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Renewable Energy in Bihar: Unlocking Potential Amidst Evolving Challenges

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I. Abstract:

Bihar is poised to change its electricity landscape with its energy shift. 'Promotion of Bihar New and Renewable Energy Sources 2025,' the state's renewable energy program, aims for 23.96 GW of renewable energy capacity and 6.1 GW of energy storage by 2029-30. Historical dependency on coal, an acute energy shortfall exacerbated by previous events, and robust economic growth driving demand drive this strategic change. The strategy aims to attract ₹1.5 trillion in investments and generate 125,000 employment, positioning Bihar as a leader in India's green energy industry and a key contributor to national net-zero goals. Renewable energy industries provide several options. Through huge parks, innovative floating and agri-voltaic systems, and broad rooftop installations, Bihar is developing solar energy using its abundant radiation. The state's substantial river and canal systems, which provide grid stability, offer untapped hydroelectric power potential, notably pumped storage. Wind energy is still developing but has increased procurement goals and regulatory support. Biomass and waste-to-energy projects use the state's agricultural wastes and animals to boost rural economies and waste management. Exploration of geothermal resources diversifies the energy portfolio. These lofty goals face many obstacles. Poor grid infrastructure with high transmission and distribution losses needs major improvements. Land purchase is difficult owing to limited availability, high expenses, and complex ownership patterns, sometimes affecting landless communities economically. To rectify past under-allocation, financing requires continual public and private investment, even with attractive policy incentives. A skill gap and low public awareness hinder human capital development and decentralised energy use. Financial incentives, land waivers, and regulatory assistance are part of Bihar's strategy to solve these issues. Manufacturing incentives and research and development support show the state's commitment to a self-sufficient green energy environment. The shift demands strategic preparation, meticulous execution, and equitable development. Other developing areas seeking energy security and economic progress might learn from Bihar.

Key-index: Renewable Energy, Bihar, Energy Transition, Capacity Targets, Investment

II. Introduction: Bihar's Energy Landscape and Renewable Imperative

Bihar's energy profile is marked by a substantial and continually expanding demand for electricity, which currently stands at approximately 6,500 megawatts (MW). Projections indicate a further escalation, with the number of electricity consumers anticipated to reach 1.90 crore and

consumption estimated to hit 45.5 million units by the financial year 2024-25. This escalating demand underscores a critical need for a robust and sustainable energy supply. Historically, Bihar's energy infrastructure has been heavily reliant on conventional, fossil fuel-based sources. As of March 2016, the state's installed power capacity was 2984.79 MW, with an overwhelming 92% of this capacity derived from coal. This deep dependence on coal has created an energy structure that is both environmentally unsustainable and inherently vulnerable to supply fluctuations. The challenges in Bihar's energy sector were significantly exacerbated by its bifurcation, a historical event that resulted in the state losing the majority of its thermal power plants and vital natural resources, particularly coal mines, to the newly formed state of Jharkhand. This historical context largely explains Bihar's persistent energy deficit and the urgent imperative to diversify its energy mix. Currently, green energy sources contribute a mere 6% to the state's total electricity production, highlighting the magnitude of the shift required. Furthermore, Bihar's power sector has been identified as one of the worst-performing in India, primarily due to high transmission and distribution (T&D) losses and suboptimal revenue collection, causing the state to lag behind the national average in energy supply relative to its demand. The current energy landscape in Bihar, characterized by a historical reliance on coal and the subsequent loss of significant conventional power assets following bifurcation, presents a unique and complex challenge. This structural deficit, compounded by the state's rapid economic expansion and a projected surge in electricity demand, creates an urgent and fundamental economic imperative for a swift and decisive transition to renewable energy. The state's current low share of green energy underscores that renewable energy development is not merely an environmental choice but a critical factor in overcoming bottlenecks to sustained economic growth and alleviating energy poverty. Renewable energy (RE) is recognized as a pivotal enabler for achieving sustainable growth in Bihar, one of India's fastest-growing states, where rapid economic growth and infrastructural development demand a proportional increase in electricity generation. Beyond merely providing an alternative energy source, RE serves as a fundamental instrument for addressing pressing developmental needs. These include enhancing energy security and access, mitigating the adverse health and environmental impacts associated with fossil fuels, and reducing greenhouse gas (GHG) emissions. Bihar's commitment to RE development is in direct alignment with India's national climate objectives, including the ambitious target of sourcing 40% of the country's power generation from renewable sources by 2030 and the broader commitment to achieving net-zero emissions by 2070. Bihar's progress in this domain is therefore integral to India's overall trajectory towards these national and international climate goals. Bihar's proactive pursuit of renewable energy, despite its historically underperforming power sector, positions it as a compelling case study for other developing regions globally. The state is attempting to bypass traditional, fossil-fuel-intensive development pathways while simultaneously confronting deep-seated infrastructural and systemic challenges. The strategies and outcomes of Bihar's RE transition will offer invaluable lessons for other energy-deficient, rapidly developing economies grappling with similar pressures to meet escalating energy demand sustainably. This positions Bihar as a potential proving ground for innovative RE integration models within complex socio-economic environments.

