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Integrating Solar Energy into Urban Infrastructure in Jharkhand: Pathways Toward Smart and Green Cities

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Abstract

Urban centers in Jharkhand, including Ranchi, Jamshedpur, Dhanbad, and Bokaro, face the twin challenges of growing susceptibility to climate change and rapid urbanization as they undergo sustained growth and modernization. The area's urban infrastructure offers a revolutionary chance to advance resilience, sustainability, and energy independence through the integration of solar energy. This article examines how solar technologies can reshape Jharkhand's cities into smart and green ecosystems. Key pathways discussed include building-integrated photovoltaics (BIPV), solar-ready planning for new urban developments, smart grids with storage capabilities, solar-powered transport infrastructure, and inclusive community solar initiatives, especially for underserved populations.

Even though these solutions can improve the environment of the state of Jharkhand and the economy by creating jobs and reducing energy poverty, they still need to overcome obstacles, including high upfront costs, legal restrictions, and geographic restrictions. Public-private partnerships, localized rules, regulations, and green financing can all help scale solar integration. This article analyses the potential and significance of rooftop solar urbanism for an inclusive, future-ready urban vision in Jharkhand that is in line with India's clean energy goals.

Keywords: Solar Urbanism, Smart Cities, BIPV, Energy Resilience, Green Infrastructure

1. Introduction

The eastern Indian state of Jharkhand, rich in minerals, is gradually but significantly changing. Cities like Ranchi, Dhanbad, Jamshedpur, and Deoghar quickly became industry, trade, and government hubs. Given urban expansion, these cities must reevaluate their approaches to energy use, environmental impacts, and quality of life.

Urbanization in Jharkhand is often characterized by high energy use, rising temperatures, an inconsistent power supply, and increased car emissions, making transitioning to cleaner and more resilient energy systems imperative. One plentiful and underutilized possibility to alleviate these issues is solar energy. Integrating technology like rooftop solar panels, solar-powered street lighting, and smart metering might lessen reliance on coal-based electricity, which still dominates the grid, providing favorable solar insolation and growing awareness of renewables. Under national initiatives like the Pradhan Mantri Awas

Yojana (Urban) and the Smart Cities Mission, this shift is in line with Jharkhand's objectives (UDHD, Government of Jharkhand, 2016).

In addition to rooftop installations, solar integration encompasses cutting-edge uses such as community solar parks, decentralized solar microgrids in peri-urban areas, solar-powered EV charging stations, and building-integrated photovoltaics (BIPV) in public and commercial buildings. Despite these remarkable developments, the development of solar energy is hampered by issues like outdated codes, a lack of technological expertise, and other pertinent financial limitations (Corti et al., 2024).

This study looks at ways to incorporate solar energy into Jharkhand's urban landscape using models and legal frameworks that can help with the transition. With the right planning and assistance, the state can potentially lead eastern India in solar-powered, sustainable urban expansion.

2. Objective of the Study

To help Jharkhand create smart and green cities, examining the possibilities and workable plans for incorporating solar energy into the state's urban infrastructure is necessary.

3. Methodology

Using a qualitative and descriptive research methodology, the study mostly uses secondary data gathered from government reports, policy documents, scholarly journals, and official records from the Jharkhand's Ministry of New and Renewable Energy (MNRE), Jharkhand Renewable Energy Development Agency (JREDA), and Smart Cities Mission documents (MNRE, 2022). Solar integration initiatives in other Indian states and international smart city models are compared (JREDA, 2022).

4. Literature Review

Numerous studies have demonstrated how renewable energy can transform urban surroundings as the foundation of urban growth; to fulfill the Mission, the Ministry of Housing and Urban Affairs' Smart Cities initiative promotes clean and resilient infrastructure. According to research (MNRE, 2022), decentralized solar power is essential for sustainably supplying urban electricity needs.

The goal of 2,000 MW of solar energy by 2022 is outlined in Jharkhand's own (IForest, 2024), although institutional, technical, and financial obstacles have caused unequal development. Energy-efficient public infrastructure, smart street lighting, and solar microgrids are all viable options in states like Jharkhand (Callejo, 2020), which have much solar potential (Gopalakrishnan, 2022). Global sustainability initiatives now depend heavily on integrating solar energy into urban infrastructure. Many academics have studied its implications for environmental sustainability, energy security, and urban design (Impact Day, 2025). According to the study, there are significant challenges and great potential for adopting solar technologies in India and Jharkhand specifically.

