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Renewable Energy for a Sustainable Society: Vital Need of Pakistan

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ABSTRACT

In the context of accelerating global environmental change, the transition to renewable energy is widely viewed as a critical pathway toward achieving a sustainable society. This article examines how renewable energy adoption contributes to environmental, economic, and social dimensions of sustainability. The problem statement identifies the dependence on fossil fuels, greenhouse gas emissions, energy security and inequitable access as core challenges. The objectives are to investigate the role of renewable energy in promoting sustainability, to assess barriers and enablers, and to analyze empirical data from selected countries/regions. The methodology employs a mixed-method approach combining literature review and secondary data analysis. Data collection draws on international databases and published reports; data analysis uses descriptive statistics and comparative assessment. The findings emphasize that renewable energy deployment correlates with improved environmental outcomes, enhanced energy security, and socio-economic benefits—yet significant technical, policy and financial barriers remain. The article concludes with recommendations for policy, investment and future research.

Keywords: Renewable Energy, Sustainable Society, Energy Transition, Sustainability, Energy Policy.

INTRODUCTION

The world stands in a pivotal era in which the energy systems underpinning modern societies must undergo profound transformation. Traditional reliance on fossil fuels is generating mounting ecological pressures—ranging from elevated greenhouse gas (GHG) emissions and climate change to air pollution, resource depletion and energy insecurity. In response, renewable energy sources (RES) such as solar, wind, hydro, geothermal and biomass have emerged as viable alternatives that support the three pillars of sustainability: environmental protection, economic development and social equity. Research indicates that the field of renewable energies and sustainable development has grown significantly. For example,

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García-Lillo et al. (2023) found that research efforts on renewable energies grew substantially in recent years and that the transition to a new, more sustainable energy model is key to ensuring human action remains sustainable. This article focuses on how renewable energy adoption can foster a sustainable society. By examining both theoretical frameworks and empirical data, this work explores the impact, opportunities and barriers of renewable energy deployment within a sustainability lens.

Problem Statement

Despite advances in renewable energy technologies, global energy systems continue to depend heavily on fossil fuels. This dependency creates multiple problems:

- High greenhouse gas emissions contributing to climate change, threatening ecological systems, weather patterns and human well-being.
- Air pollution, ecosystem degradation and health burdens in many regions.
- Energy security vulnerabilities arising from fuel price volatility, supply disruptions and geopolitical risks.
- Social and economic inequities: many low-income households and regions lack reliable, affordable, clean energy access.
- Technological and infrastructural mismatches: integrating high shares of intermittent RES into existing grids poses engineering, regulatory and investment challenges. For instance, integration of high levels of RES into grids brings control issues, reduced system inertia, higher uncertainty and power-quality concerns. (arXiv)
- Thus, the central problem is: *How can renewable energy adoption be scaled and managed to support a sustainable society—balancing environmental protection, economic growth and social equity—while overcoming technical, policy and financial barriers?*

Objectives of the Study

The objectives of this research are:

- To examine the role that renewable energy plays in advancing the three dimensions of sustainable development (environmental, economic, social).

- To assess the current level of renewable energy deployment and its outcomes in selected regions or globally.
- To identify the key enabling factors and barriers for renewable energy adoption within the sustainability framework.
- To analyze secondary data to evaluate relationships between renewable energy usage and selected sustainability indicators (e.g., emissions reduction, energy access, economic performance).
- To provide recommendations for policy makers, industry stakeholders and researchers on how to accelerate renewable energy for a sustainable society.

Scope of the Study

The scope of the study is defined as follows:

- **Geographic scope**: The study draws on international literature and global or regional secondary data. It does not conduct primary data collection at the local community level, but focuses on aggregated data and published reports.
- **Temporal scope**: The study covers recent trends in renewable energy deployment and sustainability outcomes up to the most recently available data (generally last 5-10 years).
- **Technological scope**: It considers major renewable energy technologies (solar photovoltaic, wind, hydroelectric, geothermal, biomass).
- **Analytical scope**: The study focuses on macro-level relationships (e.g., renewable energy share, emissions, energy access, economic indicators) rather than detailed engineering modelling.
- **Limitations**: Because the study uses secondary data, causality may be difficult to firmly establish; additionally, regional heterogeneity (e.g., grid conditions, policy environments) means findings may not apply uniformly everywhere.

SIGNIFICANCE OF THE STUDY

This study is significant for several reasons:

- **Theoretical Significance:** By synthesizing literature and data through the lens of sustainability, the study adds to the body of knowledge on how renewable energy adoption intersects with economic, environmental and social outcomes.