III. Bihar's Renewable Energy Policy 2025: A Catalyst for Growth

Overview of the 'Promotion of Bihar New and Renewable Energy Sources 2025' Policy

The Bihar Cabinet officially sanctioned the 'Promotion of Bihar New and Renewable Energy Sources 2025' policy on July 11, 2025. This pivotal policy effectively supersedes the preceding 2017 framework, signaling a significantly more aggressive and strategically focused direction for the state's energy transition. Manoj Kumar Singh, Bihar's Energy Secretary, has characterized the policy as "one of the most progressive policies in the country," underscoring its potential to establish Bihar as a frontrunner in the clean energy sector and a key contributor to India's broader net-zero commitments. Designed as a comprehensive five-year strategic blueprint, the policy is intended to remain operational for this period, thereby offering a stable and predictable regulatory environment crucial for attracting and retaining investor confidence. The Bihar Renewable Energy Development Agency (BREDA) was responsible for the meticulous drafting of this policy. Its development involved a thorough study of successful models and best practices implemented in other leading Indian states, including Maharashtra, Andhra Pradesh, and Gujarat. This approach ensured that the policy is both practical in its application and forward-looking in its strategic vision, incorporating lessons learned from diverse regional experiences.

Key Targets and Ambitions

The policy articulates an ambitious target to develop nearly 23.96 gigawatts (GW) of renewable energy capacity and 6.1 GW (or 6.1 GWh) of energy storage by the conclusion of Financial Year (FY) 2029-30. This represents a substantial leap from the state's current capacities. To facilitate the achievement of these targets, the policy aims to attract significant capital, with an estimated potential to draw ₹1.5 lakh crore (₹1.5 trillion) in investments from both public and private sector renewable energy developers. Beyond energy generation, a critical objective of the policy is the creation of substantial employment opportunities, with a target of 1.25 lakh (125,000) jobs projected across the state by FY 2029-30. A primary strategic goal is for Bihar to ascend into the ranks of India's top-10 green energy producing states by 2030. The state has formally committed that by March 2030, approximately 44% of the total electricity supplied in Bihar will be derived from green energy sources. This marks a profound increase from the current share, which stands at less than 15%. Specific targets for solar energy are particularly noteworthy, aiming for 24.81% of total energy from solar in 2023-24, further increasing to 33.57% by 2030. Similarly, electricity generated from wind and water sources is targeted to increase by an astounding 850 times, highlighting a significant challenge and opportunity for power companies.

