning from BAU to VHRED. Under the VHRED scenario, characterized by robust policy support and heightened public awareness for REG, the region has the potential to achieve a remarkable 40% renewable energy share of the total primary energy supply by 2030.

However, not all experts share this optimistic outlook. Weng et al. [20] argued that the scenarios proposed by [14] are unrealistic and fail to account for vital considerations. These considerations encompass the availability and quality of renewable energy resources, the land use and water consumption associated with renewable energy technologies, grid integration, and reliability concerns related to intermittent RES, and social acceptance and equity issues associated with renewable energy development. They advocate for a more realistic and comprehensive scenario that balances the trade-offs between renewable energy and other development objectives.

Similarly, [15]. formulated three scenarios for energy efficiency improvement (EE) in South Asia by 2030, ranging from "business as usual" (BAU) to "high energy efficiency improvement" (HEEI). In the HEEI scenario, characterized by effective policy implementation and widespread consumer adoption of EE, the region could potentially reduce its primary energy demand by 25% and its greenhouse gas emissions by 28% by 2030.

However, skeptics such as [18] criticize these EE scenarios as overly optimistic and incomplete. They argue that these scenarios neglect the "rebound effect" of EE improvement, wherein lower energy prices or increased income due to improved efficiency can paradoxically lead to increased energy consumption. Zhang et al. [18] estimate that the rebound effect could offset a sizable portion of the energy savings and emissions reduction achieved by EE improvement in South Asia. Moreover, these scenarios do not consider other green energy sources, such as renewable heat generation, renewable transport fuels, and carbon pricing mechanisms, which may have significant synergies or trade-offs with EE improvement.

Despite these valuable contributions, a notable limitation in most of these studies is their exclusive focus on the potential and scenarios of renewable electricity generation (REG), overlooking the potential and scenarios of renewable heat generation (RHG), renewable transport fuels (RTF), and energy efficiency (EE), all of which are pivotal to the green energy transition in South Asia. Furthermore, these scenarios, though insightful, may be overly simplistic and optimistic, failing to capture the intricate and diverse nature of green energy transition in the region. A more comprehensive approach is urgently required, encompassing all green energy sources, and employing diverse models and methodologies capable of accommodating the uncertainty and variability inherent in green energy systems.

Future research endeavors must delve into assessing the synergies and trade-offs among various dimensions of green energy transition in South Asia, including REG, RHG, RTF, and EE. These studies should expand their horizons to explore and compare the impacts and implications of different scenarios of green energy development in South Asia across various facets of sustainable development, such as poverty reduction, gender equality, health, education, and human rights.

For example, future research can address pressing questions concerning the potential contributions or challenges of different green energy development scenarios to the achievement of Sustainable Development Goals (SDGs) in South Asia. It can also investigate the influence of these scenarios on access, affordability, and the quality of energy services for diverse segments of the population in the region. Furthermore, research should explore how these scenarios influence the empowerment and participation of women and marginalized groups in the energy sector in South Asia, fostering a more inclusive and equitable green energy transition. By enhancing the comprehensiveness and depth of research, we can truly unveil the potential and complexities of green energy transition in South Asia, contributing to informed decision making in this vital domain.

3.2. Evaluations of Green Energy Policies and Targets in SAARC Countries

The second theme of our inquiry centers around the evaluation of green energy objectives and policies within the SAARC countries. Numerous studies have undertaken a comprehensive examination of the national green energy targets and policies in SAARC nations. This encompasses a deep dive into renewable energy aspirations, energy efficiency standards, carbon pricing strategies, subsidies, regulatory frameworks, and the institutional landscape.

For instance, [21] undertook a review of renewable energy targets and policies in SAARC countries. They uncovered an interesting contrast in that while many nations set lofty renewable energy targets, the lack of effective policies and institutions often hinders the realization of these objectives.

However, [22] argue that the evaluation by Bhattacharyya and Timilsina fails to capture the full picture. They emphasize the regional dimension of renewable energy development, highlighting the potential benefits of South Asian cooperation, including cross-border trade, joint investments, and knowledge sharing.

Moving on to energy efficiency standards and policies in SAARC countries, [20,23,24]) found that while many countries have adopted some energy efficiency standards, enforcement and monitoring mechanisms remain inconsistent.

Conversely, [20] critiqued Sovacool et al. [20,23,24]'s evaluation as narrow and outdated. They contend that it disregards behavioral and social aspects of energy efficiency and relies on outdated data, failing to reflect current energy efficiency trends in South Asia.

In a similar vein, [25] delved into carbon pricing mechanisms and policies in SAARC countries. Their findings revealed that most nations have implemented some form of carbon pricing but face challenges such as low coverage, high exemptions, and governance issues.

