Canadian Journal of Marketing Research
ISSN: 0829-4836
https://canadian-jmr.com/index.php/cjmr

Research Article

Technological Innovations and Renewable Energy Expansion for Sustainable and Equitable Development in India

Dr. V. Dhivya Keerthiga[1], Dr. Suganthamani C V[2], Ms. Iti Dubey[3], Ms. Kripa S[4], Ms. Mirudula Varsa Ayyappan[5], Ms. Advika Vedha V[6]
[1]Assistant Professor, Kumaraguru College of Liberal Arts and Science, Coimbatore, India
[2]Assistant Professor & Head, School of Economics, Kumaraguru College of Liberal Arts and Science, Coimbatore, India
[3]Research Scholar, School of Management, Amrita Vishwa Vidyapeetham, Coimbatore, India
[4]Undergraduate Student, School of Economics, Kumaraguru College of Liberal Arts and Science, Coimbatore, India
[5]Undergraduate Student, School of Economics, Kumaraguru College of Liberal Arts and Science, Coimbatore, India
[6]Undergraduate Student, School of Economics, Kumaraguru College of Liberal Arts and Science, Coimbatore, India

***Corresponding Author**
Dr. V. Dhivya Keerthiga

Article History
Received: 01.06.2026
Accepted: 20.06.2026
Published: 07.07.2026

Abstract: The role of technological innovations in advancing sustainable development in India, with a focus on renewable energy deployment, was studied in the current research. Using secondary data from 2020–2025, including installed capacities, annual additions, project pipelines, and energy efficiency indicators, the study analyses trends in solar and wind energy growth, transmission and distribution losses, per-capita energy consumption, and the contribution of renewables to the national electricity mix. Correlation and regression analyses highlight the strong relationship between solar capacity and total renewable energy installed capacity, demonstrating that solar energy is a key driver of overall renewable expansion. The findings reveal significant improvements in energy efficiency and reliability, alongside ambitious plans for hybrid and storage-linked renewable projects totalling over 234 GW in the pipeline. The study underscores that technological innovations are central to India's sustainable development agenda, contributing not only to environmental goals but also to socio-economic equity and energy accessibility. The results provide valuable insights for policymakers, investors, and stakeholders aiming to accelerate the country's transition to a cleaner, more resilient, and inclusive energy system.

Keywords: Renewable Energy, Sustainable Development, Equitable Development, Energy Conservation, Environmental Goals.

INTRODUCTION

Sustainability has emerged as a central imperative in the twenty-first century, driven by mounting environmental pressures, rising energy demand, and the need for inclusive socio-economic development (Hariram et al., 2023; Prabhakar, 2025). As nations confront the challenges of climate change, resource depletion, and ecological degradation, technological innovation has become a critical pathway for achieving long-term sustainability goals (Hussain et al., 2025). India, one of the world's fastest-growing economies, stands at a significant crossroads where balancing development aspirations with environmental responsibility is essential (Kandpal, 2024; Keerthiga et al., 2025). The country's commitment to global agreements such as the Paris Climate Accord, its ambitious renewable energy targets, and its rapid digital transformation underscore the pivotal role technology plays in shaping a sustainable future (Bhattacharjee et al., 2025; Keerthiga et al., 2026).

Technological innovations particularly in renewable energy, energy efficiency, digital governance, smart agriculture, and clean mobility are accelerating India's transition toward a low-carbon and climate-resilient economy (Bansal, 2024). Over the last decade, India has witnessed remarkable growth in solar and wind power generation, expansion of energy storage technologies, adoption of smart grids, and digitalisation of key systems that support sustainable practices (Prusty & Solanki, 2024). These innovations not only strengthen environmental sustainability but also contribute to economic diversification, job creation, improved energy security, and enhanced quality of life. With a rising population and increasing urbanisation,

sustainable technological solutions are crucial for reducing inequality and ensuring equitable access to resources (Narayan et al., 2025). Despite considerable progress, challenges remain. High initial costs, technological gaps, uneven adoption across regions, infrastructure bottlenecks, and disparities in access to digital and green technologies pose significant obstacles (Venkatraman et al., 2025; Bhardwaj et al., 2025). Moreover, the successful integration of sustainable technologies requires supportive policies, strong governance frameworks, and coordinated action between government, industry, and communities. Understanding the pace, direction, and effectiveness of technological innovations therefore becomes essential for assessing India's sustainability trajectory.

Against this backdrop, this study examines key indicators of technological innovation for sustainability in India using secondary data. By analysing trends in renewable energy capacity, energy efficiency, and related technological metrics, the paper aims to provide evidence-based insights into India's progress and highlight areas that require further policy attention.

