

Renewable Energy Transition in Odisha: Opportunities and Challenge

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Abstract

The transition towards renewable energy has become a key component of India's strategy to achieve sustainable economic growth, energy security, and climate resilience. As one of India's major energy-producing states, Odisha occupies a strategic position due to its abundant coal reserves, expanding industrial base, and significant renewable energy potential. This study examines the opportunities and challenges associated with Odisha's renewable energy transition through a descriptive policy analysis based on secondary data obtained from government reports, policy documents, statistical publications, and institutional databases. The analysis reveals that Odisha possesses substantial renewable energy potential, particularly in solar, hydropower, biomass, and floating solar resources; however, much of this potential remains underutilized. Although renewable energy capacity has expanded steadily over the past decade, coal continues to dominate the state's electricity mix. The study identifies key challenges, including inadequate transmission infrastructure, limited energy storage, financing constraints, land acquisition issues, policy implementation gaps, and the need for a just transition in coal-dependent regions. At the same time, renewable energy development offers significant opportunities to strengthen energy security, reduce greenhouse gas emissions, attract investment, generate employment, and promote sustainable industrial and rural development. The study recommends strengthening grid infrastructure, expanding energy storage, promoting private investment, improving institutional coordination, and implementing

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just transition policies to accelerate Odisha's transition towards a cleaner, more resilient, and inclusive energy system.

Keywords: Renewable energy, Odisha, India, energy transition, solar power, coal dependence, sustainable development, just transition, energy policy, clean energy.

1. Introduction

India's growing energy demand, rapid industrialization, and increasing environmental concerns have accelerated the transition towards cleaner and more sustainable energy systems (International Energy Agency [IEA], 2021; NITI Aayog, 2023). As the world's third-largest energy consumer, India has committed to expanding renewable energy capacity to strengthen energy security, reduce greenhouse gas emissions, and fulfil its climate commitments under the Paris Agreement, including the target of achieving 500 GW of non-fossil fuel installed electricity capacity by 2030 (Government of India, 2022; United Nations Framework Convention on Climate Change [UNFCCC], 2015).

Within this national transition, Odisha occupies a strategically important position owing to its abundant mineral resources, coal-based industrial economy, and growing electricity demand (Government of Odisha, 2022; Ministry of Power, Government of India, 2024). The state is one of India's leading energy-producing regions, supported by extensive coal reserves, thermal power generation capacity, and energy-intensive industries such as steel, aluminium, mining, and manufacturing (Central Electricity Authority [CEA], 2024). While this coal-based energy system has played a vital role in supporting economic growth and industrialization, it has also contributed to greenhouse gas emissions, air pollution, and environmental degradation, increasing the need for a transition towards cleaner and more sustainable sources of energy (IEA, 2021; Intergovernmental Panel on Climate Change [IPCC], 2023).

The urgency of this transition has grown as Odisha faces increasing climate-related risks, including cyclones, floods, rising temperatures, and coastal vulnerability, alongside rising electricity demand and the need for sustainable industrial development (Government of Odisha, 2022; IPCC, 2023). At the same time, the state possesses considerable renewable

energy potential, particularly in solar energy, hydropower, biomass, and emerging technologies such as floating solar and green hydrogen, providing significant opportunities to diversify its energy mix, strengthen energy security, attract investment, generate employment, and support low-carbon economic growth (Government of Odisha, 2022; International Renewable Energy Agency [IRENA], 2024; Ministry of New and Renewable Energy [MNRE], 2024).

Recognizing these opportunities, both the Government of India and the Government of Odisha have introduced several policy initiatives to accelerate renewable energy deployment. National programmes, including the Jawaharlal Nehru National Solar Mission, Green Energy Corridor Programme, PM-KUSUM, and the National Green Hydrogen Mission, have established an enabling framework for renewable energy expansion across the country. Complementing these initiatives, the Odisha Renewable Energy Policy, 2022 seeks to promote private investment, strengthen renewable energy infrastructure, improve energy security, and position the state as a renewable energy hub in eastern India (Government of India, 2022; Government of Odisha, 2022; MNRE, 2024).