Comprehensive Investor Incentives and Regulatory Support

The policy introduces a highly competitive array of financial benefits designed to attract investors. These include a 100% exemption from electricity duty for a period of 15 years , full reimbursement of State Goods and Services Tax (SGST) , and complete exemption from transmission and wheeling charges. Furthermore, projects will not be required to provide free power or contribute to the Local Area Development Fund. Recognizing land acquisition as a significant barrier, the policy offers a full waiver of stamp duty and registration fees for the lease, sale, or transfer of land for RE projects. This is complemented by a 100% reimbursement of land conversion fees. To promote electric vehicle (EV) infrastructure, government land is allotted at a 50% concessional rate for the first 1,000 EV charging stations or 50 MW capacity, whichever is higher, for RE-based stations. The policy promises a streamlined single-window clearance system to expedite project approvals. It grants deemed industry status for RE projects and introduces relaxed norms for rooftop solar installations to encourage broader adoption. The framework also facilitates energy banking, green tariffs, and carbon credit trading. State

utilities are mandated to cover the cost of building transmission and distribution infrastructure up to 10 kilometers from the project site, with shared responsibility for distances beyond that. The policy also ensures a robust payment security mechanism, minimum generation compensation, and customized feed-in tariffs for various RE technologies. RE projects will benefit from 'Must Run' status, and developers are assured of a guaranteed market within the state, as the Central Electricity Authority's (CEA) Resource Adequacy Plan stipulates that Bihar must procure approximately 23 GW of RE by FY30. Compensation for generation loss due to grid failure is also provisioned within the policy. To cultivate a local RE manufacturing ecosystem, the policy offers manufacturers priority allotment of government land on long-term lease, a five-year electricity duty exemption, investment subsidies on SGST, and a 100% customs duty exemption for five years for RE equipment manufacturers. Furthermore, a minimum of 5% of the state's annual renewable energy budget will be exclusively allocated for Research and Development (R&D) initiatives, guided by a newly established Bihar R&D and Innovation Committee. The Bihar Renewable Energy Policy 2025 demonstrates an aggressive strategic positioning, explicitly designed to surpass the concessions offered by other leading states. This approach is particularly timely and impactful given that the "free ISTS (inter-state transmission system) regime is drawing to a close". As developers face increasing costs for inter-state power transmission, the attractiveness of robust in-state incentives becomes paramount for project viability. This indicates that Bihar is not merely aiming to meet national renewable energy targets but is actively competing to redirect investment from traditionally dominant RE states. The success of this highly competitive policy could fundamentally reshape India's renewable energy investment landscape, channeling capital towards a region previously considered less developed in this sector. The policy's broad scope, extending beyond mere power generation targets to include incentives for electric vehicle (EV) charging infrastructure, local manufacturing of RE components, and dedicated R&D allocation, signifies a holistic approach to renewable energy ecosystem development. This comprehensive framework suggests a long-term vision for Bihar to evolve into a self-sufficient "renewable hub". Such an integrated strategy is designed to foster indigenous innovation, create high-value employment opportunities, and reduce reliance on external supply chains, ensuring that the economic and environmental benefits of the energy transition are largely retained within the state. This integrated development is crucial for building a resilient and sustainable green economy.

Table 1: Bihar's Renewable Energy Policy 2025: Key Targets and Incentives

CATEGORY	SPECIFICS	DETAILS
POLICY OBJECTIVES & TARGETS	Target RE Capacity (by FY2029-30)	23.96 GW
	Target Storage Capacity (by FY2029-30)	6.1 GW / 6.1 GWh
	Target Investment (by FY2029-30)	₹1.5 lakh crore (₹1.5 trillion)
	Target Job Creation (by FY2029-30)	1.25 lakh (125,000) jobs

