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Renewable Energy Development and the Sustainable Development Goals in Rajasthan

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Abstract

Rajasthan has emerged as one of India's important regions for renewable energy development because of its high solar radiation, extensive land resources and favourable climatic conditions. The rapid expansion of solar and wind energy has the potential to transform the state's energy structure while contributing to environmental protection, economic development and social well-being. This study examines the relationship between renewable energy development in Rajasthan and the achievement of the Sustainable Development Goals (SDGs), with particular emphasis on SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). The study adopts a geographical and sustainability-oriented perspective to assess how the expansion of renewable energy can reduce dependence on conventional energy sources, support low-carbon development and contribute to climate-change mitigation. At the same time, it recognises emerging concerns related to land-use transformation, ecological sensitivity, water requirements, biodiversity, local livelihoods and the equitable distribution of development benefits. The study argues that renewable energy expansion alone cannot ensure sustainable development unless environmental safeguards, efficient resource management, technological innovation and community participation are incorporated into planning and implementation. A balanced approach integrating renewable-energy targets with ecological conservation and inclusive socio-economic development is therefore essential. The study concludes that Rajasthan can make a significant contribution to India's SDG agenda by promoting a renewable-energy transition that is environmentally responsible, economically viable and socially inclusive.

Key-words - Renewable Energy, Sustainable Development Goals, Rajasthan, Solar Energy, Environmental Sustainability, Climate Action.

Introduction

The transition towards renewable energy has emerged as one of the most important dimensions of contemporary sustainable development. Rapid economic growth, urbanisation, industrialisation and rising living standards have substantially increased global energy demand, while continued dependence on fossil fuels has intensified greenhouse-gas emissions, climate change, environmental degradation and energy-security concerns. In this context, renewable energy sources such as solar, wind, biomass and small hydropower offer an important pathway for reconciling economic development with environmental sustainability. The significance of renewable energy extends beyond electricity generation because access to clean, reliable and affordable energy influences poverty reduction, employment, public health, food production, technological development and ecological conservation. Thus, renewable energy development has become

closely interconnected with the broader framework of the Sustainable Development Goals (SDGs), particularly SDG 7, which seeks to ensure access to affordable, reliable, sustainable and modern energy for all (United Nations, 2015).

The adoption of the 2030 Agenda for Sustainable Development in 2015 established 17 interconnected SDGs as a global framework for addressing economic, social and environmental challenges. Energy occupies a central position within this framework because progress in energy access and clean-energy transition has implications for several other goals. SDG 7 specifically emphasises universal access to modern energy services, increasing the share of renewable energy and improving energy efficiency. At the same time, renewable-energy expansion contributes directly or indirectly to SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible

Consumption and Production) and SDG 13 (Climate Action). The interconnected nature of these goals means that renewable energy should not be examined merely as an alternative source of electricity but as an instrument of inclusive and environmentally sustainable development. NITI Aayog, which serves as India's nodal institution for SDG implementation and monitoring, also emphasises the localisation of SDGs through state-level planning and performance assessment (NITI Aayog, 2024).

India's energy transition is particularly significant because of the country's large population, expanding economy and growing energy requirements. The country has progressively increased its renewable-energy capacity through policy initiatives, investment incentives, technological development and institutional reforms. As of 31 August 2026, India's cumulative renewable-energy capacity, excluding large hydropower, had reached approximately 243.49 GW, including about 168.04 GW of solar and 58.52 GW of wind capacity (Ministry of New and Renewable Energy [MNRE], 2026). This expansion indicates the increasing importance of renewable sources within India's energy system. However, the sustainability of the energy transition depends not only on installed capacity but also on affordability, reliability, grid integration, energy storage, employment generation, equitable distribution of benefits and the environmental consequences associated with large-scale renewable-energy infrastructure.

