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Solar energy development and avian survival in India: Critical perspectives

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Abstract
India's transition toward renewable energy has positioned solar power as the cornerstone of its climate and development agenda. By 2030, the country aims to achieve 500 GW of non-fossil fuel capacity, with large-scale solar parks proliferating across arid ecosystems such as Rajasthan and Gujarat. While solar expansion reduces dependence on fossil fuels, its ecological consequences for avifauna remain underexplored. Birds face direct threats from panel reflection ("lake effect"), collisions, and associated infrastructure, as well as indirect pressures from habitat fragmentation, altered microclimates, and disruption of migratory corridors. The Great Indian Bustard (*Ardeotis nigriceps*), a critically endangered species with fewer than 200 individuals, epitomizes this conflict between renewable energy growth and avian survival, as its range overlaps extensively with India's renewable energy projects (The Hindu, 2019; Kumar *et al*., 2019) [7, 12].
This paper critically examines the intersection of solar energy development and avian conservation in India. Drawing on peer-reviewed studies, government reports, and policy analyses, it explores the ecological trade-offs of solar expansion, the governance challenges of integrating biodiversity safeguards, and potential mitigation strategies. It argues that India's renewable energy future must incorporate avian-sensitive planning and ecological justice frameworks. By situating India's solar growth within global debates on "green colonialism" and undervalued ecosystems such as grasslands (Vagh & Ratnu, 2024; Bindra, 2017) [1, 14], the study emphasizes that climate mitigation should not come at the cost of biodiversity collapse.

Keywords: Solar energy development, avian survival, renewable energy, habitat fragmentation, great indian bustard

Introduction

Context and Significance

India is among the world's fastest-growing solar energy producers, propelled by ambitious national policies such as the Jawaharlal Nehru National Solar Mission (2010) and subsequent renewable energy targets. The International Solar Alliance, headquartered in Gurugram, reflects India's leadership in global solar diplomacy. With abundant solar insolation, especially in western deserts, the government envisions mega-parks like the Bhadla Solar Park in Rajasthan, one of the world's largest, as symbols of a green transition (Ortiz *et al*, 2022) [10].
However, the rapid acceleration of solar infrastructure has ecological implications that are less frequently acknowledged. India's subcontinent hosts over 1,300 bird species, of which several are globally threatened and many depend on fragile habitats that overlap with renewable energy projects. Grasslands, deserts, and scrublands—often dismissed in policy as "wastelands"—are in fact vital ecosystems supporting raptors, bustards, and migratory birds (Vagh & Ratnu, 2024) [14]. Yet, these landscapes are among the prime sites for solar installations due to low population density and high solar potential.

Problem Statement

The development of solar energy presents a paradox. On one hand, it promises reduced greenhouse gas emissions, energy security, and sustainable growth. On the other hand, it risks accelerating biodiversity decline through habitat loss, infrastructural hazards, and ecological disruption. Unlike fossil fuels, renewable energy projects often escape stringent environmental scrutiny, being classified as "green" by default (Bindra, 2017) [1]. The result is that birds—already vulnerable due to climate change, land-use change, and hunting—face compounded risks from solar expansion.
The Great Indian Bustard (GIB) has emerged as the focal species in this debate. Once widespread across the subcontinent, it now survives in small fragmented populations, primarily in Rajasthan and Gujarat. Collisions with overhead transmission lines and habitat conversion from renewable projects are among its leading threats (The Hindu, 2019; Indian Express, 2021) [4, 12]. In 2021, the Supreme Court of India directed that transmission lines in GIB habitats be placed underground, highlighting the seriousness of the issue. Yet, implementation challenges persist, and new proposals continue to emerge that risk further encroachment (Financial Times, 2024) [3].

Research Questions

This paper seeks to address three interlinked questions:

1. What are the direct and indirect impacts of solar energy development on avian species in India?
2. How do policy frameworks and governance mechanisms balance renewable energy growth with avian conservation?
3. What mitigation strategies and critical perspectives can reconcile India's solar future with ecological justice?