	Aim for Top 10 Green Energy States by 2030	Yes
	Target Green Energy Share in Total Electricity by 2030	44% (from <15% currently)
	Specific Solar Targets (2023-24 & 2030)	24.81% (2023-24), 33.57% (2030)
	Wind & Water Sources Increase Target	850 times by 2030
KEY INCENTIVES	**FINANCIAL**	
	Electricity Duty Exemption	100% for 15 years
	SGST Reimbursement	100%
	Transmission & Wheeling Charges Exemption	Full exemption
	No Free Power/LADF Contribution	Yes
	LAND-RELATED	
	Stamp Duty/Registration Fees Waiver	Full waiver for lease/sale/transfer
	Land Conversion Fees Reimbursement	100%
	Concessional Land for EV Charging	50% concessional rate for first 1,000 stations or 50 MW capacity (RE-based)
	REGULATORY & EASE OF DOING BUSINESS	
	Single-Window Clearances	Yes
	Deemed Industry Status	Yes
	Open Access	Long-term (25 years/whole tenure)
	Energy Banking	Yes

	Green Tariffs	Yes
	Carbon Credit Trading Facilitation	Yes
	Relaxed Rooftop Solar Norms	Yes
	GRID & PAYMENT SECURITY	
	State Utilities T&D Cost Bearing	Up to 10 km from project site
	Payment Security Mechanism	Robust mechanism
	Minimum Generation Compensation	Yes
	Customized Feed-in Tariffs	Yes
	'Must Run' Status	Yes
	Compensation for Grid Failure Loss	Yes
	MANUFACTURING	
	Priority Govt Land Lease	Yes (long-term)
	Electricity Duty Exemption	5 years
	SGST Investment Subsidy	Yes
	Customs Duty Exemption	100% for 5 years
	RESEARCH & DEVELOPMENT (R&D)	
	Annual RE Budget Allocation	Minimum 5%

Source: Author's compilation from Ministry of Power and Energy(several reports)

IV. Opportunities Across Renewable Energy Sectors

Solar Energy

Bihar is endowed with significant solar radiation, rendering it highly conducive for the development of solar power plants. As of August 31, 2023, solar energy contributes 218 MW to Bihar's green energy production. This capacity is distributed across 141 MW from on-grid ground-mounted projects, 56 MW from rooftop installations, and 21 MW from off-grid solar power plants. The state's 2017 renewable energy policy had set a target of 2969 MW solar capacity by 2022, including 1000 MW

from grid-connected rooftop PV projects. While Bihar significantly underperformed against its overall 2022 RE target , the new 2025 policy maintains a strong and renewed emphasis on solar development. Currently, 450 MW of solar energy projects are under various stages of development, including a 200 MW project at Kajra in Lakhisarai and a 250 MW project at Pirpainti in Bhagalpur, both slated to commence production in 2024. Additionally, Sutlej Jal Vidyut Nigam (SJVN) is actively developing solar units with capacities of 125 MW in Jamui and 75 MW in Banka, with land acquisition and tendering processes nearing completion. Bihar is actively exploring and implementing diverse solar deployment models to maximize its potential and address land constraints. The Bihar Renewable Energy Development Agency (BREDA) has initiated projects to set up solar power plants on canal banks, such as a 2 MW plant near Bikram in Patna district and a 10 MW plant at Phulwaria reservoir near Nawada. Grid-connected rooftop solar power plants are being systematically installed on government buildings, with 20 MW already operational and work orders issued for an additional 65 MW, targeting a total addition of 150-200 MW. The 2025 policy further encourages the development of large-scale solar parks, floating solar plants, elevated solar installations over ponds, and agri-voltaic systems, demonstrating a commitment to innovative and multi-use land solutions.