Within this national context, Rajasthan occupies a particularly important position in India's renewable-energy landscape. The state possesses exceptional solar-energy potential because of its extensive arid and semi-arid landscapes, high solar radiation and large areas suitable for solar-power development. Its geographical conditions also provide opportunities for wind-energy development, while hybrid renewable-energy systems and emerging technologies can further diversify the state's clean-energy portfolio. Rajasthan has therefore become an important destination for large-scale renewable-energy investment. The state's policy framework reflects this strategic orientation. The Rajasthan Renewable Energy Policy, 2023 targets the development of 90 GW of renewable-power projects by 2029–30, comprising 65 GW of solar, 15 GW of wind and hybrid projects, and 10 GW from hydropower, pumped-storage and battery-energy-storage systems (Government of Rajasthan, 2023).

The scale of renewable-energy development in Rajasthan has important implications for the achievement of SDG 7 at the state level. Rajasthan's SDG framework identifies affordable and clean energy as a critical component of sustainable development and monitors progress through state-level indicators. According to the Rajasthan SDG portal, renewable energy accounted for 39.73% of total installed electricity-generation capacity in 2024–25, while solar energy constituted 22.93% of the state's total final energy mix during the same period. These developments demonstrate that renewable energy is becoming an increasingly significant component of Rajasthan's energy structure. At the national level, Rajasthan received a score of 100 for SDG 7 in the SDG India Index 2023–24, placing it in the highest-performing category for affordable and clean energy. Nevertheless, high performance in SDG 7 does not necessarily imply that all dimensions of sustainable energy development

have been equally addressed. Questions relating to energy affordability, decentralised access, transmission infrastructure, land requirements, ecological impacts and the distribution of economic benefits remain important areas of inquiry.

The relationship between renewable-energy development and sustainable development in Rajasthan is therefore multidimensional. Large solar parks and wind projects can contribute to low-carbon electricity generation and reduce dependence on conventional fuels, but their expansion may also create pressures related to land use, biodiversity, water requirements, transmission corridors and local livelihoods. Similarly, renewable-energy investments can generate employment, attract capital and encourage technological innovation, but the extent to which local communities participate in and benefit from these opportunities requires systematic assessment. The challenge is consequently not simply to increase renewable-energy capacity but to ensure that energy transition remains socially inclusive, economically viable and ecologically responsible.

Moreover, Rajasthan's renewable-energy trajectory has implications for climate resilience. As a state characterised by water scarcity, climatic variability, desertification pressures and recurrent heat extremes, Rajasthan is particularly vulnerable to environmental and climatic stresses. Renewable energy can contribute to climate mitigation by reducing carbon-intensive electricity generation, while decentralised solar systems can improve energy resilience in remote and rural areas. Renewable energy can also support sustainable agriculture through solar irrigation, strengthen rural enterprises through reliable electricity supply and contribute to cleaner urban development. These linkages demonstrate that SDG 7 should be interpreted in conjunction with SDGs 1, 2, 6, 8, 9, 11, 12, 13 and 15 rather than as an isolated development target.

Renewable Energy Development and the Sustainable Development Goals in Rajasthan, seeks to examine the emerging relationship between the state's renewable-energy transition and the wider objectives of sustainable development. The study focuses on the growth and spatial significance of renewable energy, particularly solar and wind power, and evaluates its contribution to selected SDGs. It also considers the opportunities and challenges associated with Rajasthan's renewable-energy expansion and examines whether increasing clean-energy capacity is translating into broader environmental, economic and social benefits. By linking renewable-energy development with the SDG framework, the study attempts to provide a more comprehensive understanding of Rajasthan's pathway towards a low-carbon, inclusive and sustainable energy future. Such an assessment is essential for developing policies that simultaneously promote energy security, economic opportunity, environmental protection and social well-being while supporting India's commitment to the 2030 Sustainable Development Agenda.

Study Area

Rajasthan, located in north-western India, constitutes the study area of the present research. Covering approximately 342,239 km², it is the largest Indian state by geographical area and extends between about 23°03' and 30°12' N latitudes and 69°30' and 78°17' E longitudes. The state shares international boundaries with Pakistan to the west and north-west and borders

Punjab, Haryana, Uttar Pradesh, Madhya Pradesh and Gujarat within India (Government of Rajasthan, 2024). Its distinctive physical setting includes the Thar Desert, the Aravalli Range, extensive semi-arid plains and varied climatic conditions, creating considerable spatial differences in natural-resource availability.

