

# A Comprehensive Review of India's Energy Scenario in the 21st Century

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## ABSTRACT

*India stands at a critical juncture in its energy evolution, balancing the dual imperatives of fueling rapid economic growth and mitigating climate change. This paper reviews India's energy landscape from the early 2000s to the present, analyzing the transition from a coal-hegemonic system to a diverse mix increasingly driven by renewables. As of late 2024, India has achieved an installed capacity exceeding 460 GW, with non-fossil sources constituting nearly 48% of the total. While policy interventions like the Electricity Act (2003) and the "Panchamrit" commitments at COP26 have accelerated renewable adoption, structural bottlenecks remain. This review critically examines the financial distress of distribution companies (DISCOMs), grid integration challenges, and the nascent storage infrastructure. Finally, it projects future pathways toward the 2030 non-fossil target of 500 GW and the ambitious 2070 Net Zero goal, concluding that while the trajectory is promising, the pace of grid modernization must match generation capacity additions.*

**Keywords:** - Energy Transition, Renewable Energy, Decarbonization, DISCOMs, Net Zero 2070, Energy Policy.

## 1. INTRODUCTION

The 21st century has witnessed a paradigm shift in the global energy narrative, with India emerging as a central player due to its sheer scale and developmental dynamism. As the world's third-largest energy consumer, India's energy decisions have global ramifications [1]. The country faces the "energy trilemma": ensuring energy security, maintaining affordability for a growing population, and achieving environmental sustainability. Historically reliant on fossil fuels, India has embarked on an aggressive transition strategy. The demand for power is projected to quadruple by 2047, necessitating a robust expansion of infrastructure that decouples growth from carbon emissions [2]. This paper provides a critical review of India's energy sector evolution from 2000 to the present, evaluates the efficacy of policy mechanisms, and analyzes the challenges hindering the transition toward the 2070 Net Zero target.

## 2. HISTORICAL CONTEXT (2000–2015): THE ERA OF COAL AND ACCESS

At the turn of the millennium, India's energy strategy was primarily focused on deficit reduction and access. The enactment of the **Electricity Act, 2003** was a watershed moment, delicensing generation and encouraging private participation [3]. During this period, coal-fired thermal power was the bedrock of India's energy security, accounting for over 70% of generation.

Policy efforts between 2000 and 2015 largely targeted rural electrification through schemes like the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), later subsumed under Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY). Renewable energy (RE) was a peripheral component until the launch of the **Jawaharlal Nehru National Solar Mission (JNNSM)** in 2010, which set an initial modest target of 20 GW by 2022—a target that was later revised aggressively upwards, signaling the first major policy pivot toward renewables [4].

## 3. CURRENT STATUS (2023–2024): THE GREEN SHIFT

As of late 2024, India's energy sector demonstrates a significant structural transformation. Data from the Central Electricity Authority (CEA) indicates that India's total installed power capacity has reached approximately **475 GW** [5]. A defining characteristic of this period is the rising share of non-fossil fuel capacity (including solar, wind, hydro, and nuclear), which now stands at approximately **48%** of the total installed base.

**Renewable Dominance:** Total renewable energy capacity (excluding large hydro) crossed **203 GW** by October 2024 [6]. Solar energy has emerged as the frontrunner with an installed capacity exceeding **94 GW**, driven by sharp cost reductions and policy incentives.

**Generation vs. Capacity:** despite high installed capacity, the actual generation mix remains skewed toward coal, which contributes nearly 70-75% of the electricity consumed due to its baseload nature, while renewables

contribute approximately 22% [5]. This disparity highlights the challenge of intermittency inherent in RE sources.

#### 4. RENEWABLE ENERGY GROWTH AND STRATEGIC INITIATIVES

The acceleration in RE deployment is underpinned by diverse technological and policy interventions.