4.1 Global Perspectives on Solar Urban Integration

Studies by (Kalogirou, 2004) and (Hernandez et al., 2014) emphasize the increasing feasibility of solar photovoltaics (PV) in urban environments due to technological advancements and declining costs. Urban solar applications, ranging from rooftop systems to building-integrated photovoltaics (BIPV), are becoming integral to achieving smart city goals.

According to (IEA, 2021), urban solar infrastructure can contribute up to 60% of a city's renewable energy requirement if spatial and regulatory constraints are minimized.

4.2 Solar Energy in the Indian Urban Context

In India, solar energy is central to the national strategy for renewable energy expansion under the Jawaharlal Nehru National Solar Mission (Krishna & Akoijam, 2017). Research by Gupta et al. (2022) reveals that urban centres have made substantial progress through net metering, rooftop incentives, and solar parks. However, studies also note disparities in regional adoption due to differences in policy frameworks, urban density, and local governance capacity (NITI Aayog, 2021).

4.3 Energy Landscape and Urbanization in Jharkhand

Despite having high solar insolation (4.5–5.5 kWh/m²/day), Jharkhand remains underutilized in terms of solar infrastructure, especially in urban areas like Ranchi, Jamshedpur, and Dhanbad (Bahadur, 2024). Pandey et al. (2022)observe that the state faces challenges regarding land availability, funding constraints, and limited awareness among municipal bodies. Nonetheless, initiatives like the Jharkhand Renewable Energy Development Agency (JREDA) have begun implementing rooftop solar programs and decentralized solar lighting in public spaces (JREDA, 2001).

4.5 Policy Frameworks and Barriers

According to the literature, federal government incentives like the MNRE subsidies stimulate solar expansion. Manufacturing of Hybrid and Electric Vehicles (FAME), bureaucratic bottlenecks, and a lack of skilled workers hinder implementation in Jharkhand. Governments like Jharkhand should align their urban planning frameworks with renewable energy targets to accelerate uptake (World Bank, 2020). The objectives of the Indian Smart Cities Mission align with integrating solar energy into Jharkhand's urban infrastructure (JREDA, 2022).

According to researchers like Ramesh et al. (2020), solar integration lowers peak demand loads, improves air quality, and increases energy resilience. Solar street lighting and public building retrofits are being tested in cities like Ranchi. However, there are still issues with scalability and monitoring.

5. **Pathways for Integration**

a. Building-Integrated Photovoltaics (BIPV)

Building-integrated photovoltaics (BIPV) represents a transformative approach wherein solar modules are embedded directly into architectural elements like facades, rooftops, and windows. For urban centers like Ranchi and Jamshedpur, which are experiencing infrastructural growth, integrating BIPV in new constructions can convert idle surfaces into productive, power-generating assets. Adoption can be encouraged through local amendments to green building codes and policy incentives such as property tax rebates.

The Jharkhand State Solar Policy (2022) emphasizes distributed solar systems, which align well with BIPV deployment, especially in residential and institutional buildings in Jharkhand, India.

b. Solar-Ready Urban Planning

Solar readiness is a core component that will help Jharkhand's cities to be future-proof. Moreover, urbanizing optimal building orientation, minimizing roof obstructions, enabling shared access to sunlight, and installing centralized inverter banks in housing clusters.

Urban Local Bodies (ULBs), with support from the Jharkhand Renewable Energy Development Agency (JREDA), can integrate these requirements into municipal building permit processes. With the expectation of the state's rapidly rising electricity demand (expected to hit a 20% deficit in 2024-25), enabling solar-ready development is an energy and planning imperative.

c. Smart Grids and Energy Storage

Smart grid infrastructure is critical for managing two-way electricity flows between distributed solar producers and the grid. Integration of lithium-ion storage systems at residential, commercial, and utility levels would reduce grid stress during peak hours and improve overall system resilience.