Hydro and Pumped Storage

Bihar's distinctive geography, characterized by numerous rivers originating from Nepal that traverse its northern plains, coupled with an extensive network of canals, creates a "huge potential" for hydroelectric power generation. The Bihar State Hydroelectric Power Corporation (BHPC), established in 1982, was specifically tasked with planning, promoting, and developing all types of renewable power projects, including hydro-electric ones. Small hydro power (SHP) projects currently contribute 71 MW to Bihar's green energy mix. According to the Central Electricity Authority (CEA) data as of June 30, 2024, Bihar has an exploitable conventional hydro potential of 130 MW (for projects above 25 MW) and an identified pumped storage potential of 1,500 MW. This indicates a significant untapped resource for energy storage and grid stability. A major initiative is underway in the hills of Kaimur, where the power company has identified the possibility of generating 1,000 to 1,500 MW of electricity through pumped storage. WAPCOS Limited, a professional organization, has been commissioned to conduct a study for this project, with a report expected within three months, after which work is planned to commence. Pumped storage hydropower (PSH) plants are crucial for grid reliability and resilience, capable of storing large quantities of energy for extended periods. The Bihar Renewable Energy Policy 2025 explicitly covers pumped hydro technology and emphasizes the development of significant battery energy storage systems, including 1,600 MWh of pumped storage, aligning with the state's broader energy storage goals.

Wind Energy

While historically less prominent than solar or hydro, wind energy is gaining traction in Bihar's renewable energy strategy. The Bihar Renewable Energy Policy 2025 explicitly includes wind energy as a key technology for development. The state's Resource Adequacy Plan, published by the Central Electricity Authority (CEA) on May 6, 2024, stipulates an annual procurement of 700 MW of wind power from FY 2025-26. Bihar faces projected wind power obligation deficits of 1,433 MU in FY 2026-27 and 1,275 MU in FY 2027-28, potentially escalating to 2,551 MU by FY 2029-30. To address this, the Bihar Electricity Regulatory Commission (BERC) has approved tariffs for 312 MW of wind power projects. This includes 200 MW from NLC India at ₹3.74/kWh and 112 MW from Adyant Enersol at

₹3.81/kWh, with an additional trading margin for SJVN. These procurements are deemed necessary to fulfill the state's Renewable Purchase Obligation (RPO) targets and contribute to the national 500 GW RE target by 2030. A study evaluating wind energy potential in three northern districts (Bettiah, Madhubani, and Muzaffarpur) found average wind speeds ranging from 3.2 m/s to 4.7 m/s at 40m height. While these speeds are suitable for small-scale wind turbine setups, the study concluded that these locations are "not suitable for widespread wind power extraction at a hub height of 40 m". This suggests that while wind energy is a viable option, large-scale utility projects may require higher hub heights or more favorable locations, necessitating further detailed resource assessments. The state's 2017 policy also acknowledged Bihar's "good potential for development of non-conventional energy sources" including wind.

Biomass and Waste-to-Energy

Bihar possesses a substantial livestock population and generates considerable organic waste and agricultural residues, making biomass a promising renewable energy option. The principal sources of biomass include rice husk, woody biomass (like Julie flora, casurina), and various agro-residues such as stalks, cobs, shells, sugarcane trash, and cotton stalks. The Bihar Biofuels Production Promotion (Amendment) Policy 2025, a modification of the 2023 policy (which itself expanded from the 2021 Ethanol Production Promotion Policy), aims to boost clean energy, attract private investment, and support farmers. This policy supports both fuel-grade ethanol and Compressed Bio-Gas (CBG)/bio-CNG plants, utilizing agricultural residues, animal dung, and waste. It offers incentives such as a capital subsidy of 15% of plant and machinery cost (or Rs 5 crore, whichever is lower), with higher subsidies for specific entrepreneurial groups. The GOBARdhan (Galvanizing Organic Bio-Agro Resources Dhan) scheme, launched in 2018, is central to Bihar's biogas efforts, aiming to convert cow dung and organic waste into biogas. As of October 2024, 14 biogas plants are functional in Bihar, with construction ongoing in 29 locations, and financial assistance of up to Rs 50 lakh per district available under the Swachh Bharat Mission. A notable community biogas plant in Sonmai Panchayat (Patna district) has been operational since May 2023, using 1,500 kg of cow dung daily to supply gas to 20-22 households. Biomass projects offer significant employment opportunities, with a 10 MW biomass power project potentially creating 100 jobs during construction and 25 full-time operational jobs, plus 35 jobs in biomass collection and transport. The Biofuels policy aims to increase farmer income by providing a market for agricultural waste and animal dung, while reducing pollution. Saran Renewable Energy's biomass initiative has successfully replaced unreliable diesel generators, supplying power to businesses, households, schools, and clinics, leading to economic growth and reduced carbon emissions. Bihar is implementing a low-carbon waste management strategy, aiming for Net Zero by 2070. This plan includes improving waste management procedures like composting and biomethanation, and recovering methane from wastewater treatment. Proper waste management can reduce greenhouse gas emissions by up to 50%. Companies like Grow Billion Trees are pioneering industrial waste management in Bihar, utilizing advanced technologies for waste treatment, including incineration for energy generation.

