Assignment

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Semester: 8th **Date:** 12/04/2025
Subject Name: Electrical Energy Conservation And Auditing **Subject Code:** ELO-413

Case Study: The Impact of Renewable Energy Policies on India's Energy Transition

- **Executive Summary:**

India faces the dual challenge of meeting rapidly growing energy demands while transitioning away from fossil fuels to combat climate change. Since 2015, the country has implemented ambitious renewable energy policies aiming to transform its energy landscape. This case study examines the effectiveness of these policies, their outcomes, key challenges, and lessons learned to evaluate India's progress in its energy transition journey.

India has emerged as a global leader in renewable energy expansion, with installed capacity growing from 35 GW in 2015 to over 175 GW by early 2025. Policy frameworks including the National Solar Mission, competitive auction systems, and financial incentives have driven substantial private investment. However, challenges around grid integration, land acquisition, and financing continue to present obstacles to achieving the country's ambitious target of 500 GW of non-fossil fuel capacity by 2030..

- **Introduction:**

India, the world's third-largest energy consumer, has historically relied on fossil fuels—particularly coal—to power its economic growth. As of 2015, coal accounted for approximately 70% of the country's electricity generation, with renewable energy contributing less than 15%. However, energy security concerns, rising pollution levels in major cities, international climate commitments, and falling costs of renewable technologies have prompted a significant policy shift toward clean energy..

Significance of India's Energy Transition

India's energy transition carries global significance for several reasons:

1. **Climate Impact**: As the world's third-largest emitter of greenhouse gases, India's energy choices directly impact global emissions trajectories.

2. **Scale and Replicability**: India's renewable energy models, if successful, provide templates for other developing economies.
3. **Economic Transformation**: The transition represents a major economic restructuring, affecting employment, manufacturing, and investment patterns.
4. **Energy Access**: India must balance clean energy transitions with expanding electricity access to millions still lacking reliable power.

Key Renewable Energy Policies (2015-2025)

National Solar Mission (Expanded in 2015)

Initially launched in 2010, the National Solar Mission saw significant expansion in 2015 when Prime Minister Narendra Modi increased the 2022 solar capacity target from 20 GW to 100 GW. The policy included:

- Dedicated solar parks to reduce land acquisition barriers
- Viability gap funding for projects in less sunny regions
- Net metering policies for rooftop solar installations
- Mandatory renewable purchase obligations for utilities

Outcomes: Solar capacity grew from approximately 3 GW in 2014 to over 70 GW by early 2025, making India the third-largest solar market globally. Solar tariffs fell dramatically from ₹8-9/kWh in 2014 to historic lows below ₹2/kWh by 2020, making solar power cheaper than coal in many instances.

National Wind-Solar Hybrid Policy (2018)

This policy promoted optimal utilization of transmission infrastructure and land by combining wind and solar resources at single locations. Key features included:

- Battery storage integration incentives
- Procurement through transparent bidding processes
- Technical requirements for grid integration
- Tax incentives for hybrid projects

Outcomes: By 2025, India had successfully implemented over 15 GW of hybrid projects, improving capacity utilization of transmission assets by 20-30% compared to standalone projects.

Production Linked Incentive (PLI) Scheme for Solar Manufacturing (2021)

To reduce dependency on imported solar modules (primarily from China), India implemented the PLI scheme with a budget of ₹24,000 crore (approximately $3.2 billion). The scheme offered:

- Financial incentives based on sales of domestically manufactured components
- Higher incentives for higher efficiency modules
- Support across the manufacturing value chain (polysilicon, wafers, cells, modules)

Outcomes: Domestic manufacturing capacity expanded from under 10 GW in 2021 to over 35 GW by 2025, reducing import dependence from 85% to approximately 50%.

Green Energy Corridors (Phases I & II)

Recognizing transmission as a key constraint, India invested heavily in dedicated green energy transmission corridors:

- Phase I (2015-2022): ₹43,000 crore ($5.8 billion) for interstate and intrastate transmission
- Phase II (2022-2027): ₹12,000 crore ($1.6 billion) focused on renewable-rich states

Outcomes: Enhanced grid reliability and reduced curtailment of renewable energy from 9.5% in 2019 to 3.2% by 2025, enabling effective integration of variable renewable energy sources.