Despite these policy initiatives and abundant renewable resources, Odisha's energy transition continues to face significant structural, infrastructural, financial, environmental, and institutional challenges. Continued dependence on coal-based industries, transmission bottlenecks, financing constraints, land acquisition issues, and implementation gaps has slowed the pace of renewable energy deployment (Government of Odisha, 2022; IEA, 2021; NITI Aayog, 2023). While a growing body of literature has examined India's renewable energy transition, relatively few studies have comprehensively analysed Odisha's transition by integrating renewable resource potential, policy initiatives, opportunities, and implementation challenges within a single framework.

Against this backdrop, the present study examines the opportunities and challenges associated with Odisha's renewable energy transition. Specifically, the study (i) assesses the state's renewable energy potential across major renewable resources, (ii) evaluates the policy and institutional framework supporting renewable energy development, (iii) analyses the key opportunities associated with renewable energy expansion, including environmental sustainability, energy security, employment generation, and investment

potential, (iv) identifies the major economic, infrastructural, environmental, and institutional barriers affecting the transition, and (v) proposes policy measures to support a faster, more inclusive, and sustainable renewable energy transition in Odisha. By providing a comprehensive assessment of Odisha's renewable energy landscape, the study contributes to the growing literature on sub-national energy transitions and offers policy-relevant insights for achieving sustainable and resilient energy development in India.

The remainder of the paper is organized as follows. Section 2 reviews the existing literature on renewable energy transition, with particular emphasis on policy, institutional, and state-level perspectives. Section 3 outlines the research methodology and data sources used in the study. Section 4 assesses Odisha's renewable energy resource potential and analyses trends in installed capacity and the current energy mix. Section 5 examines the policy and institutional framework supporting renewable energy development in the state. Sections 6 and 7 discuss the major opportunities and challenges associated with Odisha's renewable energy transition. Finally, Section 8 presents the conclusions and policy recommendations for accelerating a sustainable, resilient, and inclusive renewable energy transition in Odisha.

2. Literature Review

The renewable energy transition has become a major area of research in India due to growing concerns over climate change, energy security, environmental sustainability, and rising energy demand. Existing studies broadly examine renewable energy from four perspectives: (i) its contribution to economic growth and sustainable development, (ii) the effectiveness of policy and institutional frameworks, (iii) barriers to renewable energy deployment, and (iv) regional disparities in renewable energy development (Bhattacharya et al., 2016; International Energy Agency [IEA], 2021; International Renewable Energy Agency [IRENA], 2023).

2.1 Renewable Energy and Sustainable Development

A substantial body of literature suggests that renewable energy contributes to sustainable economic development by improving energy security, reducing greenhouse gas emissions, attracting investment, and creating employment opportunities. Bhattacharya et al. (2016) found that renewable energy consumption positively influences economic growth in developing countries, while IRENA (2023) highlighted its role in employment generation and industrial development. Similarly, the IEA (2021) emphasized that expanding renewable energy is essential for reducing dependence on fossil fuels and supporting long-term climate and energy security objectives.

2.2 Policy and Institutional Framework

Several studies emphasize that supportive policy and institutional frameworks are critical for accelerating renewable energy deployment. National initiatives such as the Jawaharlal Nehru National Solar Mission, Renewable Purchase Obligations (RPOs), competitive bidding mechanisms, and more recent programmes including PM-KUSUM and the National Green Hydrogen Mission have significantly expanded renewable energy capacity in India (Bhattacharya & Kojima, 2012; Ministry of New and Renewable Energy [MNRE], 2024; Shukla et al., 2019). However, effective implementation depends on institutional capacity, regulatory stability, and coordinated policy support across different levels of government (IEA, 2021).

2.3 Barriers to Renewable Energy Deployment

Despite significant policy progress, the literature identifies several barriers that continue to constrain renewable energy development. Financial constraints, inadequate transmission infrastructure, technological limitations, regulatory uncertainty, and land acquisition issues remain among the most frequently cited challenges (Painuly, 2001; Shrimali & Aggarwal, 2014). Recent studies further emphasize that strengthening grid infrastructure, improving access to finance, and expanding energy storage systems are

essential for integrating higher shares of renewable energy into electricity networks (CEA, 2024; IEA, 2021).