Rajasthan has exceptionally favourable conditions for renewable-energy development, particularly solar and wind energy. High solar radiation, a large number of sunshine hours and extensive areas of relatively low population density provide significant opportunities for utility-scale solar projects. Western districts such as Jaisalmer, Barmer, Jodhpur and Bikaner have emerged as major centres of solar and wind-energy development. The state has consequently become a major contributor to India's renewable-energy transition (Ministry of New and Renewable Energy [MNRE], 2026). Rajasthan's renewable-energy expansion is also closely linked with SDG 7, while its implications extend to employment, infrastructure, climate action, sustainable production and environmental conservation. Therefore, Rajasthan provides an appropriate geographical setting for examining how renewable-energy development can contribute to the broader achievement of the Sustainable Development Goals (NITI Aayog, 2024).

Research Methodology

The present study adopts a descriptive and analytical research design to examine the relationship between renewable-energy development and the Sustainable Development Goals (SDGs) in Rajasthan. The study is primarily based on secondary data collected from reliable governmental and international sources. Data on installed renewable-energy capacity, electricity generation, energy composition and related indicators are obtained from the Ministry of New and Renewable Energy (MNRE), Government of India, the Rajasthan Renewable Energy Corporation Limited (RRECL), the Energy Department of Rajasthan and other relevant government publications. Information related to SDG performance is obtained from NITI Aayog and the Government of Rajasthan's SDG monitoring framework (NITI Aayog, 2024).

The study covers major renewable-energy sources, particularly solar and wind energy, and examines their spatial and temporal development in Rajasthan. Quantitative data are analysed through percentages, growth rates, comparative analysis and trend analysis to identify changes in renewable-energy development over time. The contribution of renewable energy is subsequently examined in relation to selected SDGs, particularly SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) (United Nations, 2015).

The methodology therefore combines quantitative analysis with qualitative interpretation to assess the opportunities, challenges and sustainability implications of Rajasthan's renewable-energy transition.

Result and Discussion

The results of this research study highlight the growth, spatial distribution and developmental significance of renewable energy in Rajasthan. The findings are discussed in relation to selected Sustainable Development Goals, with particular emphasis on

economic development, environmental sustainability, energy security, infrastructure and climate action.

Growth and Temporal Trends of Renewable Energy Development in Rajasthan

Rajasthan has emerged as one of India's major renewable-energy regions, particularly because of its exceptional solar-resource potential and favourable conditions for wind-energy development. The expansion of renewable energy has accelerated through state policies, private investment and large-scale solar and hybrid projects. The Rajasthan Renewable Energy Policy, 2023 envisages the development of 90 GW of renewable-power projects by 2029–30, including 65 GW of solar, 15 GW of wind and hybrid projects, and 10 GW from hydropower, pumped storage and battery energy-storage systems (Government of Rajasthan, 2023).

The state's official SDG framework reports that renewable energy constituted 39.73% of total installed electricity-generation capacity in 2024–25, indicating its increasing significance within Rajasthan's energy structure (Government of Rajasthan, 2025). This temporal expansion represents a significant shift from conventional energy dependence towards a more diversified energy system. However, continued growth will require adequate transmission infrastructure, storage capacity, grid management and environmentally responsible project planning.

Spatial Distribution and Regional Pattern of Renewable Energy Projects

The distribution of renewable-energy infrastructure in Rajasthan is strongly influenced by variations in solar radiation, wind conditions, land availability and accessibility to transmission networks. Western Rajasthan, particularly the districts associated with the Thar Desert, has become a major concentration zone for utility-scale solar development. Large projects have transformed parts of Jaisalmer, Jodhpur, Barmer and Bikaner into important renewable-energy landscapes. The spatial concentration reflects the geographical advantages of high solar irradiance and extensive areas suitable for large-scale installations.