National Hydrogen Mission (2021)

Launched to position India as a global hub for green hydrogen production and export, the mission included:

- Production targets of 5 million tonnes of green hydrogen by 2030
- Mandatory purchase obligations for refineries and fertilizer companies
- Viability gap funding for electrolyzer manufacturing
- Tax incentives for green hydrogen production

Outcomes: By early 2025, India had commissioned approximately 1.5 GW of electrolyzer capacity and established several demonstration projects across industrial applications.

Case Analysis: Key Impact Areas

Economic Impacts

1. **Investment Growth**: Renewable energy attracted over $80 billion in investments between 2015-2025, creating a vibrant clean energy economy.
2. **Job Creation**: The sector generated approximately 1.3 million direct and indirect jobs by 2025, with solar deployment being the largest employer.
3. **Cost Reductions**: The levelized cost of electricity (LCOE) from renewables declined by:
   - Solar PV: 85% reduction (2015-2025)
   - Wind: 40% reduction (2015-2025)
   - Battery storage: 75% reduction (2018-2025)
4. **Manufacturing Ecosystem**: Domestic manufacturing expanded substantially, though significant imports continue. India established capabilities across wind components and solar modules, though silicon wafer and cell production remained limited.

Environmental Impacts

1. **Emissions Avoidance**: Renewable deployment avoided approximately 325 million tonnes of CO_2 emissions between 2015-2024.
2. **Air Quality Improvements**: Major cities experienced measurable reductions in particulate matter as coal plant operations reduced in favor of renewables.
3. **Land Use Challenges**: Utility-scale renewables faced increasing scrutiny over land conversion issues, particularly in agricultural areas and ecologically sensitive regions.
4. **Water Conservation**: Renewable energy saved an estimated 1.8 billion cubic meters of water annually by 2024 compared to equivalent coal-based generation.

Power System Transformation

1. **Grid Integration**: The share of variable renewable energy in the electricity mix grew from under 5% in 2015 to approximately 25% by early 2025, necessitating significant system flexibility improvements.
2. **Reliability and Balancing**: Initial integration challenges caused grid stability issues, but investments in forecasting, balancing markets, and flexible operations protocols reduced these problems over time.
3. **Energy Access**: Distributed renewable energy solutions provided electricity to over 18,000 previously unelectrified villages, though reliability challenges remained.
4. **Market Design Evolution**: Power markets evolved to accommodate renewables through:
    - Introduction of real-time markets (2020)
    - Ancillary services market reforms (2022)
    - Green day-ahead market (2023)

Critical Challenges and Policy Responses

Financial Challenges

Challenge: Distribution companies (DISCOMs) with poor financial health delayed payments to renewable generators, creating liquidity issues for developers.

Policy Response: The government implemented payment security mechanisms (2019) requiring DISCOMs to open letters of credit for power purchases and established a payment clearinghouse (2021) to prioritize renewable energy payments.

Outcome: While delayed payments improved somewhat (from average delays of 8-9 months to 4-5 months), the structural financial health of DISCOMs remained a persistent concern.

Land Acquisition Issues

Challenge: Land availability and acquisition delays became significant bottlenecks, particularly for large solar parks.

Policy Response: The government promoted:

- Dual-use agricultural solar (agrivoltaics)
- Floating solar on reservoirs and canals
- Repurposing defunct coal mining areas for renewable projects

Outcome: By 2025, innovative land use models had facilitated approximately 12 GW of projects that might otherwise have faced significant delays.

Grid Integration and Flexibility

Challenge: Managing increasing proportions of variable renewable energy strained grid operations.

Policy Response:

- Forecasting regulations with graduated penalties (2018)
- Must-run status for renewables (2020)
- Flexibility retrofits for existing coal plants (2021-2025)
- Storage obligation policies (2023)

Outcome: Grid integration improved substantially, enabling higher renewable penetration without reliability compromises, with curtailment rates declining despite higher renewable penetration.