Scope and Contribution

The paper adopts a critical ecological and governance perspective. It draws on case studies from desert ecosystems (e.g, Rajasthan, Gujarat) where large-scale solar parks overlap with bird habitats, integrating findings from both peer-reviewed studies (Kumar *et al*., 2019; Suthar *et al*., 2017; Environmental Science & Pollution Research, 2019) [2, 7, 11] and gray literature (Times of India, 2023; Mongabay, 2018) [9, 13]. By situating India's experience in a global

context, the study contributes to debates on the ecological sustainability of renewable energy transitions.

Literature Review

1. Solar Energy Growth in India

India has prioritized solar energy as the cornerstone of its renewable portfolio. The Jawaharlal Nehru National Solar Mission (2010) envisioned India as a global leader in solar adoption, with subsequent commitments under the Paris Agreement reinforcing this trajectory. Ortiz *et al*. (2022) [10] developed an artificial intelligence dataset of solar energy locations in India, highlighting the rapid expansion of solar parks, particularly in Rajasthan, Gujarat, and Maharashtra. Such concentration in arid zones increases the overlap between energy infrastructure and avian habitats.

2. Birds and Renewable Energy: Global Perspectives

Globally, studies have highlighted avian vulnerability to renewable infrastructure. Mellinger *et al*. (2022) [8] demonstrated how solar and wind facilities can cause fatalities, disturb migratory pathways, and fragment habitats. In Central Europe, Jarčuška *et al*. (2024) [6] found that solar parks can sometimes enhance bird diversity in agricultural landscapes, provided they are managed with biodiversity-sensitive practices. This suggests that solar infrastructure need not always be ecologically detrimental, but its impact depends on siting, design, and management.

3. Avian Impacts of Wind and Solar in India

Most empirical studies in India have examined wind energy. Suthar *et al*. (2017) [11] reported frequent collisions and electrocutions of wetland and migratory birds around Porbandar, Gujarat. Similarly, Kumar *et al*. (2019) [7] documented avian mortalities at wind farms in Kutch (Gujarat) and Davangere (Karnataka), affecting raptors and bustards. The Wildlife Institute of India (2025) [15] estimated significant bird mortality at Thar Desert wind farms, underscoring risks in arid ecosystems where many endangered species persist.

Solar-specific research remains limited. Environmental Science & Pollution Research (2019) [2] studied bird droppings on photovoltaic panels in Rajasthan, revealing indirect interactions between birds and solar arrays. Vagh and Ratnu (2024) [14] examined biodiversity effects in the Pugal region, finding microclimate changes, vegetation alteration, and bird displacement linked to solar installations. News and advocacy reports, such as Bindra (2017) [1] and Times of India (2023) [13], have highlighted threats to migratory birds and the Great Indian Bustard from solar and wind projects.

4. The Great Indian Bustard Case

The Great Indian Bustard (*Ardeotis nigriceps*) has become emblematic of the conflict between renewable energy expansion and avian conservation. The species is critically endangered, with fewer than 200 individuals remaining (The Hindu, 2019). Power-line collisions are among its greatest threats, leading the Supreme Court of India (2021) to mandate undergrounding of transmission lines in its core habitat. However, policy disputes continue (Indian Express, 2021, 2024; Financial Times, 2024) [3, 4, 5], revealing tensions between conservation mandates and energy development priorities.

5. Policy and Governance Context

Mongabay (2018) [9] reported efforts to develop guidelines for wind farms to reduce bird mortality, but no equivalent solar-specific guidelines exist. Grasslands and deserts remain undervalued in India's land classification system, often labeled as "wastelands" and thereby targeted for industrial-scale solar development (Vagh & Ratnu, 2024) [14]. This institutional framing contributes to ecological blind spots, as areas critical for avian diversity are systematically deprioritized in planning.