2.4 Regional Disparities in Renewable Energy Development

Renewable energy development in India exhibits considerable regional variation, reflecting differences in resource availability, infrastructure, investment climate, and policy implementation. States such as Gujarat, Rajasthan, Karnataka, and Tamil Nadu have emerged as leaders in renewable energy deployment due to favourable policy environments, stronger transmission infrastructure, and greater private sector participation. In contrast, several coal-dependent states continue to face difficulties in balancing industrial growth with environmental sustainability (Bhattacharyya & Palit, 2014; IEA, 2021; MNRE, 2024; NITI Aayog, 2023).

2.5 Renewable Energy Transition in Odisha

Existing research on Odisha has primarily focused on its coal-based economy, thermal power generation, mining activities, and associated environmental challenges (CEA, 2024). Although the state possesses considerable renewable energy potential in solar, biomass, hydropower, and offshore wind, renewable energy deployment has progressed relatively slowly. The literature attributes this to transmission constraints, financing gaps, policy implementation challenges, land acquisition issues, and the continued dependence of the state's economy on coal-based industries (Government of Odisha, 2022; IEA, 2021; MNRE, 2024).

Researchers have also highlighted the important role of the Odisha Renewable Energy Development Agency (OREDA) in promoting decentralized renewable energy, rural electrification, and solar energy programmes. Nevertheless, greater institutional coordination, improved grid connectivity, enhanced private sector participation, and stronger policy implementation are considered necessary to accelerate renewable energy adoption in the state (Government of Odisha, 2022; MNRE, 2024). Furthermore, Odisha's

high vulnerability to cyclones, floods, and other climate-related disasters reinforces the need for resilient and decentralized renewable energy systems (IPCC, 2023).

2.6 Research Gap

Although the literature provides extensive evidence on India's renewable energy transition, relatively few studies examine Odisha from a comprehensive policy perspective. Most existing research focuses either on India's national renewable energy transition or on Odisha's coal-based industrial economy. Limited attention has been paid to evaluating the state's renewable energy transition by integrating its resource potential, policy framework, institutional mechanisms, opportunities, and implementation challenges within a single analytical framework. This study addresses this gap by providing a comprehensive assessment of Odisha's renewable energy transition and identifying policy measures required to support a sustainable, secure, and inclusive energy future.

3. Methodology

This study employs a descriptive policy analysis using secondary data obtained from government reports, policy documents, statistical publications, and peer-reviewed literature. The primary sources include the Ministry of New and Renewable Energy (MNRE), Central Electricity Authority (CEA), National Power Portal (NPP), Government of Odisha, Odisha Renewable Energy Development Agency (OREDA), International Energy Agency (IEA), International Renewable Energy Agency (IRENA), and NITI Aayog (Government of Odisha, 2022; IEA, 2021; MNRE, 2024; NITI Aayog, 2023).

Trend analysis is used to examine changes in Odisha's installed electricity capacity between 2015–16 and 2025–26, while comparative and qualitative analyses are employed to assess renewable energy potential, policy initiatives, and the key opportunities and challenges influencing the state's renewable energy transition.

4. Renewable Energy Potential in Odisha

Odisha possesses considerable renewable energy resources owing to its favourable geographical conditions, diverse natural resource base, and growing demand for clean and reliable electricity. Although the state's electricity sector has historically depended on coal-based thermal power generation, increasing concerns over climate change, environmental sustainability, and energy security have strengthened the emphasis on renewable energy development. Supported by national and state policy initiatives, renewable energy is expected to play an increasingly important role in diversifying Odisha's energy mix and supporting sustainable economic development (Government of Odisha, 2022; International Energy Agency [IEA], 2021; Ministry of New and Renewable Energy [MNRE], 2024).

Table 1: Renewable Energy Potential in Odisha by Source.