However, [18] dispute this evaluation, arguing that it simplistically assumes carbon pricing as the most effective policy instrument while ignoring co-benefits and trade-offs associated with other policy instruments. They also highlight the misleading nature of comparing carbon pricing levels across countries without considering economic structure, emission intensity, income level, and policy context.

Despite these valuable insights, most studies have primarily focused on national-level green energy targets and policies, often neglecting the potential of regional cooperation and integration among SAARC countries. Such collaboration can offer significant advantages for South Asia's green energy transition, including economies of scale, resource optimization, technology transfer, policy harmonization, and market development.

For example, [26] examined the potential of regional electricity trade using RES and its capacity to reduce electricity generation costs, enhance reliability, and mitigate environmental impacts. Similarly, [22] explored the feasibility of regional solar PV manufacturing among SAARC countries and its potential to boost competitiveness, create jobs, and reduce import dependence.

Moreover, [19] proposed a hybrid optimization model that, after considering resource availability, cost, emissions, and reliability, suggested the optimal renewable energy mix for the region. Nevertheless, they acknowledged limitations in their model, such as spatial and temporal resolution, input data uncertainty, and the exclusion of factors like grid integration, policy support, and social acceptance.

The social and political aspects of South Asia's green energy transition, including public awareness, stakeholder engagement, governance, and conflict resolution, have yet to be thoroughly explored in the context of regional cooperation and integration. Key questions persist, such as how regional cooperation can foster a shared vision and identity among SAARC countries for green energy transition. It must also address challenges tied to power imbalances, mistrust, and security concerns among the nations.

Additionally, the comparison and evaluation of various models and methods that can accurately capture the complexity and diversity of green energy systems in South Asia, such as agent-based modeling, system dynamics, multi-criteria decision analysis, and scenario analysis, warrant more attention. This includes addressing questions about managing the

uncertainty, variability, and interdependence of green energy sources and incorporating the multiple dimensions and objectives of green energy transition: economic, environmental, social, and technical. These methods should also aim to facilitate communication and collaboration among different stakeholders and experts engaged in green energy transition.

3.3. Advancing of Green Energy Deployment and Performance in SAARC Countries

Within this section, we embark on a compelling exploration of green energy deployment in SAARC countries. Green energy deployment entails harnessing renewable sources like solar, wind, hydro, biomass, and biofuels to fulfill the energy requirements of diverse sectors, ranging from electricity and heating to transport and industry. Several studies have diligently assessed and compared sectoral performance in SAARC nations using an array of key performance indicators. These include gauging the share of renewable energy generation and consumption, evaluating emissions reduction levels, and scrutinizing the cost-effectiveness of renewable energy technologies.

For instance, [27,28] delved into the electricity sector in SAARC countries, uncovering that India led with the highest share of renewable electricity generation (16%), while Bhutan exhibited the highest share of renewable electricity consumption (100%). However, a critical aspect was overlooked, i.e., the potential advantages of cross-border electricity trade among SAARC nations, leveraging RES to foster regional integration and cooperation, as highlighted by [26]

Shrestha et al. [29,30] directed their focus towards the heating sector in SAARC countries. Their findings revealed Nepal's leading position with an 87% share of renewable heat generation, while the Maldives demonstrated a 100% share of renewable heat consumption. Nevertheless, these assessments omitted the consideration of the diversity and quality of renewable heat sources, such as solar thermal, geothermal, biomass, and biogas, which can have varying impacts on the environment and society, as emphasized by [31,32].

Similarly, [33,34] scrutinized the transport sector in SAARC countries, identifying India as the leader in renewable transport fuel production (3%), and Sri Lanka as the leader in renewable transport fuel consumption (10%). However, they failed to explore the associated challenges and opportunities in scaling up the utilization of renewable transport fuels in SAARC countries. Factors such as policy frameworks, infrastructure development, technology transfer, and public awareness, as noted by [35] play a pivotal role in this context.

The literature to date accentuates the technical and economic aspects of renewable energy source (RES) deployment, albeit overlooking the potential for cross-sectoral integration and optimization of RES systems. This raises intriguing research questions: How can the electricity, heating, and transport sectors within the SAARC region collaborate and coordinate to achieve the optimal utilization of RES? What benefits stem from interconnecting and interoperating RES systems across different sectors and nations? Moreover, what are the policy and regulatory challenges and opportunities associated with harmonizing and aligning different sectoral and national frameworks to facilitate RES integration and optimization in the region?

3.4. Green Energy Transition Challenges and Opportunities in South Asia

This section zeroes in on the intricate terrain of identifying the challenges and opportunities embedded within the green energy transition in South Asia. Numerous studies have diligently pinpointed the key factors driving or impeding this transition. These factors span the technical, economic, social, political, and institutional spheres.