- **Policy Significance:** Insights emerging from the data analysis can assist policy makers and planners in devising strategies and regulations to accelerate renewable energy deployment while managing associated challenges.

- **Practical Significance:** Stakeholders (governments, utilities, private sector, communities) can leverage the findings to design and implement renewable energy projects that contribute to sustainable development goals (SDGs).

- **Social Significance:** Understanding barriers to access and adoption, particularly for disadvantaged groups, supports the goal of equitable energy transition and greater energy justice.

- **Global Relevance:** Given the urgency of climate action and energy transformation, the study contributes to broader dialogues on meeting the goals of low-carbon societies and sustainable energy systems.

LITERATURE REVIEW

This literature review provides a comprehensive foundation for understanding renewable energy's role in achieving UN SDG 7 (Affordable and Clean Energy) and fostering a sustainable society. Each citation aligns with key themes such as technological advancements, policy frameworks, socio-economic impacts, and future challenges.

A comprehensive review of published scholarly articles, reports and reviews on renewable energy and sustainable development was undertaken. Key databases and sources include journal articles such as “Renewable Energies and Sustainable Development: A Bibliometric Overview” (García-Lillo et al., 2023) and “Renewable Energy and Sustainability from the Supply Side: A Critical Review and Analysis” (Applied Sciences, 2020). The review focused on the intersections of renewable energy deployment, sustainability dimensions (environmental, economic, social) and barriers/enablers.

Types of Renewable Energy Sources

Solar energy harnesses sunlight through photovoltaic cells and solar thermal systems. It is abundant, scalable, and reduces dependency on fossil fuels (IRENA, 2022). *Wind turbines* convert kinetic energy into electricity. Offshore and onshore wind farms are increasingly efficient and cost-effective (GWEC, 2023). *Hydropower* generates electricity from flowing water. Large-scale dams and small hydro projects provide reliable energy with minimal emissions (IHA, 2021). *Biomass Energy* utilizes organic materials like agricultural waste and wood pellets. It supports waste management and rural development (FAO, 2022).

Benefits of Renewable Energy

Environmental Benefits; reduces greenhouse gas emissions, lowers air and water pollution, conserves natural resources. *Economic Benefits;* creates jobs in manufacturing, installation, and maintenance, reduces energy import dependency, Stabilizes energy prices. *Social Benefits;* improves energy access in remote areas, enhances public health by reducing pollution-related diseases, challenges and Solutions, intermittency and Storage. Renewable sources like solar and wind are intermittent. Advances in battery storage and grid integration mitigate this issue (DOE, 2023).

Global Energy Transition and SDG 7

The literature on global energy transition and SDG 7 paints a picture of significant momentum but also unfinished business. The transition away from fossil fuels toward modern, clean energy systems is underway — driven by cost reductions, innovation and growing policy support — yet substantial gaps remain, particularly in access, infrastructure, finance, governance and justice. Achieving SDG 7 by 2030 will require not only technological deployment but also systemic transformation, inclusive governance, integrated policy mixes and demand-sensitive strategies. For researchers, continuing to explore context-specific pathways, equity dimensions, lifecycle impacts and integrated models presents compelling opportunities.

Solar Energy and Sustainability

Solar energy is highly sustainable because it's a renewable resource that produces no emissions during electricity generation and does not use finite resources like fossil fuels. While the manufacturing and transportation of solar panels have an environmental impact, the energy required to create them is recouped relatively quickly, and their overall emissions are significantly lower than those from fossil fuels. Solar energy offers sustainability benefits by reducing greenhouse gas emissions, improving public health, and increasing energy supply reliability.

Wind Energy and Economic Growth

Wind energy positively affects economic growth by creating jobs, lowering energy costs, and fostering investment, while also mitigating climate change. The relationship is complex, with some studies finding a bidirectional link where economic growth also drives more wind energy consumption. Investment in the sector stimulates manufacturing, installation, and maintenance, which are all significant economic drivers.

Hydropower and Environmental Impacts

Hydropower's environmental impacts include altering river flow and ecosystems, impeding fish migration, and flooding land for reservoirs, which destroys habitats and can release methane from decomposing organic matter. Additionally, dam construction requires significant resources and can negatively affect water quality and regional climate through changes in evaporation and sediment transport.

Biomass and Waste-to-Energy Solutions

Biomass and Waste-to-Energy (WtE) solutions convert organic materials and waste into usable energy like heat, electricity, or biofuels through processes such as combustion, gasification, and anaerobic digestion. These technologies reduce landfill waste, create renewable energy, and can support rural economies, but also present challenges related to cost and technology scalability.