Renewable Energy Source	Resource Potential (MW)	Utilization of Resource Potential (%)
Hydro (including Pumped Storage)	7,620	28.27
Solar	1,39,470	0.66
Small Hydro	286.22	49.13
Bio-Power	299	21.48

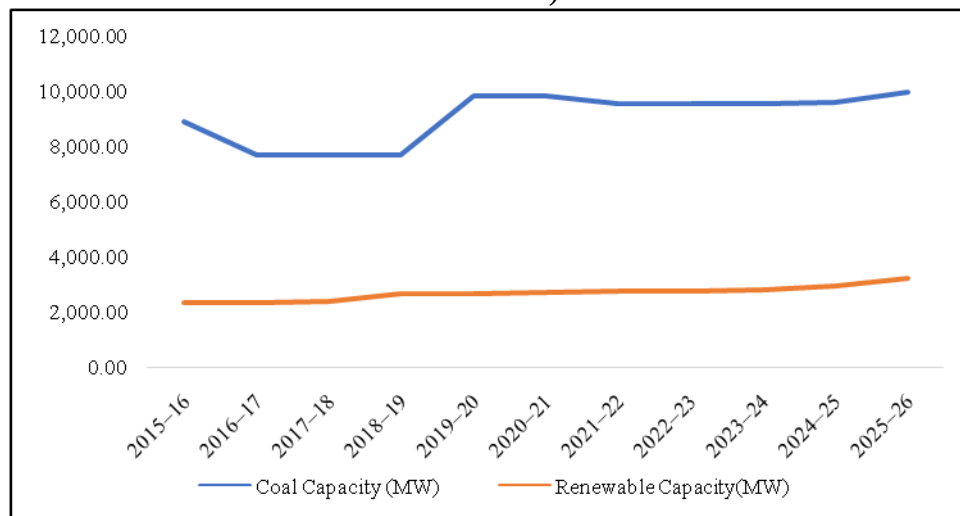
Source: NITI Aayog. (2025). India Climate & Energy Dashboard (ICED): Odisha State Report

Table 1 indicates that Odisha possesses substantial renewable energy resources, although much of this potential remains underutilized. Solar energy represents the largest resource, with an estimated potential of 139,470 MW, yet only 0.66% has been developed, highlighting significant opportunities for utility-scale and distributed solar deployment. Among the currently exploited resources, small hydropower records the highest utilization rate (49.13%), followed by hydropower including pumped storage (28.27%) and bio-power (21.48%). Although Odisha has a long coastline and recognised wind resource potential, commercial wind power development remains negligible, indicating scope for future investment as resource assessment and technology continue to improve

(Ministry of New and Renewable Energy [MNRE], 2024; National Institute of Wind Energy [NIWE], 2023).

Figures 1 and 2 collectively illustrate the evolution and current composition of Odisha's installed electricity generation capacity. Figure 1 shows that coal remained the dominant source of electricity generation throughout 2015–16 to 2025–26, with installed capacity increasing from 8,880 MW to 9,950 MW, despite minor fluctuations. Over the same period, renewable energy capacity grew steadily from approximately 2,336 MW to more than 3,240 MW, representing an increase of nearly 39%, primarily driven by the expansion of solar power. This trend reflects Odisha's progress in promoting renewable energy in line with national and state policy initiatives (Ministry of New and Renewable Energy [MNRE], 2024).

Figure 1: Installed Capacity by Energy Source in Odisha (2015–16 to 2025–26)

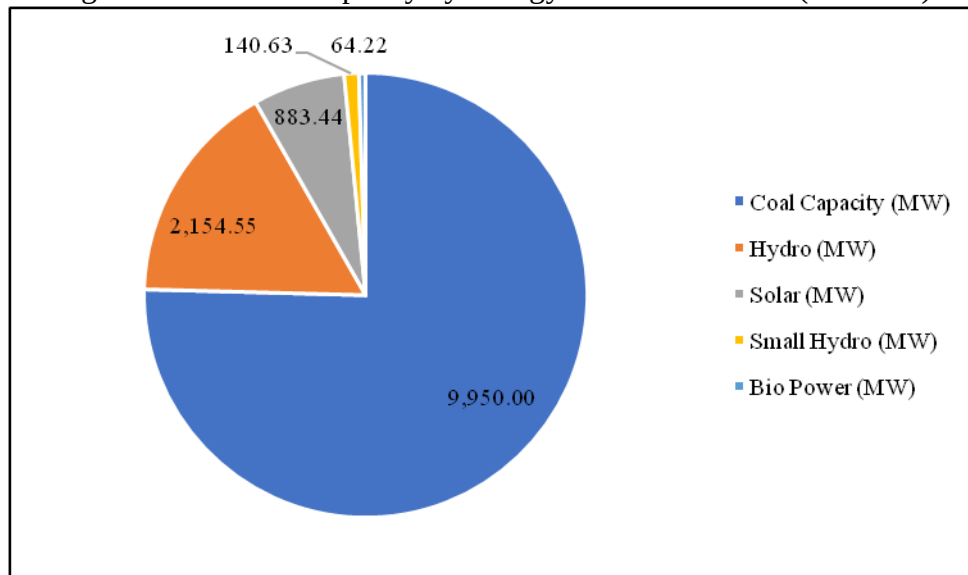


Source: NITI Aayog. (2025). India Climate & Energy Dashboard (ICED): Odisha State Report