For instance, [36,37] adeptly identified and discussed the technical and economic drivers and barriers in South Asia's journey towards renewable energy. Their insights encompass resource availability and potential, technology costs and innovation, market conditions, subsidies, and incentives. Notably, South Asia brims with abundant renewable energy resources and potential, yet it grapples with daunting technical and economic chal-

lenges, including substantial upfront costs, limited grid integration, inadequate financing, and pricing distortions.

On a parallel path, [38–40] investigated the social and political dynamics influencing energy efficiency in South Asia. Their exploration uncovered the role of consumer preferences and behavior, stakeholder engagement, policy support and coordination, governance, and accountability. While the region demonstrates a substantial appetite for energy efficiency improvements, it faces various social and political challenges, including limited awareness, resistance to change, fragmented policies, and weak institutions.

Nonetheless, certain studies have raised questions and objections regarding the identification of green energy transition drivers and barriers. Ref. [3], for instance, argued that [36,37] identification of technical and economic drivers and barriers to renewable energy transition in South Asia is incomplete and overlooks the environmental and social impacts and benefits of RES. Similarly, [18] challenged the identification of social and political drivers and barriers to energy efficiency transition by [39,40]), branding them as biased and outdated. They contended that these identifications hinge on a narrow definition of energy efficiency that focuses solely on technical aspects, neglecting the crucial behavioral and cultural aspects, including awareness, motivation, and societal norms.

Expanding further, several studies have explored institutional drivers and barriers to green energy transition in South Asia, encompassing the legal, regulatory, organizational, and normative aspects. Ref. [41] uncovered challenges related to energy access in South Asia, a prerequisite for green energy transition, including inadequate legal frameworks, inefficient regulatory mechanisms, organizational deficiencies, and conflicting normative values. Similarly, Ref. [42] probed into the institutional drivers and barriers governing energy policy decisions in South Asia, vital for green energy transition. They highlighted obstacles such as data availability, uncertainty, simplification of models and frameworks, and feasibility and acceptability of policy options.

However, these studies have primarily dwelled on the national level, bypassing regional or sub-regional dynamics and interactions. They have overlooked the influence of external actors and factors, such as international organizations, donors, trade partners, and global environmental regimes, in shaping or facilitating green energy transition. Furthermore, they have yet to delve into the potential co-benefits and trade-offs tied to green energy transition concerning other development goals or sectors, such as poverty reduction, health enhancement, water management, or urban planning.

As a result, a comprehensive and integrated framework is urgently needed to capture the multifaceted interplay among the various drivers and barriers of green energy transition in South Asia. This framework should grapple with essential questions: How can the interplay between drivers and barriers, encompassing feedback loops, trade-offs, synergies, and co-benefits, be accounted for? How can the diverse perspectives and preferences of stakeholders and actors involved in green energy transition be incorporated? Furthermore, how can the identification and prioritization of the most critical and influential drivers and barriers to green energy transition in South Asia be facilitated?

A significant research gap also lies in the exploration and evaluation of alternative pathways and scenarios of green energy transition in South Asia. These explorations should consider various assumptions and conditions, including the level of regional cooperation and integration, the degree of policy support and coordination, and the rate of technology innovation and diffusion. Future research endeavors must unravel how these factors impact the potential and feasibility of green energy transition in South Asia.

3.5. The Conceptual Model for the Green Energy Transition in South Asia

Based on the preceding review of the literature, we have developed a conceptual model for the development and growth of green energy in South Asia which comprises five pivotal variables (Figure 1):