However, renewable-energy development also creates questions concerning the equitable distribution of infrastructure and economic benefits. The Government of Rajasthan has increasingly incorporated district-level SDG monitoring to promote localisation of sustainable development and identify geographical differences in performance (Government of Rajasthan, 2024). Therefore, the spatial pattern of renewable energy should be assessed not merely in terms of installed capacity but also through its relationship with population distribution, employment, local livelihoods, infrastructure and environmental sensitivity. A geographically balanced approach can improve the developmental benefits of Rajasthan's energy transition.

Solar Energy Expansion and Its Contribution to SDG7

Solar energy represents the most prominent component of Rajasthan's renewable-energy transition. High solar radiation and extensive land availability have enabled the development of large solar parks and utility-scale photovoltaic projects. Rajasthan's official SDG framework indicates that solar energy accounted for 22.93% of the state's total final energy mix in 2024–25, demonstrating its growing contribution to the energy

system (Government of Rajasthan, 2025). The expansion of solar power directly supports SDG 7, which seeks affordable, reliable, sustainable and modern energy for all (United Nations, 2015).

At the national level, Rajasthan received a score of 100 for SDG 7 in the SDG India Index 2023–24, placing the state in the Achiever category (NITI Aayog, 2024). Solar expansion can also reduce dependence on conventional fuels and contribute to long-term energy security. Nevertheless, the sustainability of large-scale solar development depends on appropriate land management, grid connectivity, energy storage and consideration of ecological and community concerns.

Wind and Hybrid Renewable Energy Development in Rajasthan

Although Rajasthan is particularly recognised for solar energy, wind power and solar-wind hybrid systems are also important components of its renewable-energy strategy. Wind resources are especially relevant in selected western and north-western parts of the state, where suitable atmospheric conditions can complement solar generation. Hybrid projects have particular significance because combining different renewable sources can improve the utilisation of transmission infrastructure and potentially reduce fluctuations associated with individual technologies. Rajasthan's Renewable Energy Policy, 2023 specifically targets 15 GW of wind and hybrid renewable-energy projects by 2029–30 (Government of Rajasthan, 2023).

The development of hybrid systems is therefore consistent with the state's objective of diversifying its renewable-energy portfolio. From an SDG perspective, such infrastructure supports SDG 7 through increased clean-energy availability and SDG 9 through technological innovation and infrastructure development (United Nations, 2015). However, effective integration requires forecasting systems, transmission expansion, storage solutions and appropriate regulatory mechanisms. Thus, wind and hybrid energy can strengthen Rajasthan's transition towards a more flexible renewable-energy system.

Renewable Energy, Economic Growth and Employment Generation (SDG 8)

Renewable-energy development can contribute to economic growth by attracting investment, creating infrastructure and generating employment across construction, operation, maintenance, manufacturing and associated service sectors. Rajasthan's expanding solar and wind sector has consequently become an important component of its emerging green economy. The state's renewable-energy policy seeks to facilitate large-scale investment and establish Rajasthan as a major renewable-energy production centre (Government of Rajasthan, 2023).

These investments can generate direct employment in project development and indirect employment through transport, construction, equipment supply and maintenance services. Renewable energy can also stimulate local economic activity in areas hosting major projects. From the SDG perspective, these linkages connect SDG 7 with SDG 8, which promotes sustained economic growth and productive employment (United Nations, 2015). However, the quantity and quality of employment should be evaluated carefully because large renewable projects may be capital-intensive and may not automatically generate substantial long-term local

employment. Skill development and local participation are therefore essential for ensuring that renewable-energy growth produces inclusive economic benefits.

Renewable Energy, Infrastructure and Technological Innovation (SDG 9)

The transition towards renewable energy requires substantial investment in electricity transmission, distribution networks, energy storage, forecasting systems and digital technologies. Consequently, renewable-energy development is closely associated with SDG 9, which promotes resilient infrastructure, inclusive industrialisation and innovation. Rajasthan's large-scale solar and wind projects have increased the need for transmission infrastructure capable of integrating geographically concentrated renewable generation into wider electricity markets.