- **Solar and Wind:** India now houses some of the world's largest solar parks (e.g., Bhadla, Pavagada). The recent launch of the **PM Surya Ghar: Muft Bijli Yojana** in 2024 aims to solarize 10 million households, decentralizing generation and reducing transmission losses [7].
- **Green Hydrogen:** The National Green Hydrogen Mission, with an outlay of ₹19,744 crore, targets a production capacity of 5 Million Metric Tonnes (MMT) by 2030, aiming to decarbonize hard-to-abate sectors like steel and refining [8].
- **Bioenergy:** While often overshadowed, bioenergy and waste-to-energy capacities have seen steady growth, critical for a circular economy approach.

#### 5. POLICY DRIVERS AND INTERNATIONAL COMMITMENTS

India's energy trajectory is heavily influenced by its climate diplomacy. At the COP26 summit in Glasgow (2021), Prime Minister Narendra Modi articulated the "**Panchamrit**" (five nectar elements) strategy:

1. Reach 500 GW non-fossil energy capacity by 2030.
2. Meet 50% of energy requirements from renewables by 2030.
3. Reduce total projected carbon emissions by 1 billion tonnes by 2030.
4. Reduce the carbon intensity of the economy by less than 45% by 2030.
5. Achieve the target of **Net Zero by 2070** [9].

Domestically, the **Energy Conservation (Amendment) Act 2022** facilitates the establishment of carbon markets and mandates the use of non-fossil sources for raw materials in industries. Furthermore, Production Linked Incentive (PLI) schemes for High-Efficiency Solar PV Modules and Advanced Chemistry Cell (ACC) Batteries are fostering domestic manufacturing ecosystems to reduce import reliance.

#### 6. CHALLENGES: THE 'ACHILLES HEEL' OF THE SECTOR

Despite impressive capacity additions, the sector faces entrenched structural challenges.

- **DISCOM Distress:** The financial health of state-owned Distribution Companies (DISCOMs) remains the weakest link. In FY 2023-24, Aggregate Technical and Commercial (AT&C) losses rose to **16.12%**, reversing previous gains [10]. Accumulated losses for DISCOMs have ballooned to over ₹6.9 trillion, limiting their ability to purchase power and invest in grid modernization.
- **Grid Integration and Storage:** As RE penetration increases, grid stability becomes precarious. The lack of adequate storage solutions (Pumped Storage Projects and Battery Energy Storage Systems) leads to curtailment of solar and wind power. The CEA estimates a requirement of **411 GWh** of energy storage capacity by 2031-32 to manage grid inertia [11].
- **Capital and Land:** Achieving the 2030 targets requires an estimated investment of \$1.2–1.6 trillion. Additionally, land acquisition for large-scale solar parks continues to face social and legal hurdles.

#### 7. FUTURE VISION (2030–2070)

Looking ahead, NITI Aayog's energy security scenarios suggest that for India to meet its 2070 Net Zero target, the power sector must be nearly decarbonized by 2050 [12].

- **2030 Outlook:** India is on track to meet the 500 GW non-fossil target, provided the pace of annual RE addition accelerates to ~50 GW per year.
- **2047 Aspirations:** By the centennial of its independence, India aims for "Energy Independence," implying minimal reliance on imported fossil fuels. This will require massive electrification of transport (EVs) and green hydrogen adoption.
- **2070 Net Zero:** The long-term transition will necessitate the phasing down of coal, which currently provides the baseload. This "Phase Down" vs. "Phase Out" debate remains central to India's developmental duality.

#### 8. CONCLUSION

India's energy transition is a globally significant endeavor, characterized by rapid renewable expansion and bold policy targets. The shift from 2000 to 2024 has been remarkable, moving from energy deficits to a surplus capacity scenario with a near 50% clean energy share. However, the path to 2070 is fraught with challenges, primarily financial insolvency in distribution and the technical complexities of grid integration. Success will

depend not just on adding gigawatts of generation, but on holistic reforms that fix the "leaky bucket" of distribution and foster a domestic innovation ecosystem for storage and green hydrogen.

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