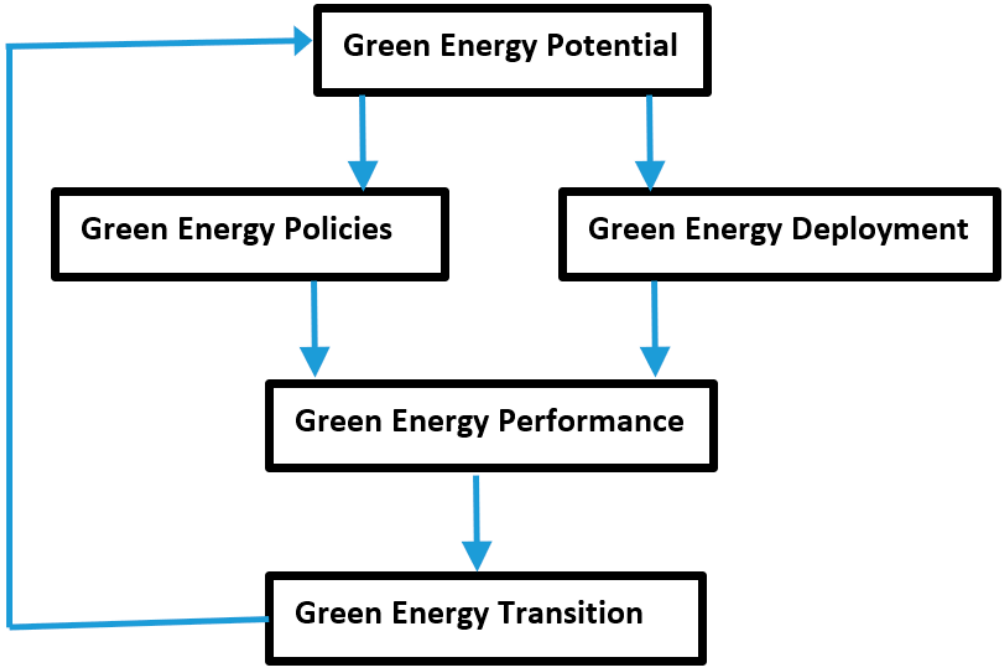

Figure 1. The conceptual model for the green energy transition in South Asia.

1. Green Energy Potential: The bedrock of our model, this variable encapsulates the availability and quality of renewable energy resources (RES) in South Asia. Nature's artistry, as witnessed through factors like climate, geography, and seasonality, mingles with human ingenuity, showcased through technology, infrastructure, and energy demand. Green energy potential is the guardian of possibilities, holding the power to shape the entire ecosystem. This variable casts a positive influence, nurturing green energy policies and stimulating green energy deployment, thereby fostering supportive policies, and enhancing RES utilization.
2. Green Energy Policies: The conductor orchestrating the symphony of South Asia's energy transformation, these policies encompass a range of measures adopted by SAARC countries. In the vibrant orchestra of policies, you will find renewable energy targets, energy efficiency standards, carbon pricing mechanisms, subsidies, incentives, regulatory frameworks, and institutional arrangements. These policies emerge from the political and economic realms, sculpted by factors such as public awareness, stakeholder participation, policy coordination, governance, market conditions, financing options, and cost-effectiveness. Green energy policies guide the crescendo, positively impacting green energy deployment and performance, driving effective policies to boost RES utilization and amplify the RES impact.
3. Green Energy Deployment: At the heart of the action, this variable embodies the dynamic utilization of RES across various sectors within South Asia, from electrifying moments to warming interactions, transportation breakthroughs, and industrial endeavors. Technical aspects, such as resource availability, technology costs, innovation, grid integration, and reliability, converge with the social nuances of consumer preferences and trust in RES technologies and providers. Green energy deployment is the pulse of progress, enhancing green energy performance and facilitating a swift transition towards a low-carbon economy. Here, the more RES utilization, the merrier the outcomes.
4. Green Energy Performance: The critical assessment of RES impact within South Asia takes center stage, with a spotlight on the share of renewable energy generation and consumption, emissions reduction levels, and the cost-effectiveness of RES technologies. It is a delicate balance between the forces of environmental preservation and fossil fuel's legacy, with greenhouse gas emissions and environmental pollution as

key players. Green energy performance holds the potential to be the pivot-offering a positive or negative influence on green energy transition, dependent on whether it aligns with or surpasses the expectations and targets set by SAARC countries.

5. Green Energy Transition: The grand finale of the South Asian energy transformation unfolds on the global stage, as South Asia shifts from fossil fuels to RES, driven by its pursuit of sustainable development goals. External actors, including international organizations, donors, trade partners, and global environmental regimes, make a cameo appearance, either smoothing the transition or adding complexity to the narrative. Green energy transition wields a dual-edged sword, impacting green energy potential. It can either shrink the RES availability and quality, or magnify it, reshaping South Asia's energy landscape.

Our conceptual model is a captivating, dynamic lens through which we can view and comprehend the multifaceted journey towards green energy transition in South Asia. It reveals the intricate interplay of drivers and barriers that shape the RES landscape, offering us insights into the leverage points and intervention strategies that can elevate the performance and outcomes of RES systems. With the ability to guide our understanding of the region's energy transition, our conceptual model invites empirical validation in future research endeavors.

4. Comparative Analysis of the Green Energy and Environment Policies in South Asia

South Asia is one of the most vulnerable regions to the impacts of climate change, such as rising temperatures, extreme weather events, sea level rise, and water scarcity. At the same time, the region is also facing the challenges of meeting the growing energy demand, ensuring energy security and access, and reducing poverty and inequality. Therefore, the region needs to adopt and implement green energy and environmental policies that can balance the objectives of mitigation and adaptation, as well as economic and social development.