Jharkhand's older cities are struggling because of their antiquated grid infrastructure; therefore, solar adoption must prioritize improving these systems. The risk is also drawn attention to in the CEA Power Generation Balance Assessment (2024–25). It emphasizes how important it is for Jharkhand to use energy efficiently (NITI Aayog, 2015).

d. Solar-Powered Transport Infrastructure

Transport-linked solar infrastructure presents an untapped opportunity. Ranchi's Bus Rapid Transit (BRT) corridor and emerging EV hubs in Jamshedpur can host solar rooftops, panels on shelters, and EV charging stations powered by solar microgrids. This would reduce the operational carbon footprint and cut costs for urban transport systems. Since iFOREST estimates that Jharkhand has 52 GW of surplus solar potential, installing such infrastructure might positively impact the environment and the general public.

e. Community and Shared Solar Projects

Rooftop solar may not be feasible. Shared solar parks and community solar gardens offer collective solutions. These projects allow multiple households—especially low-income families—to co-invest in or lease clean energy from a centralized solar facility.

This participatory model supports equitable energy access and aligns with iFOREST's recommendation for local technician training and renewable energy entrepreneurship to create green jobs in the region (IForest, 2024).

6. **Challenges and Implementation Gaps**—approximately ₹0.21/unit higher than states like Rajasthan—due to weaker solar irradiance and logistical costs. This makes projects economically challenging without state-specific subsidies or concessional financing..

a. Energy Deficit in Jharkhand (IForest, 2024)

Year	Energy Deficit (MUs)	Deficit (%) of Requirement
2022–23	Data not specified	7.6%
2024–25 (proj.)	2,764 MUs	20% (Highest in India)

b. Current Energy Mix (2024) (IForest, 2024)

Source	Installed Capacity (MW)	Share (%)
Thermal (coal-based)	2,607 MW	>85% (Utility segment)

c. Installed Renewable Energy Capacity in Eastern States: Sep 2024 (IForest, 2024)

State	Installed RE Capacity (MW)
Jharkhand	200 MW

Bihar	456 MW
Chhattisgarh	>1,500 MW

Note: Jharkhand added only 100 MW since the Jharkhand State Solar Policy 2022, against a target of 697 MW by 2024 and 4,000 MW by 2027.

d. Theoretical Renewable Energy Potential in Jharkhand (IForest, 2024)

Energy Type	**Potential Capacity**	**Details**
Solar	52 GW	Giridih: 6.5 GW; Palamu, Bokaro, Saraikela-Kharsawan, Hazaribagh, Deoghar, Dumka: 2–3 GW each
Wind	22 GW at 150m AGL	Ranchi (100m AGL) and Giridih (150m AGL) have large wind potential
Biomass	3 GW	Primarily from Kharif rice production (97% of biomass)

e. Biomass Generation Capacity by District (IForest, 2024)

District	**Potential Capacity (MW)**
Gumla	240–360 MW
Ranchi	240–360 MW
West Singhbhum	240–360 MW

f. Economic Dependence on Coal: 2023–24 (IForest, 2024)

Total Non-Tax Revenue	**Revenue from Coal Royalties**	**Share from Coal**
₹1.6 billion (₹16,116 Cr)	₹1.28 billion (approx.)	80%

7. **High Initial Capital Costs**

Despite decreasing solar technology costs nationwide, Jharkhand faces higher Levelized Costs of Energy (LCOE)Lack of Technical Expertise and Awareness

8. **Lack of Technical Expertise and Awareness**

a. Energy Access vs Demand
b. Jharkhand achieved 100% household electrification under the **Saubhagya scheme** by 2020.
c. However, rising urban and industrial demand has led to **persistent and widening power shortages**.

9. **Renewable Lag in the Eastern Region**
a. Despite **high solar irradiance** and large tracts of **wasteland**, Jharkhand has the **lowest installed RE capacity** in Eastern India.
b. It remains heavily dependent on **coal-based thermal power**, contrary to national trends.

10. **Policy Developments**
- **Jharkhand State Solar Policy (2022)** and **Green Open Access Regulations (2024)** were significant steps.
- Yet, RE growth has been **slower than policy targets** due to:
- Limited incentives
- Lack of diversified policy frameworks beyond solar
- **Higher LCOE** for solar (₹0.21/unit more than states like Rajasthan or Karnataka)

11. **Institutional Gaps: JREDA's Role (JREDA, 2001)**
a. The **Jharkhand Renewable Energy Development Agency (JREDA)** needs:
b. Organizational strengthening through expanded workforce and governance reforms
c. Regular training for technical staff
d. Creation of technology-specific teams for solar, wind, and biomass
e. Simplified clearance processes, land identification, and infrastructure support
f. Investment in green skill development and RE entrepreneurship

12. **India's National Energy Transition**
From 2017 to 2024:
a. 87 GW of renewable energy capacity added
b. Only 24 GW of thermal capacity added
Jharkhand must align with India's net-zero ambitions and global shift toward decarbonization by leveraging its 52 GW solar potential. Many urban households and local businesses remain unaware of solar installation procedures, government schemes, and maintenance requirements (Al Qubeissi et al., 2020). Capacity constraints within ULBs and limited solar training programs aggravate this knowledge gap.