Figure 2 further highlights the state's current energy mix in 2025–26, revealing that coal-based power accounts for 9,950 MW, or approximately 75.4% of the total installed capacity of 13,192.84 MW. Among renewable energy sources, hydropower contributes the largest share (2,154.55 MW), followed by solar power (883.44 MW), while small hydropower and bio-power account for relatively modest capacities. Although renewable

energy has expanded steadily over the past decade, it still contributes less than one-quarter of Odisha's installed capacity. Overall, the figures suggest that renewable energy is currently complementing rather than replacing conventional coal-based generation. Odisha's energy transition is therefore progressing gradually, and realizing the state's substantial untapped renewable resource potential will require continued investments in renewable energy deployment, grid modernization, energy storage, and supporting infrastructure to reduce long-term dependence on coal and promote a more sustainable energy system (International Energy Agency [IEA], 2021; Central Electricity Authority [CEA], 2024; NITI Aayog, 2023).

Figure 2: Installed Capacity by Energy Source in Odisha (2025–26)



Source: NITI Aayog. (2025). India Climate & Energy Dashboard (ICED); Odisha State Report

5. Policy Perspective

The renewable energy transition in Odisha is guided by a combination of national clean energy policies and state-level initiatives that seek to accelerate renewable energy deployment, strengthen energy security, attract private investment, and promote sustainable industrial development. Over the past decade, India has introduced several policy interventions to expand renewable energy capacity and achieve its climate commitments. Complementing these efforts, the Government of Odisha has adopted state-

specific policies that leverage the state's abundant renewable energy resources while supporting economic growth and industrial competitiveness (Government of Odisha, 2022; Ministry of New and Renewable Energy [MNRE], 2024).

5.1 National Renewable Energy Policy Framework

India's renewable energy transition has been driven by several flagship national initiatives. The Jawaharlal Nehru National Solar Mission (JNNSM) laid the foundation for India's large-scale solar expansion by promoting utility-scale and rooftop solar projects. Since its launch, the mission has contributed significantly to India's emergence as the world's third-largest solar market, with cumulative installed solar capacity exceeding 110 GW by 2025 (International Renewable Energy Agency [IRENA], 2025; MNRE, 2025).

Similarly, the Green Energy Corridor Programme has strengthened interstate and intrastate transmission infrastructure to facilitate renewable energy integration, although further transmission expansion remains necessary in renewable-rich states such as Odisha (Central Electricity Authority [CEA], 2024). The PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan) scheme has promoted decentralized renewable energy through solar-powered irrigation pumps and small solar power plants, improving rural energy access while creating additional income opportunities for farmers (MNRE, 2024).

Another important initiative is the National Green Hydrogen Mission, launched in 2023 to establish India as a global hub for green hydrogen production. The mission encourages investments in electrolyser manufacturing, renewable energy capacity, and green industrial development, creating significant opportunities for industrial states such as Odisha (Government of India, 2023; MNRE, 2024).

India has also made substantial progress towards its broader climate commitments. By 2025, the country had installed approximately 262 GW of non-fossil fuel electricity capacity, accounting for more than half of its total installed electricity capacity. These achievements indicate that India remains broadly on track to achieve its target of 500 GW

of non-fossil fuel installed electricity capacity by 2030 (Government of India, 2022; MNRE, 2025).

5.2 Odisha Renewable Energy Policy, 2022

To complement national initiatives, the Government of Odisha introduced the Odisha Renewable Energy Policy, 2022, which serves as the state's primary policy framework for renewable energy development. The policy seeks to accelerate investments in solar, biomass, small hydropower, floating solar, green hydrogen, and energy storage technologies while promoting private sector participation and enhancing energy security (Government of Odisha, 2022).