The region has made some progress in setting and implementing green energy and environmental policies in recent years. All the countries in the region have submitted their nationally determined contributions (NDCs) under the Paris Agreement, which include various targets and actions to reduce greenhouse gas (GHG) emissions and enhance climate resilience. For example, India has pledged to reduce its emissions intensity by 33–35% by 2030 from 2005 levels, increase its renewable energy capacity to 175 GW by 2022 and 450 GW by 2030, and create an additional carbon sink of 2.5–3 billion tonnes of CO_2 equivalent through forest and tree cover by 2030 [43]. Similarly, Bangladesh has committed to reduce its GHG emissions by 5% by 2030 from the BAU scenario, increase its renewable energy share to 10% by 2021 and 20% by 2030, and implement various adaptation measures in sectors such as agriculture, water, coastal zones, health, and disaster management [44].

However, the region also faces many challenges and barriers in achieving its green energy and environmental goals. Some of the familiar challenges include the lack of adequate financial resources, technical capacity, institutional coordination, policy coherence, stakeholder participation, public awareness, and political will. Moreover, the region also faces some trade-offs and conflicts between different policy objectives and interests. For example, while renewable energy can provide multiple benefits such as reducing emissions, enhancing energy security, creating jobs, and improving health, it also entails some costs and risks such as high upfront investment, grid integration issues, land acquisition problems, and social opposition [21].

Need for regional cooperation and coordination. According to [45] climate change challenges and opportunities in South Asia require enhanced regional cooperation and coordination among the countries in the region, as well as with other stakeholders such as civil society, the private sector, academia, the media, and international organizations. The [45] study identifies some of the existing and potential areas for regional cooperation, such as the following:

- Sharing best practices and lessons learned from national and subnational climate actions, such as mitigation strategies, adaptation measures, disaster risk management, and climate finance.
- Developing common standards and frameworks for measuring, reporting, and verifying greenhouse gas emissions and climate actions, as well as for assessing climate vulnerability and resilience.
- Harmonizing policies and regulations to facilitate cross-border trade and investment in low-carbon and climate-resilient technologies, products, and services.
- Building regional infrastructure and institutions to support regional integration and connectivity, such as power grids, transport networks, water management systems, and early warning systems.
- Promoting regional research and innovation to foster knowledge creation and dissemination, technology development and transfer, capacity building and training, and public awareness and education.
- Strengthening regional dialogue and advocacy to enhance political will and commitment, mobilize resources and support, address conflicts and disputes, and engage with global climate negotiations.

However, [45] also acknowledges some of the gaps and barriers that hinder regional cooperation on climate change in South Asia, such as the following:

- Lack of trust and confidence among the countries due to historical, political, and security issues.
- Divergent interests and priorities among the countries due to various levels of development, vulnerability, capacity, and ambition.
- Weak institutional mechanisms and platforms for regional cooperation due to limited mandate, resources, participation, coordination, and accountability.
- Insufficient data availability and quality for regional analysis and planning due to gaps in collection, sharing, standardization, validation, and dissemination.
- Limited stakeholder involvement and consultation for regional decision making due to lack of representation, transparency, accessibility, and feedback.

RE policies in South Asia. According to [21] renewable energy policies and programs in six South Asian countries (Bangladesh, Bhutan, India, the Maldives, Nepal, and Sri Lanka) vary in terms of their scope, scale, and effectiveness. They use a *comparative analysis framework* that considers four dimensions of renewable energy development: potential, policy, performance, and promotion. Based on this framework, they find the following:

- Bangladesh has a high potential for solar, wind, and biomass energy, but its policy framework is weak and fragmented, its performance is low and dependent on donor support, and its promotion is limited by lack of awareness and coordination.
- Bhutan has a huge hydropower potential, but its policy framework is focused on exporting electricity to India, its performance is constrained by transmission and distribution issues, and its promotion is hampered by environmental and social concerns.
- India has a diverse potential for solar, wind, biomass, small hydro, and waste-to-energy sources, but its policy framework is complex and inconsistent, its performance is mixed and uneven across states, and its promotion is challenged by financial and institutional barriers.
- The Maldives has a high potential for solar and wind energy, but its policy framework is nascent and underdeveloped, its performance is negligible and reliant on pilot projects, and its promotion is hindered by a lack of capacity and resources.
- Nepal has a large potential for hydropower and biomass energy, but its policy framework is outdated and inadequate, its performance is poor and affected by political instability, and its promotion is obstructed by technical and regulatory obstacles.
- Sri Lanka has a moderate potential for solar, wind, biomass, small hydro, and waste-to-energy sources, but its policy framework is comprehensive and supportive, its

performance is high and impressive across sectors, and its promotion is facilitated by strong stakeholder involvement and public–private partnerships.