Geothermal Energy

Bihar possesses geothermal resources, particularly in areas like Bhimband, which is a geothermal hotspot along the Munger-Saharsa Ridge fault zone. The Bhimband area exhibits a geothermal potential of 60–65°C with surface manifestation temperatures and a cumulative flow rate of 1.2 to 5.5 l/sec. Geochemical and geophysical surveys in Bhimband indicate the presence of various elements and oxides,

with water pH ranging from 6.2 to 6.4. Geophysical data, including gravity and magnetic surveys, suggest the presence of geothermal reservoirs. While identified as a low-enthalpy geothermal zone, studies suggest that thermodynamic cycles like binary cycles could be incorporated to generate power for grid transmission. The Bihar Renewable Energy Policy 2025 explicitly includes geothermal energy as one of the technologies covered, indicating the state's intent to explore and develop this resource. This inclusion suggests a forward-looking approach to diversify Bihar's renewable energy portfolio, leveraging all available natural resources.

V. Challenges and Mitigation Strategies

Infrastructure and Grid Integration

A significant challenge for renewable energy expansion in Bihar is the existing electricity grid infrastructure, which requires substantial upgrading to accommodate the influx of variable renewable energy sources like solar and wind. The state's power sector has historically been one of India's worst-performing, plagued by high transmission and distribution (T&D) losses. These losses are partly due to technical factors, such as energy dissipation in conductors and transformers, and exacerbated by widespread electricity theft through illegal connections, which leads to commercial setbacks for distribution companies and a decline in power supply quality. While injecting small capacities of power into existing substations can improve grid stability and power availability without costly upgrades , large-scale RE integration necessitates more comprehensive modernization. The intermittent nature of wind energy, for instance, requires robust energy storage solutions to ensure grid stability. The Bihar Renewable Energy Policy 2025 directly addresses grid integration by mandating state utilities to bear the cost of transmission and distribution infrastructure up to 10 kilometers from the project site, with shared responsibility beyond that point. The policy also emphasizes the development of significant battery energy storage systems (BESS), targeting 4,500 MWh of grid-level battery storage and 1,600 MWh of pumped storage. These storage solutions are crucial for managing RE variability and ensuring grid stability. Furthermore, the policy supports innovative models like hybrid parks and renewable energy zones , which can optimize grid connectivity and integration.

Land Acquisition

Land acquisition presents a major hurdle for large-scale renewable energy projects in Bihar. As a densely populated agricultural state with a population density of 1106 per square kilometer compared to India's 382, land is scarce and expensive, with most farmers owning less than two hectares. This makes securing sufficient land for utility-scale solar and wind farms challenging and time-consuming, often extending beyond a year. The process is complicated by fragmented land ownership, requiring consent from multiple individuals or entities holding surface and subsurface rights. Legal and regulatory hurdles, including extensive environmental impact assessments (EIAs) and compliance with zoning laws, further contribute to delays and potential litigation. Inadequate or unfair compensation for landowners can also lead to protracted disputes and project delays. Large-scale RE projects, particularly solar farms, can lead to a significant reduction in cultivated land and the loss of land-based livelihoods for agricultural laborers and pastoralists, who often do not own land and thus do not directly benefit from land lease agreements. This can compel workers to travel to nearby villages or migrate to other towns or cities in search of alternative employment. There is a risk that the employment opportunities generated by solar