13. **Policy Gaps and Bureaucratic Delays**
a. **Bureaucratic Delays** in approvals, poor cooperation between DISCOMs and municipal departments, and the lack of legally binding solar mandates impede the implementation of plans such as JSSP 2022 (Down to Earth, 2024).
b. **Infrastructure and Grid Readiness** Outdated electrical infrastructure in older cities poses a serious constraint. Congested layouts and transformer limitations often inhibit decentralized solar units' safe and effective integration.

14. **Recommendations**
a. performance-based incentives through JREDA, including capital subsidies for BIPV, net-metering rebates, and green credit lines via public banks.

b. **Capacity Building and Training Programme:** Jharkhand must institutionalize regular training programs for municipal engineers, urban planners, and electricians. Strengthening JREDA's workforce and governance capabilities is essential for scaling renewable energy across sectors.
c. **Solar Mandates for Public Buildings:** Under the Jharkhand Energy Conservation Building Code, mandatory solar installation for all government buildings—including offices, schools, and hospitals—will reduce recurring electricity bills and set visible examples of green leadership.
d. **Public-Private Partnerships (PPPs):** Urban solar development can be accelerated through PPP models like Build-Operate-Transfer (BOT). Municipal corporations can partner with private firms to co-develop large-scale solar parks, smart grid nodes, and EV infrastructure.
e. **Awareness Campaigns:** City-wide campaigns using community meetings, local media, and school outreach programs can improve public understanding and acceptance of solar energy. Demonstration projects and citizen feedback loops should support these.
f. **Policy Incentives and Green Financing:** The state should roll out targeted.

15. Analysis and Discussion

Incorporating solar energy into Jharkhand's urban infrastructure is urgently necessary and a transformative opportunity. The state is currently dealing with a worsening energy crisis brought on by increasing urbanization, industrialization, and a coal-dominated power mix, even though the Saubhagya project achieved 100% household electrification by 2020.

The projected energy deficit of 2,764 million units (MUs) in 2024–25, representing 20% of the total electricity requirement, is the highest in India—underscoring the inadequacy of the current energy model and the need for a decentralized, renewable-based strategy.

Jharkhand's current energy mix remains heavily skewed toward fossil fuels, with over 85% (2,607 MW) of its utility power generated through coal-based thermal plants. In stark contrast, the state's installed renewable energy (RE) capacity is just 200 MW as of September 2024, far behind neighbouring states like Chhattisgarh (>1,500 MW) and Bihar (456 MW). This is despite Jharkhand having a theoretical solar energy potential of 52 GW, with regions like Giridih, Palamu, and Hazaribagh alone accounting for 2–6.5 GW each.

The Jharkhand State Solar Policy (2022) set a target of 697 MW by 2024, and 4,000 MW by 2027, yet only 100 MW has been added since its launch. This shortfall is attributed to multiple factors:

Higher Levelized Cost of Energy (LCOE)—₹0.21/unit more than in Rajasthan—due to moderate solar irradiance and logistical challenges.

Institutional bottlenecks include weak inter-agency coordination, limited technical expertise, and a slow approval process.

Outdated infrastructure, particularly in older urban areas like Dhanbad and Ranchi, where congested grids and undersized transformers limit solar integration.

However, the state's solar resources remain largely untapped. With high solar insolation levels (4.5–5.5 kWh/m^2/day)and large tracts of wasteland, Jharkhand is well-positioned to transition toward clean energy—if its urban planning frameworks and policy instruments are realigned.

Several viable pathways for solar integration in urban Jharkhand have emerged from both literature and practice:

Building-integrated photovoltaics (BIPV) could be deployed in new constructions across growing urban centres like Ranchi and Jamshedpur, converting facades and rooftops into energy-generating assets.