Challenges and Future Directions

Challenges for renewable energy include intermittency, the need for significant infrastructure and storage investments, and policy inconsistencies. Future directions focus on overcoming these by developing advanced energy storage, building smart grids, using technologies like agrivoltaics to combine land use, and fostering supportive policies and international collaboration to accelerate the transition to 100% renewable systems

METHODOLOGY

This research adopts a mixed-method secondary analysis methodology combining literature review and quantitative data assessment.

Data Collection

Secondary data were collected from international sources, such as peer-reviewed articles, global energy agency reports, and regional data sets. Relevant variables include:

- Renewable energy share in total energy production
- Greenhouse gas emissions (CO_2)
- Energy access (percentage of population with modern energy)
- Economic indicators (GDP growth, employment in energy sector)

- Policy and regulation indicators (as described in literature) Data was triangulated from multiple sources to enhance reliability.

Data Analysis

Quantitative data analysis was primarily descriptive and comparative. Steps included:

- Tabulation of renewable energy deployment trends across countries/regions.
- Calculation of correlation between renewable energy share and sustainability indicators (e.g., emission levels, energy access).
- Comparative assessment of best-practice and lagging regions in terms of renewable energy contributions to sustainability.
- Qualitative synthesis of barriers and enabling factors identified in the literature review, mapped into thematic categories (technical, regulatory/policy, financial, social). While advanced statistical modelling (e.g., regression, causality tests) is beyond the scope of this paper, the descriptive analysis supports the study objectives and frames areas for future research.

DATA FINDINGS AND ANALYSIS

Trends in Renewable Energy Deployment

The literature indicates the growth of renewable energy deployment globally. For instance, (García-Lillo et al. 2023) highlight that the domain of renewable energies and sustainable development has seen significant research growth, indicating heightened interest and importance. (Manso & Behmiri 2020) emphasise that renewable energy adoption is increasingly important as fossil fuel reserves deplete and pollution burdens grow. These studies reflect that many nations have ramped up solar, wind, hydro and biomass installations. Also, cost reductions in renewables and associated technologies have improved competitiveness.

Renewable Energy and Environmental Sustainability

Renewable energy contributes to environmental sustainability primarily through GHG emissions reduction, fossil fuel displacement, and improved ecological outcomes. Lin & Ren (year not specified) argue that because renewable energy is cleaner than fossil fuels, it supports improved environment, fuel diversity, stable energy supply and economic development. Also, studies on supply-side sustainability (Appl. Sci., 2020) analysed how RES deployment affects economic,

social and environmental dimensions. They note that while renewable energy improves environmental outcomes, the extent of impact depends on country context, technology type and regulatory environment. From descriptive data, one sees that regions with higher renewable shares tend to exhibit lower CO_2 emissions per unit of energy output, and greater energy security (e.g., lesser dependence on imported fuels). Though direct numeric tables are not reproduced here (due to data access limitations), the literature supports the positive relationship.

Renewable Energy and Economic/ Social Sustainability

Beyond environmental impact, renewable energy fosters economic and social gains:

- Job creation in manufacturing, installation, operation of RES infrastructure.
- Local economic development in regions hosting renewable projects (e.g., rural wind farms, solar plants).
- Enhancement of energy access for underserved communities, supporting social equity and inclusion. For instance, Fazal, Hayat & Al Mamun (2023) explored renewable energy adoption among low-income households in an emerging economy, showing intention and consumption behaviours tied to affordability, awareness and policy incentives. These outcomes align with sustainability in the social dimension—greater access, reduced energy poverty—and economic dimension—growth, new industries, diversified energy supply.

Barriers and Enablers

From the literature review, key barriers and enablers to renewable energy for a sustainable society emerge:

Enablers

- Declining costs and improved efficiencies of renewable technologies.
- Supportive policies and regulatory frameworks (feed-in-tariffs, incentives, renewable portfolio standards).
- Technological innovations (energy storage, smart grids) that manage intermittency and grid integration.
- Stakeholder collaboration (government, industry, communities) and awareness.
- Financing mechanisms and investment flows into renewable projects.

Barriers

- Intermittency and variability of solar and wind power, creating grid integration challenges (inertia reduction, fault ride through, reserve management) as discussed in "High-Level Penetration of Renewable Energy with Grid: Challenges and Opportunities".
- Infrastructure adaptation costs and legacy systems designed for fossil fuels.
- Regulatory and policy uncertainty or lack of coherence.
- Financial constraints, especially in developing countries.
- Social and institutional inertia, inadequate capacity and awareness.
- Technology mismatch and local context (resource availability, geographic constraints) limiting certain RES.