Bhattacharyya and Timilsina [21] conclude that renewable energy development in South Asia faces many common challenges such as lack of financial resources, technical capacity, institutional coordination, policy coherence, stakeholder participation, public awareness, and political will.

Energy efficiency policies in South Asia. Similarly, while energy efficiency can improve the productivity and competitiveness of the economy, it also faces some barriers such as low consumer awareness, high transaction costs, split incentives, market failures, and policy gaps [20,23,24]. Ref. [20] provide a comprehensive and comparative analysis of energy efficiency policies and measures in four South Asian countries (Bangladesh, India, Nepal, and Sri Lanka) and evaluate their impacts on energy savings, emissions reduction, and economic benefits. They use a *multi-criteria decision analysis* (*MCDA*) framework that considers four dimensions of energy efficiency: technical, economic, environmental, and social. Based on this framework, they find the following:

(i) Energy efficiency can provide significant benefits for South Asia, such as reducing energy consumption by 13–59%, reducing CO_2 emissions by 19–65%, and increasing GDP by 3–8% by 2030, compared to the business-as-usual scenario;
(ii) Energy efficiency can also improve the productivity and competitiveness of the economy, as well as the welfare and equity of the society, by creating jobs, reducing poverty, enhancing energy access and security, improving health and education, and empowering women and marginalized groups.

However, energy efficiency also entails some costs and risks, such as high upfront investment, long payback period, low consumer awareness, high transaction costs, split incentives, market failures, and policy gaps. Therefore, energy efficiency requires more integrated and coherent policies that can address the multiple dimensions of energy efficiency and overcome the barriers and constraints that hinder its implementation.

These challenges and trade-offs require careful analysis and evaluation of the green energy policies and their impacts on various dimensions of sustainable development. However, most of the existing studies on green energy policies in South Asia have focused on a single or a few aspects of green energy development, such as renewable energy potential [46], renewable energy consumption [47], renewable energy policies [42,48], or energy efficiency improvement [7,15,49,50]. Moreover, most of these studies have used different models and methods that are not comparable or consistent across different scenarios and countries. Therefore, there is a need for more comprehensive and integrated studies that can assess the potential of all types of green energy sources in the region, using different models and methods that can capture the complexity and diversity of green energy systems. Moreover, there is a need for more comparative and consistent studies that can use common assumptions and parameters across different scenarios and countries to facilitate cross-country and cross-scenario analysis. Such studies can help policymakers, stakeholders, and researchers to make better-informed decisions on green energy policies and their impacts on sustainable development in South Asia.

Therefore, the region needs to adopt a more holistic and integrated approach to green energy and environmental policymaking and implementation. This requires addressing the root causes and drivers of GHG emissions and climate vulnerability, as well as the synergies and trade-offs between different policy options and outcomes. It also requires enhancing regional cooperation and coordination among the countries in South Asia, as well as engaging with other stakeholders such as civil society, the private sector, academia, the media, and international organizations. Some of the potential areas for regional cooperation include sharing best practices and lessons learned, developing common standards and frameworks, harmonizing policies, and regulations, facilitating cross-border trade and investment, building regional infrastructure and institutions, promoting regional research and innovation, and strengthening regional dialogue and advocacy [25,45]. Utilizing

the conceptual model, given in Figure 1, decision makers can take initiatives to deploy resources for the development and growth of green energy in their countries.

5. Discussion: Unveiling the Nexus of Green Energy and Environmental Policies in South Asia

As we delve into the discussion, it becomes evident that South Asia is treading a delicate path. The region finds itself at a crossroads, where economic development, societal well-being, and environmental sustainability intersect, each demanding its due attention. With the potential for abundant renewable energy resources and energy efficiency improvements within grasp, South Asia is beset by formidable barriers and constraints. To navigate this challenging terrain, the region must formulate policies that strike a harmonious balance, addressing the multifaceted drivers, impacts, and trade-offs inherent to its green energy and environmental transition.

Our analysis unearths critical implications that underscore the complexity and uncertainty of South Asia's operational environment. This region is exposed to an array of external and internal shocks and stresses, including the disruptive forces of the COVID-19 pandemic, geopolitical tensions, natural disasters, social conflicts, and institutional weaknesses. These tumultuous elements have the potential to disrupt the availability, affordability, accessibility, and acceptability of green energy and environmental options in South Asia. Therefore, a more adaptive and flexible policy approach is essential, capable of responding to the ever-evolving circumstances and uncertainties.