Solar-Ready Urban Planning can ensure that new developments are designed for optimal sunlight access, rooftop usability, and centralized inverter integration, thereby supporting collective generation models.
Smart grids and battery storage, especially lithium-ion systems, are essential to accommodate two-way power flow and reduce stress during peak demand.
Solar-powered transport infrastructure—such as rooftop solar on Ranchi's Bus Rapid Transit (BRT) system and EV charging hubs—can reduce urban transit emissions while enhancing energy efficiency.
Community and shared solar parks can be crucial for high-density areas where rooftop solar is not feasible, offering collective ownership models and cost-sharing benefits.
Moreover, Jharkhand also possesses significant renewable potential beyond solar—including 22 GW of wind energy(notably in Ranchi and Giridih) and 3 GW of biomass capacity, primarily from Kharif rice production, with districts like Gumla, Ranchi, and West Singhbhum each contributing 240–360 MW in biomass potential. These statistics demonstrate Jharkhand's multifaceted renewable energy potential, which is yet underutilized.
Economically speaking, coal royalties account for 80% of Jharkhand's non-tax revenue (₹1.28 billion of ₹1.6 billion in 2023–2024), indicating a structural susceptibility to changes in the price of fossil fuels and upcoming decarbonization projects. Because of the state's economic over-reliance on coal, it is even more critical to diversify its energy and revenue sources.
After the discussion, the following crucial recommendations are made in order to utilize Jharkhand's solar potential properly:
To unlock Jharkhand's full solar potential, the discussion leads to the following key recommendations:
To reduce project-level financial risks, green financing through JREDA must include performance-based incentives, capital subsidies for BIPV, and concessional loans via public banks.
Capacity building is essential. Regular training of ULB officials, electricians, and planners, alongside structural strengthening of JREDA with specialized renewable energy divisions, will ensure scalable implementation.
Mandatory solar mandates under the Jharkhand Energy Conservation Building Code for all public institutions—including schools, offices, and hospitals—can create visible green exemplars and reduce government electricity expenses.
Public-Private Partnerships (PPP) Investment in smart grids, EV infrastructure, and solar parks can be stimulated via Public-Private Partnerships (PPP) that employ Build-Operate-Transfer (BOT) models. Awareness efforts must demystify the solar adoption process, emphasize the financial advantages, and encourage citizen participation, particularly in urban areas, homes, and small companies.
The future of Jharkhand in urban areas energy rests on transforming theoretical potential into real progress. A comprehensive, data-driven approach to renewable energy implementation is the way to go, considering the 52 GW of solar potential, rising urban demand, and expanding energy shortages. The crisis of Jharkhand state energy might be remedied, and it could serve as a model for smart, inclusive, and green urban change throughout eastern India and beyond if this is effectively pursued.

16. **Conclusion**

Sustainable growth, energy security, and long-term urban resilience depend on integrating solar energy into Jharkhand's urban infrastructure. Rapid urbanization and economic change in Jharkhand are putting more and more strain on traditional power sources as the state's cities see increased energy consumption.

The state is projected to have more than 52 gigawatts of solar energy potential, which might be used to satisfy these expanding demands. Strategically deploying solar energy—through initiatives like building-integrated photovoltaics (BIPV), solar-ready planning, rooftop solar programs, and solar-powered public infrastructure—mitigates carbon emissions and diversifies the state's energy portfolio. Moreover, it creates opportunities for inclusive green growth. A decentralized energy model, Jharkhand, may enhance energy access in urban and peri-urban areas, empower communities, and lower transmission losses.

To realize this vision, a coordinated, multi-stakeholder strategy is required. The creation of creative financing mechanisms to make solar systems more affordable for homes and small businesses, changes to land use and building rules to encourage the adoption of solar, and capacity building and technical skilling initiatives for local workers are all part of this. To enforce renewable energy legislation, expedite permits, and match clean energy objectives with urban growth, it encourages proactive governance, in which state agencies, corporations, and municipalities work together.

Including solar energy in urban planning and governance benefits Jharkhand in several ways, including creating jobs, economic diversification, environmental sustainability, and climate resilience. Leading the country in the green energy revolution, Jharkhand is enhancing its standing as a progressive and environmentally sensitive state. With vision, coordination, and commitment, Jharkhand can become a model for smart, green urban transformation in India and beyond.

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