Since its introduction, Odisha has recorded steady growth in renewable energy capacity, particularly in solar power. Several utility-scale solar parks, floating solar projects and pumped storage initiatives have entered various stages of planning and implementation. The policy also emphasizes decentralized renewable energy systems, industrial decarbonization, and renewable energy-based manufacturing to support sustainable economic development (Government of Odisha, 2023).

5.3 Institutional Framework and Investment Promotion

The implementation of renewable energy programmes in Odisha is coordinated primarily by the Odisha Renewable Energy Development Agency (OREDA), the state's nodal agency for renewable energy and energy efficiency. OREDA has expanded rooftop solar installations, solar street lighting, solar irrigation pumps, decentralized renewable energy systems, and rural electrification programmes, particularly in remote and tribal regions.

To encourage investment, the state government provides land facilitation, electricity duty exemptions, support for grid connectivity, and investment promotion measures for renewable energy developers. The policy framework also promotes public-private partnerships and seeks to attract domestic and foreign investment in renewable energy infrastructure (Government of Odisha, 2022; MNRE, 2024).

5.4 Alignment with India's Clean Energy and Climate Goals

Odisha's renewable energy strategy is closely aligned with India's broader commitments to sustainable development, energy security, and climate change mitigation. The state's emphasis on renewable energy expansion, green hydrogen production, pumped storage, and energy storage technologies supports national objectives of reducing fossil fuel dependence and decarbonizing energy-intensive industries such as steel, aluminium, and mining (Government of India, 2022; NITI Aayog, 2023).

By leveraging its abundant renewable resources and industrial strengths, Odisha has the potential to become an important renewable energy hub in eastern India while contributing significantly to India's clean energy transition.

5.5 Policy Implementation Challenges

Despite considerable policy progress, several implementation challenges continue to constrain renewable energy development in Odisha. Land acquisition issues, financing constraints, transmission bottlenecks, inadequate energy storage infrastructure, and administrative delays remain major barriers to large-scale renewable energy deployment. In addition, the state's continued dependence on coal-based industries presents challenges for balancing industrial growth with long-term decarbonization objectives (International Energy Agency [IEA], 2021; NITI Aayog, 2023).

Strengthening institutional coordination, accelerating transmission and storage investments, simplifying regulatory procedures, and encouraging greater private sector participation will therefore be essential for achieving Odisha's renewable energy targets.

6. Opportunities

Odisha's renewable energy transition presents significant opportunities to advance economic development, environmental sustainability, industrial competitiveness, and energy security. With abundant renewable resources, a strong industrial base, and supportive policy initiatives, the state is well positioned to become a major renewable

energy hub in eastern India while contributing to India's clean energy and climate objectives (Government of Odisha, 2022; International Energy Agency [IEA], 2021; NITI Aayog, 2023).

6.1 Lower Carbon Emissions and Environmental Sustainability

Expanding renewable energy can substantially reduce greenhouse gas emissions and local air pollution by decreasing reliance on coal-based power generation. Greater deployment of solar, biomass, small hydropower, and future wind energy can help Odisha meet India's climate commitments while improving air quality in industrial and mining regions. Reduced emissions of carbon dioxide, sulphur dioxide, nitrogen oxides, and particulate matter can also lower pollution-related health risks and enhance environmental sustainability (IEA, 2021; Ministry of New and Renewable Energy [MNRE], 2024; World Health Organization [WHO], 2021).

6.2 Strengthening Energy Security

Renewable energy provides an opportunity to diversify Odisha's electricity mix and strengthen long-term energy security. Expanding decentralized renewable energy systems—including solar photovoltaic, biomass, and small hydropower—can improve electricity access in rural and tribal areas while reducing dependence on fossil fuels and increasing resilience to fuel price volatility and climate-related disruptions (Government of Odisha, 2022; IEA, 2021; NITI Aayog, 2023).

6.3 Employment Generation and Green Investment

Renewable energy can generate employment across manufacturing, installation, operation, maintenance, and research while attracting investment into solar manufacturing, battery storage, electrolyzers, and green hydrogen industries. Odisha's industrial base, ports, and manufacturing ecosystem provide favourable conditions for developing renewable energy value chains, thereby supporting industrial diversification,

technological innovation, and regional economic growth (Government of Odisha, 2023; International Renewable Energy Agency [IRENA], 2023).