Furthermore, South Asia must harness the potential of information technology and data analytics to enrich its green energy and environmental policies. These tools offer invaluable insights and solutions for policy design, implementation, evaluation, and learning. They can facilitate the assessment of renewable energy resource potential, the evaluation of energy efficiency standards and policies, the measurement of carbon pricing mechanisms, and the identification of best practices and lessons learned from other regions. Additionally, they can enhance the transparency, accountability, participation, and coordination of policy processes and stakeholder involvement.

Sustainability and resilience emerge as paramount concerns, underlining the need for green energy and environmental policies to withstand the test of time. These policies must demonstrate their ability to achieve long-term objectives while also withstanding short-term shocks and stresses. Diversifying and balancing energy sources and systems, integrating environmental, social, and economic considerations, and considering aspects such as GHG emissions reduction, climate adaptation, energy access, affordability, equity, health, and employment all contribute to sustainability and resilience.

Partnerships and collaboration must form the bedrock of South Asia's green energy and environmental policies. These collaborations should encompass a wide spectrum of stakeholders, including governments, the private sector, civil society, academia, the media, and international organizations. Such collaborations not only mobilize and leverage financial, technical, human, and social capital and resources but also serve as conduits for sharing knowledge, experience, innovation, and best practices. Furthermore, these alliances contribute to building and reinforcing trust, commitment, ownership, and legitimacy in the policy processes and outcomes.

Considering these implications, a set of policy options and strategies emerge:

- **The Development of a Comprehensive Policy Framework**: South Asia must work towards a comprehensive, coherent, and consistent policy framework aligned with national and regional green energy and environmental goals and commitments, such as the nationally determined contributions (NDCs) under the Paris Agreement, the South Asian Association for Regional Cooperation (SAARC) Action Plan on Climate Change 2021–2030, and the South Asia Cooperative Environment Programme (SACEP) Strategic Plan 2021–2025.
- **The Establishment of Data Platforms**: Robust data platforms that collect, analyze, disseminate, and update relevant information and indicators on green energy and

environmental aspects in South Asia, such as the SAARC Energy Centre Database, the SACEP Environmental Data Centre, and the International Renewable Energy Agency (IRENA) Renewable Energy Statistics, should be a top priority.

- **The Promotion of Sustainable Energy Infrastructure**: Transparent, sustainable, and high-quality energy infrastructure development and financing in South Asia, in line with international standards and principles on environmental and social safeguards, such as the World Bank Environmental and Social Framework, the Asian Development Bank Safeguard Policy Statement, and the Equator Principles, is crucial.
- **Enhanced Regional Collaboration**: South Asia should foster regional cooperation and collaboration on green energy and environmental policies by strengthening existing mechanisms and platforms, such as the SAARC Energy Cooperation Framework, the SACEP Climate Change Programme, the SAARC Development Fund, the South Asia Regional Initiative for Energy Integration, and more.
- **Engagement with Stakeholders**: Facilitating dialogue, consultation, participation, feedback, and evaluation opportunities and mechanisms involving various stakeholders and partners, such as the SAARC Energy Dialogue, the SACEP Regional Consultative Committee, the South Asia Forum on the Sustainable Development Goals, the South Asia Civil Society Forum on Climate Change, is essential.

Building upon the insights derived from our analysis and the lack of empirical research about the above-mentioned policy proposals, it is imperative to consider avenues for further research. The following are suggested directions for future investigations:

1. **Quantitative Analysis**: Conduct in-depth quantitative analyses to assess the effectiveness of the proposed policies and strategies, considering relevant data and indicators. Evaluate the impact of these policies on key environmental and energy metrics.
2. **Comparative Studies**: Compare the experiences of South Asia with other regions that have successfully implemented similar policies. Analyze the transferability of best practices and lessons learned.
3. **Policy Implementation and Evaluation**: Investigate the practical challenges and successes of policy implementation in South Asia. Assess the role of stakeholders and the effectiveness of policy mechanisms in achieving desired outcomes.
4. **Long-Term Policy Assessment**: Analyze the long-term sustainability and resilience of South Asia's green energy and environmental policies, considering factors like climate change adaptation, technological advancements, and evolving socio-economic conditions.
5. **International Collaboration**: Study the role of international collaboration in shaping South Asia's policies, including the alignment of regional goals with international commitments like the Paris Agreement.

In summary, this section has unraveled the findings and implications of our analysis concerning green energy and environmental policies in South Asia. It underscores the challenges, opportunities, and strategies that can enhance policy performance and impact in the region. The subsequent section will consolidate our key findings and conclusions.