The state's Renewable Energy Policy, 2023 also incorporates pumped-storage and battery-energy-storage systems within its renewable-energy development target, indicating a growing policy emphasis on system flexibility (Government of Rajasthan, 2023). Technological innovation can further improve the efficiency of photovoltaic systems, wind turbines, forecasting and energy-management systems. At the same time, infrastructure development must keep pace with installed generation capacity to avoid transmission bottlenecks and curtailment. Thus, the contribution of renewable energy to SDG 9 extends beyond generating electricity; it involves the creation of a technologically advanced, resilient and flexible energy infrastructure capable of supporting Rajasthan's long-term economic development.

Renewable Energy and Climate Change Mitigation (SDG 13)

Renewable-energy expansion is an important component of climate-change mitigation because electricity generated from solar and wind sources can reduce dependence on fossil-fuel-based generation. Rajasthan's rapid growth in renewable-energy capacity therefore has significance for SDG 13, which calls for urgent action to address climate change and its impacts (United Nations, 2015). The relationship is particularly relevant for Rajasthan because the state is exposed to climatic stresses including high temperatures, water scarcity and variability in precipitation.

Increasing the contribution of renewable electricity can support a gradual decarbonisation of the energy system while strengthening the state's alignment with India's broader climate objectives. The national SDG framework also identifies substantial progress in Goal 13 alongside improvements in Goal 7 (NITI Aayog, 2024). Nevertheless, renewable energy alone cannot address all dimensions of climate vulnerability. Adaptation, water management, ecosystem restoration and climate-resilient infrastructure remain necessary. Rajasthan's renewable-energy transition should therefore be integrated with wider climate policy rather than treated as an isolated mitigation strategy.

Renewable Energy, Environmental Sustainability and Biodiversity Conservation

Renewable energy offers major environmental advantages through reduced dependence on fossil fuels, but large-scale renewable infrastructure can also generate local environmental pressures. In Rajasthan, utility-scale solar development frequently occurs in arid

and semi-arid landscapes that may appear sparsely vegetated but can nevertheless support ecologically important habitats. Recent research and policy discussions have highlighted concerns related to land procurement, tenure, biodiversity and the ecological consequences of utility-scale solar expansion in the state (TERI & Landesa, 2026).

Consequently, the sustainability of renewable-energy development depends upon careful site selection, environmental assessment, biodiversity-sensitive planning and appropriate land-management practices. The central challenge is to reconcile the objectives of clean-energy expansion with ecosystem conservation. This is particularly important for Rajasthan because its desert and semi-desert ecosystems possess distinctive ecological characteristics. Therefore, renewable-energy projects should incorporate ecological screening, wildlife considerations, land restoration and community participation. A genuinely sustainable energy transition should minimise environmental trade-offs rather than assuming that all renewable-energy development is automatically environmentally neutral.

Challenges, Regional Disparities and Sustainability Issues

Despite Rajasthan's strong renewable-energy potential, its continued expansion faces several challenges. Large-scale projects require substantial land, while transmission infrastructure must be expanded to connect generation centres with demand centres. Land procurement can also involve questions of tenure, livelihoods and community participation. Recent research on Rajasthan's utility-scale solar transition has specifically highlighted the importance of socially inclusive land governance and sustainable land-use planning (TERI & Landesa, 2026). In addition, renewable generation is variable, making energy storage, grid flexibility and forecasting increasingly important.

Spatial concentration may also create regional disparities if investment and employment opportunities remain concentrated in selected districts. Rajasthan's district-level SDG framework demonstrates the importance of localising development outcomes rather than relying exclusively on state-level averages (Government of Rajasthan, 2024). Therefore, future renewable-energy policy should focus on equitable benefit sharing, decentralised energy opportunities, improved transmission, storage infrastructure, ecological safeguards and stronger participation of local communities. Addressing these issues will determine whether Rajasthan's renewable-energy expansion produces genuinely inclusive and sustainable development.

Overall Contribution of Renewable Energy Development to the SDGs in Rajasthan

The evidence indicates that renewable-energy development has implications extending considerably beyond SDG 7. Rajasthan's expansion of solar, wind and hybrid energy directly contributes to clean-energy availability while creating potential linkages with economic growth, infrastructure development, technological innovation and climate action. The state's SDG 7 score of 100 in the SDG India Index 2023–24 demonstrates its strong performance in affordable and clean energy (NITI Aayog, 2024). Rajasthan's own SDG monitoring framework also records a substantial

renewable-energy share in installed electricity-generation capacity (Government of Rajasthan, 2025).