6.4 Rural Development and Industrial Competitiveness

Decentralized renewable energy systems, including solar mini-grids, rooftop solar, biomass-based generation, and solar-powered irrigation, can improve electricity access, agricultural productivity, and livelihood opportunities in rural and tribal communities. At the same time, greater use of renewable energy can help energy-intensive industries such as steel, aluminium, and mining reduce carbon emissions, improve energy efficiency, and enhance competitiveness in an increasingly low-carbon global economy (IEA, 2021; MNRE, 2024).

6.5 Green Hydrogen and Energy Storage

Emerging technologies such as green hydrogen and energy storage present new opportunities for Odisha's energy transition. The state's industrial base, renewable energy resources, and port infrastructure provide favourable conditions for green hydrogen production, particularly for decarbonizing steel, fertilisers, and other energy-intensive industries. Similarly, investments in battery energy storage systems and pumped hydro storage can enhance grid flexibility, improve renewable energy integration, and support a more reliable and resilient electricity system (Central Electricity Authority [CEA], 2024; MNRE, 2023).

7. Challenges

Despite Odisha's considerable renewable energy potential, the transition towards a cleaner energy system faces several structural, infrastructural, financial, environmental, and institutional challenges. The state's long-standing dependence on coal-based industries, combined with transmission constraints, financing gaps, land-use conflicts, and implementation bottlenecks, continues to slow renewable energy deployment. Addressing

these barriers will be essential for achieving a balanced, secure, and socially inclusive energy transition (Government of Odisha, 2022; International Energy Agency [IEA], 2021; Ministry of New and Renewable Energy [MNRE], 2024; NITI Aayog, 2023).

7.1 Coal Dependence and Just Transition

Odisha's continued dependence on coal remains one of the most significant barriers to its renewable energy transition. As one of India's largest coal-producing states, Odisha has developed an extensive coal-based electricity and industrial system that supports major sectors such as steel, aluminium, mining, and manufacturing, contributing substantially to employment, exports, and state revenues (Central Electricity Authority [CEA], 2024; Ministry of Coal, 2024). While this industrial structure has supported economic growth, it also creates strong path dependency, making the transition to renewable energy economically and politically complex (Government of Odisha, 2023; IEA, 2021).

The transition also raises important social and equity concerns. A rapid shift away from coal could affect workers, coal-dependent communities, and regional economies unless accompanied by workforce reskilling, livelihood diversification, and social protection measures. At the same time, renewable energy projects may create new social challenges related to land acquisition and benefit sharing. Therefore, adopting a just transition approach that combines economic diversification, stakeholder participation, and inclusive policy planning will be essential for ensuring that the benefits of clean energy are shared equitably (International Labour Organization [ILO], 2022; Government of Odisha, 2022; NITI Aayog, 2023).

7.2 Land Acquisition and Environmental Constraints

Land acquisition remains a major challenge for renewable energy development in Odisha. Utility-scale solar parks, wind projects, and associated transmission infrastructure require substantial land resources, often competing with agriculture, forests, industrial development, and human settlements. In forested and tribal regions, renewable energy

projects may encounter resistance due to concerns regarding land rights, livelihood displacement, and ecological conservation (Government of Odisha, 2022; MNRE, 2024).

Furthermore, project sitting is constrained by environmental regulations, forest clearance requirements, and biodiversity considerations. Inadequate planning may result in habitat fragmentation and adverse impacts on ecologically sensitive areas, highlighting the need for environmentally responsible site selection and stakeholder engagement (Intergovernmental Panel on Climate Change [IPCC], 2022; Ministry of Environment, Forest and Climate Change [MoEFCC], 2023).

7.3 Grid Integration and Infrastructure Constraints

Renewable energy expansion in Odisha is constrained by inadequate transmission infrastructure, limited grid flexibility, and insufficient energy storage capacity. Although the state possesses significant renewable energy resources, transmission bottlenecks and limited evacuation infrastructure restrict the efficient integration of renewable electricity, particularly in resource-rich but remote regions (Central Electricity Authority [CEA], 2024; IEA, 2021).