Manufacturing Capacity

Challenge: Dependence on imported equipment, particularly from China, created supply chain vulnerabilities and trade balance concerns.

Policy Response: Beyond the PLI scheme, India implemented:

- Basic customs duty on solar imports (2022)
- Approved list of models and manufacturers (ALMM) requirements
- Research funding for indigenous technology development

Outcome: Domestic manufacturing grew significantly but continued to lag behind deployment needs, with limited success in upstream manufacturing (polysilicon, ingots, wafers).

Lessons Learned

Effective Policy Elements

1. **Competitive Bidding Mechanism**: Transparent auction designs drove rapid cost discovery and tariff reductions, attracting global capital.
2. **Long-term Policy Certainty**: States with consistent renewable policies (Gujarat, Rajasthan, Tamil Nadu) attracted disproportionately higher investments compared to states with frequent policy reversals.
3. **Project De-risking**: Government interventions to reduce developer risks—such as payment security mechanisms and solar park infrastructure—proved essential for attracting competitive capital.
4. **Adaptive Regulatory Frameworks**: Regulators that evolved market designs to accommodate renewables (like forecasting allowances and balancing mechanisms) facilitated higher renewable penetration.

Policy Shortcomings

1. **Inadequate DISCOM Reforms**: Despite multiple reform attempts, fundamental DISCOM financial health issues remained unresolved, creating persistent sectoral risks.
2. **Frequent Policy Changes**: Retroactive policy changes in some states undermined investor confidence and raised risk premiums.
3. **Siloed Planning**: Insufficient coordination between renewable deployment and transmission planning caused periodic bottlenecks.
4. **Insufficient Focus on Flexibility**: Early policies emphasized capacity additions without adequate attention to system integration requirements.

Future Outlook and Recommendations

Emerging Trends

1. **Storage Integration**: Battery storage and pumped hydro projects are increasingly paired with renewables to provide firm, dispatchable power.

2. **Decentralization**: The share of distributed generation is growing, with commercial and industrial consumers driving behind-the-meter solar-plus-storage adoption.
3. **Sector Coupling**: Electrification of transport, heating, and industrial processes is creating new renewable energy demand vectors.
4. **Green Hydrogen Economy**: Emerging applications in refining, ammonia production, and potentially steel manufacturing create new pathways for renewable energy utilization.

Policy Recommendations

1. **Integrated Planning Framework**: Establish a national integrated resource planning process that coordinates generation, transmission, and distribution investments.
2. **Financial Sustainability Reforms**: Implement comprehensive DISCOM reforms focused on technical loss reduction, cost-reflective tariffs, and operational efficiency.
3. **Flexibility-First Approach**: Reorient policies to value and compensate grid flexibility alongside capacity additions.
4. **Just Transition Mechanisms**: Develop comprehensive policies for managing socioeconomic impacts in coal-dependent regions during the energy transition.
5. **Climate Resilience**: Incorporate climate vulnerability assessments into renewable energy infrastructure planning, recognizing increasing extreme weather risks.
6. **R&D Ecosystem Development**: Increase domestic research and development funding to develop India-specific renewable energy innovations adapted to local conditions.

Conclusion

India's renewable energy policies have catalyzed impressive clean energy deployment over the past decade, demonstrating the potential for developing economies to leapfrog to cleaner energy systems. The combination of ambitious targets, competitive market mechanisms, and strategic public investments has transformed India into a global renewable energy leader.

However, the transition remains incomplete. Persistent challenges in financial sustainability, manufacturing capabilities, and system integration must be addressed to meet India's 2030 renewable energy targets and net-zero ambitions. The country's experience highlights that successful energy transitions require not just deployment policies but comprehensive approaches addressing the entire energy ecosystem—from supply chains to market design, workforce development, and social equity.

The coming decade will determine whether India can build on its initial renewable energy successes to complete a comprehensive transformation of its energy system. The lessons from its journey offer valuable insights for other emerging economies facing similar energy transition challenges.

References

1. Ministry of New and Renewable Energy, Government of India, Annual Reports (2015-2024)
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Context and Background

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