parks may disproportionately favor landholding families, marginalizing landless households and women. The Bihar Renewable Energy Policy 2025 directly addresses land-related issues by offering a full waiver of stamp duty and registration fees for land transactions, along with 100% reimbursement of land conversion fees. The policy also promotes innovative land-use solutions such as floating solar plants, elevated solar installations over ponds, and agri-voltaic systems, which can mitigate land scarcity by utilizing non-traditional spaces. Rooftop solar installations are also being actively promoted as a practical workaround for land scarcity, requiring minimal land compared to utility-scale projects. Transparent and inclusive consultation processes with stakeholders are crucial for fostering community support and resolving land acquisition issues, as highlighted by successful strategies in other regions.

Financing and Investment

Bihar has historically demonstrated underinvestment in renewable energy, spending less than 1% of its total budget on this sector. While renewable energy budgets have shown some increase, funding for key agencies like the Indian Renewable Energy Development Agency (IREDA) has been poor, particularly for Bihar, indicating a legacy of limited public financing for climate mitigation interventions. Securing adequate financing remains a significant hurdle for RE projects, especially for smaller-scale initiatives. State electricity agencies often face challenges such as low credit ratings and limited finances, compounded by low revenue collection and high transmission and distribution losses. The Bihar Renewable Energy Policy 2025 is specifically designed to attract private sector participation, including foreign players, by providing a conducive investment environment. The policy aims to attract ₹1.5 lakh crore in investments through a highly competitive suite of financial incentives. These include 100% SGST reimbursement, a 15-year waiver on electricity duty, and exemptions from transmission and wheeling charges. Furthermore, the policy ensures a robust payment security mechanism and minimum generation compensation for developers , directly addressing concerns about revenue realization and project viability.

Technical Expertise and Human Capital

A recognized demand-supply gap for skilled workers exists in the solar and green hydrogen sectors across India, which extends to Bihar. The lack of a skilled workforce on the ground, particularly for the operation and maintenance of decentralized renewable energy projects, has been identified as a significant challenge. While Bihar has launched initial courses through its Bihar Skill Development Mission, enrollment has been low. Concurrently, a significant portion of the population, especially in rural areas, remains unaware of emerging environment-friendly renewable energy technologies and the associated government subsidy schemes. This lack of awareness can limit the adoption and effective utilization of decentralized RE solutions and contribute to uninterested consumers. The Bihar Renewable Energy Policy 2025 aims to generate 1.25 lakh jobs by FY 2029-30 , implicitly necessitating substantial workforce development. Companies in the renewable energy sector are encouraged to prioritize skilling and upskilling initiatives, collaborating with educational institutions and vocational training centers to create industry-relevant programs covering solar panel installation, maintenance, and repair, as well as green hydrogen production, storage, and transportation. Promoting awareness and interest among students and job seekers is also crucial for bridging the skill gap. The policy's allocation of a minimum of 5% of the state's annual renewable energy budget for R&D initiatives, guided by a new Bihar R&D and Innovation Committee , can foster local expertise and innovation, contributing to a more self-sufficient green energy ecosystem.