6. Conclusions

This paper provides a novel and comprehensive analysis of the opportunities and challenges for green energy and environment transition in South Asia, a region that faces the dilemma of meeting its growing energy demand while reducing its greenhouse gas emissions and environmental vulnerability. This paper has organized the literature on green energy and environment policies in South Asia into four main themes:

1. The assessment of green energy resources potential and scenarios in South Asia;
2. The evaluation of green energy targets and policies in SAARC countries;
3. The advancement of green energy deployment and performance in different sectors;
4. The identification of green energy transition challenges and opportunities in South Asia.

Based on these themes, this paper has developed a conceptual model for the green energy transition in South Asia, which consists of five key variables: green energy potential,

green energy policies, green energy deployment, green energy performance, and green energy transition.

The main findings and implications of the analysis are as follows:

- South Asia has an enormous potential to harness its abundant renewable energy resources and improve its energy efficiency, but it also faces various barriers and constraints that hinder its progress. Therefore, the region needs to adopt and implement more effective and coherent policies that can address the drivers, impacts, and trade-offs of its green energy and environment transition.
- The region needs to cope with the complexity and uncertainty of the operational environment, where multiple factors and actors influence the policy outcomes and impacts. The region is exposed to various external and internal shocks and stresses, such as the COVID-19 pandemic, geopolitical tensions, natural disasters, social conflicts, and institutional weaknesses. These shocks and stresses can affect the availability, affordability, accessibility, and acceptability of green energy and environmental options in the region. Therefore, the region needs to adopt a more adaptive and flexible policy approach that can respond to the changing circumstances and uncertainties.
- The region needs to leverage the potential of information technology and data analytics to enhance its green energy and environmental policies. Information technology and data analytics can provide valuable insights and solutions for policy design, implementation, evaluation, and learning. For example, information technology and data analytics can help to assess the renewable energy resources potential, evaluate the energy efficiency standards and policies in different countries, measure the carbon pricing mechanisms and policies in different sectors, and identify the best practices and lessons learned from other regions. Information technology and data analytics can also help to improve the transparency, accountability, participation, and coordination of the policy processes and stakeholders.
- The region needs to emphasize the sustainability and resilience of its green energy and environment policies by promoting more diversified and balanced energy sources and systems, as well as integrating environmental, social, and economic considerations and impacts into policy decisions and actions. For example, sustainability and resilience can be enhanced by promoting more diversified and balanced energy sources such as renewable electricity generation (REG), renewable heat generation (RHG), renewable transport fuels (RTF), natural gas (NG), energy storage (ES), smart grids (SG), microgrids (MG), distributed generation (DG), etc. Sustainability and resilience can also be enhanced by integrating environmental social and economic considerations such as GHG emissions reduction, climate adaptation, energy access, affordability, equity, health, employment, etc.
- The region needs to foster partnerships and collaboration for its green energy and environment policies by establishing and strengthening the existing mechanisms and platforms such as SAARC Energy Centre (SEC) South Asian Association for Regional Cooperation (SAARC) South Asian Regional Initiative for Energy Integration (SARI/EI), etc., as well as engaging with other stakeholders and partners such as international organizations, donors, the private sector, civil society, academia, the media, etc. [17]. Partnerships and collaboration can help to mobilize and leverage the financial technical human and social capital and resources for policy implementation and scaling up. Partnerships and collaboration can also help to share and exchange knowledge experience innovation and best practices for policy improvement and learning. Partnerships and collaboration can also help to build and strengthen the trust commitment ownership and legitimacy of the policy processes and outcomes.

This paper has provided a comprehensive and systematic review of the literature on green energy and environmental policies in South Asia covering both theoretical and empirical studies from various disciplines and perspectives. This paper has proposed a novel conceptual model for green energy and environmental policies in South Asia based on the integration of the sustainable development goals (SDGs) framework the multi-level

governance (MLG) approach and the policy cycle model. This paper has demonstrated how the conceptual model can be used to guide and inform the formulation implementation evaluation and improvement of green energy and environmental policies in South Asia considering the complex and dynamic interactions among the different levels actors' factors and stages of the policy processes and outcomes.

Some of the limitations include the lack of data availability and quality the uncertainty and variability of the assumptions and parameters the simplification and generalization of the models and frameworks the subjectivity and bias of the criteria and indicators and the feasibility and acceptability of the policy options and strategies. Future research directions encompass the exploration of cutting-edge data sources, methods, tools, and techniques, including but not limited to big data, artificial intelligence, machine learning, blockchain, and others. Additionally, there is a need to create dynamic and interactive scenarios and simulations built upon the conceptual model presented in Figure 1. Furthermore, it is crucial to enhance the inclusivity of perspectives and stakeholders in policy processes and outcomes. Lastly, there is a call for more precise and customized policy interventions and experiments aligned with the conceptual model.

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