However, the relationship between renewable energy and sustainable development is not entirely linear. Land requirements, ecological impacts, regional disparities and infrastructure constraints can create trade-offs. Therefore, Rajasthan's success should be assessed through a broader framework incorporating environmental integrity, social inclusion, economic benefits and energy security. Overall, renewable energy can serve as a major instrument for advancing multiple SDGs, but its long-term contribution will depend on integrated planning, responsible land governance, technological innovation and equitable distribution of benefits.

Conclusion

The present study concludes that renewable energy development has emerged as a significant component of Rajasthan's sustainable development pathway. The state's exceptional solar radiation, favourable wind conditions, extensive land availability and growing investment in clean-energy infrastructure have created a strong foundation for the expansion of renewable energy. Among the different renewable sources, solar energy has assumed particular importance, while wind and hybrid systems are increasingly contributing to the diversification and reliability of the state's clean-energy portfolio. Rajasthan's experience demonstrates that renewable energy can play a transformative role in addressing the interconnected challenges of energy security, economic development and environmental sustainability.

The expansion of renewable energy has a direct relationship with the achievement of Sustainable Development Goal 7 by improving the availability of clean and modern energy. However, its significance extends beyond affordable and clean energy. Renewable-energy development can support employment generation, investment, technological innovation, infrastructure development and regional economic activity. It can also contribute to climate-change mitigation by reducing dependence on conventional fossil-fuel-based energy. In rural areas, decentralised renewable-energy applications have the potential to improve access to electricity, support agricultural activities, strengthen livelihoods and enhance the resilience of communities. Thus, renewable energy can generate positive linkages among several Sustainable Development Goals rather than contributing to SDG 7 in isolation.

At the same time, the study indicates that the expansion of renewable energy should not automatically be equated with complete sustainability. Large-scale solar and wind projects require considerable land and infrastructure, and their concentration in particular geographical regions may create environmental and socio-economic concerns. Changes in land use, potential impacts on biodiversity, transmission requirements and conflicts over land and local livelihoods need careful consideration. Furthermore, the intermittent nature of solar and wind generation creates challenges related to electricity storage, grid stability and reliable power supply. These issues demonstrate that the success of Rajasthan's renewable-energy transition should be evaluated not only through installed capacity but also through its environmental, social and economic outcomes.

A major conclusion of the study is that geographical planning is essential for sustainable renewable-energy development in Rajasthan. Renewable-energy resources are unevenly distributed, and development has consequently become concentrated in areas possessing favourable natural conditions. Future planning should therefore consider regional disparities, ecological sensitivity, existing land uses, population distribution and local development requirements. Greater emphasis should also be placed on decentralised renewable-energy systems so that the benefits of clean energy can reach rural and economically weaker communities.

The study further highlights the importance of integrating renewable-energy policy with broader SDG planning. Energy policies should be coordinated with policies concerning climate change, water management, agriculture, rural development, biodiversity conservation, employment and infrastructure. Technological innovation, battery storage, pumped-storage systems, smart grids and improved transmission networks will be increasingly important for maintaining the momentum of renewable-energy growth. At the same time, skill development and local employment opportunities should be strengthened so that communities hosting renewable-energy projects receive meaningful and long-term economic benefits.

Overall, Rajasthan possesses considerable potential to become a leading example of a renewable-energy-driven sustainable development model. The state has already established a strong foundation through rapid renewable-energy expansion and supportive policy measures. The future challenge is to move from capacity-oriented renewable-energy development towards an inclusive, environmentally responsible and socially equitable energy transition. If renewable-energy expansion is supported by responsible land-use planning, ecological safeguards, community participation, technological innovation and equitable benefit sharing, it can contribute substantially to multiple Sustainable Development Goals. Rajasthan can therefore use its renewable-energy advantage not only to meet growing energy requirements but also to build a resilient, low-carbon and sustainable economy capable of supporting long-term environmental and human well-being.

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