Methodological Approach

This paper adopts a critical ecological-governance perspective rather than an empirical field study. Sources include peer-reviewed studies on avian-RE interactions, government reports, and media accounts that capture ongoing conflicts. The analysis applies the framework of ecological justice, examining how renewable energy projects, though "green," may perpetuate biodiversity loss and marginalize species dependent on undervalued ecosystems. The case of the Great Indian Bustard is used as a focal lens, supplemented with evidence from migratory flyways and desert ecosystems.

Findings and Discussion

1. Direct Threats to Birds from Solar Projects

- **Collisions and Lake Effect:** Reflective panels may mimic water bodies, confusing birds, particularly migratory species. While empirical data is limited in India, studies elsewhere (Mellinger *et al*., 2022) [8] suggest this could become a major risk.
- **Solar Flux Effects:** Concentrated solar power (CSP) plants pose burn risks, though India's expansion is dominated by photovoltaic (PV) rather than CSP.
- **Panel-Associated Behavior:** Birds are attracted to perch on arrays, leading to droppings that reduce PV efficiency (Environmental Science & Pollution Research, 2019) [2].

2. Indirect Threats

- **Habitat Loss:** Grasslands converted to solar farms reduce breeding and foraging grounds for bustards, larks, and raptors (Vagh & Ratnu, 2024) [14].
- **Fragmentation:** Roads, fencing, and associated infrastructure alter landscape connectivity.
- **Migratory Disruptions:** Flyways intersect solar-rich deserts, especially for cranes and other migrants.

3. Case Study: The Great Indian Bustard

Transmission lines associated with solar and wind farms are the most lethal threats to GIB. Studies indicate that undergrounding lines could save significant numbers annually (The Hindu, 2019) [12]. The Supreme Court's 2021 ruling mandated mitigation, yet subsequent petitions from energy companies sought exemptions citing costs (Indian Express, 2021) [4]. Recent reports show ongoing disputes about implementation (Financial Times, 2024) [3]. This reveals the governance challenge of aligning energy and conservation priorities.

4. Governance and Policy Challenges

- **EIA Gaps:** Renewable projects are often exempted from rigorous Environmental Impact Assessments.
- **Institutional Biases:** Grasslands labeled as "wastelands" create systemic undervaluation of critical avian habitats.
- **Weak Enforcement:** Mandates such as bird diverters on lines remain inconsistently applied (Mongabay, 2018) [9].

Mitigation and Future Pathways

- **Infrastructure Design:** Underground or insulated power lines, panel designs minimizing reflection, and fencing that does not fragment habitats.
- **Biodiversity-Sensitive Siting:** Avoidance of critical habitats and migratory flyways; adopting landscape-level planning.
- **Offsets and Restoration:** Compensatory grassland restoration to balance habitat lost.
- **Community Involvement:** Local communities can monitor bird mortality and participate in conservation programs.
- **Research Investment:** More empirical studies needed on bird-solar interactions in India, filling current knowledge gaps.

Critical Perspectives

Renewable energy is often assumed ecologically benign, but this masks uneven ecological burdens. Critics argue that solar expansion in deserts reflects a form of green colonialism, prioritizing climate goals over local biodiversity and livelihoods (Bindra, 2017) [1]. Grasslands, though rich in species, are consistently undervalued in policy frameworks, reinforcing biases that lead to their conversion (Vagh & Ratnu, 2024) [14]. A **just transition** must therefore extend beyond social equity to include ecological justice for non-human species.

Conclusion

India's solar revolution is indispensable for climate mitigation, but it cannot come at the expense of biodiversity. Avian survival, particularly of endangered species such as the Great Indian Bustard, highlights the urgent need for integrative planning. Policy reforms must mandate biodiversity-sensitive siting, enforce infrastructure modifications, and correct institutional biases that undervalue grasslands. By embedding avian conservation within the renewable energy agenda, India can achieve a transition that is not only low-carbon but also ecologically just.

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