Socio-Economic and Environmental Impacts

Renewable energy projects are recognized as powerful tools to improve energy security and access, particularly in rural areas where electricity shortages persist. These projects attract investments, creating both one-time employment opportunities during the construction phase and permanent operation and maintenance positions throughout the project lifecycle. Solar projects, for instance, generate employment across multiple industries, contribute to local tax revenues through property taxes, sales taxes, and permitting fees, and drive infrastructure enhancements like road upgrades. Biomass projects can significantly increase farmer income by providing a reliable market for agricultural waste and animal dung. Broader green economy initiatives in Bihar prioritize social equity through skill development and employment generation in the green sector, fostering economic resilience for marginalized communities. Despite these substantial benefits, large-scale RE projects, particularly solar farms, require significant land, which can lead to land use conflicts, potential displacement of communities, and the loss of traditional land-based livelihoods for landless workers and pastoralists. These vulnerable populations, who do not own land, do not benefit from land lease agreements and may be forced to migrate for work. There is a risk that the employment benefits generated by solar parks may disproportionately favor landholding families, further marginalizing landless households and women, as observed in some case studies. While RE development inherently reduces reliance on fossil fuels and mitigates greenhouse gas emissions, contributing positively to climate change mitigation , large-scale installations can have localized environmental impacts. Solar farms, for example, can lead to habitat loss and fragmentation, displace wildlife populations, and potentially impact bird migration patterns. Construction activities can result in soil erosion and degradation, affecting water quality and biodiversity. Water usage for cleaning solar panels, though sometimes mitigated by the adoption of dry cleaning robots, can be a concern in water-stressed regions. To address the potential negative social impacts, governments and businesses should implement targeted training and upskilling programs for displaced workers, facilitating their access to new employment opportunities within the green sector. Gender-sensitive support, including provisions for safe transport, accommodation, and childcare, is essential for ensuring equitable participation of women workers in the green economy. Promoting decentralized solutions like rooftop solar can circumvent land use change and competition, reducing social friction. Environmentally, careful site selection is crucial to minimize impacts on sensitive habitats. Measures such as bird diverters, wildlife fencing, minimizing construction-related compaction, and maintaining perennial vegetation can reduce negative ecological effects. Exploring agri-voltaics and other co-use models can maximize land efficiency and provide additional ecosystem services, demonstrating a commitment to sustainable land management. Active community engagement throughout project planning and implementation is vital to ensure local acceptance, address concerns, and foster long-term project sustainability.

VI. Conclusions

Bihar's journey towards a renewable energy-dominated future is a testament to its strategic resolve to overcome historical energy deficits and meet burgeoning demand. The 'Promotion of Bihar New and Renewable Energy Sources 2025' policy is a robust framework, designed not just to meet ambitious capacity targets but also to fundamentally transform the state's energy ecosystem. Its aggressive incentives for investors, coupled with a holistic approach to developing local manufacturing and R&D capabilities, position Bihar to become a significant renewable energy hub within India. This

proactive stance, particularly as national inter-state transmission policies evolve, demonstrates a clear intent to attract and secure critical investments. The opportunities across solar, hydro, wind, biomass, and emerging geothermal sectors are substantial, underpinned by the state's natural endowments and innovative deployment models. Solar energy, with its diverse applications, and pumped hydro, crucial for grid stability, stand out as particularly promising avenues for large-scale development. Biomass and waste-to-energy initiatives offer a dual benefit of sustainable power generation and improved waste management, with direct positive impacts on rural livelihoods. However, the realization of these opportunities hinges on effectively navigating persistent challenges. The imperative to upgrade and modernize Bihar's grid infrastructure, address the complexities of land acquisition in a densely populated state, ensure sustained and diversified financing, and bridge the human capital skill gap are critical. The socio-economic implications of large-scale land use changes, particularly for landless communities, require careful and equitable mitigation strategies, emphasizing inclusive growth and community engagement.

Ultimately, Bihar's renewable energy transition is a multifaceted endeavor that extends beyond megawatts and investments. Its success will serve as a compelling model for other developing regions globally, demonstrating how a state with significant historical energy challenges can strategically leverage policy and innovation to leapfrog towards a sustainable, green economy. Continued diligent implementation of the policy, adaptive problem-solving for infrastructure and land issues, and an unwavering commitment to equitable development will be paramount in establishing Bihar as a leader in India's clean energy revolution.

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