Comparative Assessment

Countries or regions that have prioritized renewables tend to show better sustainability indicators. Although this paper does not perform a full econometric regression, the descriptive findings suggest:

- Regions with higher renewable energy penetration also tend to show improved energy security metrics and reduced emission intensities.
- Low-income households in emerging economies face higher barriers, meaning that while technology is available, adoption remains uneven (as per Fazal et al. 2023).
- Countries with coherent policy frameworks and investment in grid and storage infrastructure are better positioned to convert renewable deployment into broad sustainability benefits (García-Lillo et al. 2023).

DISCUSSION

The findings show that renewable energy adoption indeed plays an important role in advancing a sustainable society. The discussion below interprets and synthesizes key insights.

Interlinkages of Renewable Energy and Sustainability

Renewable energy's contribution to the environmental dimension is straightforward—by reducing reliance on fossil fuels and mitigating greenhouse

gas emissions. But its role in economic and social dimensions is equally vital: diversified energy supply enhances resilience; new industries support economic growth; and improved access addresses equity.

However, the transition is not automatic. Merely deploying renewable technologies does not guarantee a sustainable society unless supportive systems are in place—such as infrastructure, storage, regulatory regimes and stakeholder participation.

The Importance of Policy and Governance

The literature emphasizes that governance frameworks are critical. Policies that set clear targets, provide incentives, ensure grid access and manage market integration are central to converting technical potential into real societal benefits. Without effective policy and governance, renewable energy may be under-used or poorly integrated, limiting its contribution to sustainability.

Technical and Systemic Challenges

Technical issues remain significant: integrating variable renewables into existing grids requires adaptation of grid architecture, energy storage, forecasting, grid stability and demand-side management. As cited earlier, high levels of RES penetration bring challenges such as decreased inertia, uncertainty and fault ride-through issues. Therefore, to support sustainability, system-level planning, investment in storage and smart grids, and technological innovation are essential.

Equity and Access Considerations

Renewable energy offers social equity advantages, but disparities persist. Low-income households and remote regions may face technical, financial or regulatory barriers to adoption. The research by (Fazal et al 2023) underscores the need to understand consumption behaviours and enable access for disadvantaged groups. Hence sustainability must integrate social justice—ensuring that the energy transition does not leave behind the vulnerable.

Pathways Forward

The transition to a renewable-powered sustainable society is multifaceted. Key pathways include:

- Expanding investment in storage and grid flexibility.
- Designing policies and regulatory frameworks that align incentives with sustainability goals.

- Supporting capacity building and community engagement to ensure inclusive adoption.
- Encouraging innovation and financing models (for example, public-private partnerships, green bonds).
- Monitoring sustainability outcomes (emissions, access, economic growth) and adjusting strategies accordingly.

CONCLUSIONS

This research has explored how renewable energy adoption supports a sustainable society, emphasising the interplay between environmental, economic and social dimensions. The study has shown that:

- Renewable energy plays a pivotal role in reducing emissions, enhancing energy security and supporting economic and social development.
- Deployment of renewables has grown significantly, and the research domain is expanding rapidly.
- However, significant barriers technical, policy, financial and social—must be addressed to translate renewable energy potential into broad sustainability benefits.
- The transition requires system-level planning, governance, investment in grid and storage, and inclusive policies to ensure equity.
- For policy makers, industry and communities, aligning renewable energy initiatives with sustainable development goals is essential.

Recommendations

1. Governments should enact coherent long-term policies that set clear renewable targets, provide incentives, and integrate grid planning for storage and flexibility.
2. Investment should be increased in energy storage, smart grid infrastructure and grid integration technologies to address intermittency and reliability concerns.
3. Financing mechanisms should be tailored to support deployment in developing countries and low-income households, ensuring access and fairness.

4. Stakeholder engagement at local levels (communities, utilities, industry) should be prioritized to build capacity, acceptance and ownership of renewable projects.

5. Monitoring frameworks should be established to track the impacts of renewable energy deployment on sustainability indicators (emissions, economic growth, access, jobs) and enable adaptive policy-making.

Limitations and Future Research

This study relies on secondary data and descriptive analysis; therefore, causal inference is limited. Future research could use econometric modelling to establish causality and quantify impacts of specific renewable energy policies on sustainability outcomes. Further, in-depth case studies of individual countries or communities would provide richer understanding of context-specific enablers and barriers.

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