In addition, the limited deployment of smart grid technologies, battery energy storage systems, and pumped storage facilities reduces the power system's ability to integrate variable renewable energy. Strengthening transmission networks, expanding storage capacity, and modernizing grid infrastructure will therefore be essential for ensuring reliable and secure renewable energy integration (Ministry of Power, 2024; NITI Aayog, 2023).

7.4 Financing and Policy Implementation

Financial and institutional constraints continue to hinder renewable energy development in Odisha. Renewable energy projects require substantial upfront investment, while high financing costs, limited access to affordable credit, and delays in subsidies, regulatory

approvals, and power purchase agreements increase project risks and discourage private investment (International Renewable Energy Agency [IRENA], 2023; IEA, 2021).

Although both the central and state governments have introduced supportive policies and financial incentives, implementation challenges—including administrative delays, fragmented institutional coordination, regulatory complexity, and limited monitoring capacity—continue to slow project execution. Strengthening institutional capacity, improving policy coordination, and creating a more predictable investment environment will therefore be essential for accelerating renewable energy deployment (Government of Odisha, 2022; NITI Aayog, 2023; World Bank, 2022).

8. Conclusion and Policy Recommendations

The renewable energy transition presents Odisha with a significant opportunity to achieve sustainable economic growth while improving energy security and reducing environmental impacts. The analysis indicates that the state possesses abundant renewable energy resources, particularly in solar energy, complemented by considerable potential in hydropower, biomass, floating solar and emerging technologies such as green hydrogen. Despite steady growth in renewable energy capacity over the past decade, coal continues to dominate the state's electricity generation, reflecting Odisha's historical dependence on coal-based industries and thermal power infrastructure. Consequently, the state's energy transition remains gradual, with renewable energy currently complementing rather than replacing conventional sources (Government of Odisha, 2022; International Energy Agency [IEA], 2021; Ministry of New and Renewable Energy [MNRE], 2024).

The study further shows that while Odisha has established a supportive policy framework through the Odisha Renewable Energy Policy, 2022, several structural constraints continue to limit renewable energy deployment. These include dependence on coal, inadequate transmission infrastructure, financing constraints, land-use challenges, and implementation bottlenecks. Addressing these issues will be critical for enabling a secure, resilient, and inclusive transition that aligns with India's renewable energy and climate commitments (NITI Aayog, 2023).

To accelerate this transition, several policy measures merit priority. First, Odisha should invest in transmission corridors, smart grids, battery energy storage systems, and pumped hydro projects to facilitate the large-scale integration of renewable energy into the electricity network (Central Electricity Authority [CEA], 2024; IEA, 2021). Second, renewable energy deployment should be supported through integrated land-use planning, environmentally responsible project sitting, and effective stakeholder consultation to minimize ecological impacts and social conflicts (Intergovernmental Panel on Climate Change [IPCC], 2022; MNRE, 2024). Third, strengthening the investment climate through stable policies, streamlined approval procedures, public-private partnerships, and greater access to green finance can encourage private investment and accelerate the deployment of both utility-scale and decentralized renewable energy systems (International Renewable Energy Agency [IRENA], 2023; World Bank, 2022).

The transition should also be guided by the principles of a just transition. Workforce reskilling, livelihood diversification, social protection measures, and investments in renewable energy manufacturing and green industries will be essential for supporting coal-dependent communities while ensuring that the socioeconomic benefits of the clean energy transition are shared equitably (International Labour Organization [ILO], 2022; IRENA, 2023). Finally, strengthening institutional coordination, improving policy implementation, and enhancing regulatory efficiency will be crucial for translating policy objectives into timely project execution and sustained renewable energy growth (Government of Odisha, 2022; NITI Aayog, 2023).

Overall, Odisha possesses the natural resources, industrial capabilities, and policy foundations necessary to emerge as a leading renewable energy hub in eastern India. Realizing this potential will require sustained investments in renewable energy infrastructure, supportive governance, technological innovation, and inclusive development policies. By adopting an integrated approach that balances economic growth, environmental sustainability, and social equity, Odisha can make a significant contribution to India's long-term energy security and low-carbon development objectives (Government of India, 2022; IEA, 2021).

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