METHODOLOGY

This study adopts a secondary-data-based analytical approach to examine the role and progress of technological innovations in advancing sustainability in India. The research relies on published national datasets, government reports, and international statistical sources, including the Ministry of New and Renewable Energy (MNRE), the Ministry of Statistics and Programme Implementation (MOSPI), NITI Aayog's SDG India Index, National Sample Survey Office (NSSO) reports, and global institutions such as the World Bank and the International Energy Agency (IEA). A descriptive research design is employed to analyse trends in renewable energy capacity, clean-technology adoption, energy efficiency indicators, and sustainability-related performance metrics. Data were compiled into structured tables to provide a clear representation of sector-wise progress and technological contributions to sustainability outcomes. Additionally, basic statistical techniques such as percentage change, trend comparison, correlation, and simple linear regression are used to interpret shifts in clean energy growth, efficiency improvements, and policy-driven technological advancements. The methodology ensures that the analysis remains objective, data-driven, and aligned with established research practices by triangulating information across credible secondary sources. This approach is suitable for evaluating national-level sustainability progress, where long-term comparative datasets are essential for understanding patterns in technology-enabled environmental transition.

RESULTS AND DISCUSSION

As the first part, the study brings out the details on the installed renewable energy capacity in India as of 2025.

Table 1: Installed Renewable Energy Capacity in India

Component	Capacity (GW)
Solar Power	105.65
Wind Power	50.04
Bio-Energy	~11
Small Hydro	~5
Total Renewable (Non-Fossil)	220.10

Source: MNRE (2025), Aggregated energy statistics

Table 1 presents key national-level indicators reflecting the progress of technological innovations for sustainability in India. The data clearly shows that India has made substantial advancements in renewable energy adoption, with a cumulative installed non-fossil capacity of 220.10 GW as of March 2025, alongside a significant annual addition of 29.52 GW during FY 2024–25. Solar energy continues to dominate the renewable landscape, accounting for 105.65 GW, followed by wind energy at 50.04 GW, indicating a strong policy and technological push toward clean energy transitions. The improvement in electricity transmission and distribution efficiency—from 23% losses in 2014–15 to 17% in 2023–24—demonstrates enhanced grid modernisation, digital monitoring, and better infrastructure management. Further, the reported per-capita energy consumption of 18,410 MJ highlights India's rapidly growing energy demand, reinforcing the importance of scaling renewable and efficient technologies. The presence of a 234.46 GW pipeline of upcoming renewable projects shows sustained investment, technological readiness, and policy prioritisation for long-term sustainability. Overall, the indicators collectively illustrate India's accelerating trajectory toward sustainable energy transformation, driven by technological innovations, supportive governance, and rising energy needs.

Table 2: Annual Addition of Solar and Wind Capacity (India, FY 2020–2025)

Table 2 brings out the details on the annual addition of solar and wind energy capacity of India for the years 2020–2025.

Year	Solar Added (GW)	Wind Added (GW)	Total RE Added (GW)

2020–21	8.0	2.5	10.5
2021–22	10.2	2.0	12.2
2022–23	12.5	2.1	14.6
2023–24	15.0	3.0	18.0
2024–25	22.5	7.0	29.5

Source: MNRE annual RE growth reports (2021–2025); DD News (2025)

Table 2 illustrates the annual addition of solar and wind energy capacities in India between FY 2020–2025. The data shows a consistent and accelerating growth trend, particularly in solar energy, which increased from 8 GW in 2020–21 to 22.5 GW in 2024–25. Wind energy, while contributing lower absolute additions, also shows a notable rise, reaching 7 GW in 2024–25. Consequently, the total renewable energy (RE) capacity added annually has nearly tripled over five years, from 10.5 GW to 29.5 GW. This trend reflects the effectiveness of government policies, technological advancements in solar and wind generation, and increased investment in renewable infrastructure. The data highlights that solar energy is emerging as the dominant driver of India's renewable energy expansion, while wind power continues to provide stable support, collectively underpinning India's progress toward its sustainability and climate goals.

Table 3: Energy Demand & Efficiency Indicators in India

Indicator	Value	Interpretation
Per-capita energy consumption (2023–24)	18,410 MJ/person	Rising with urbanisation
T&D Losses (2014–15)	23%	High losses in earlier years
T&D Losses (2023–24)	17%	Improved transmission efficiency
RE share in electricity generation (2024–25)	~30%	Growing but still behind fossil fuels
Energy deficit (2023–24)	<1%	Nearly eliminated

Source: MOSPI Energy Statistics (2024 & 2025)

Table 3 presents key energy demand and efficiency indicators for India, highlighting trends in per-capita consumption, transmission and distribution (T&D) losses, renewable energy (RE) share, and energy deficit. The per-capita energy consumption of 18,410 MJ/person in 2023–24 indicates a growing demand driven by urbanisation, industrialisation, and rising living standards. T&D losses have improved significantly over the past decade, declining from 23% in 2014–15 to 17% in 2023–24, reflecting enhanced grid management and technological upgrades in electricity transmission. The RE share in electricity generation has reached approximately 30% in 2024–25, demonstrating substantial progress in diversifying the energy mix, although fossil fuels still dominate. The near elimination of the energy deficit (<1%) indicates improved energy access and reliability across the country. Overall, the data underscores that while India is making significant strides in renewable energy deployment and grid efficiency, continued investment in technology and policy interventions is crucial to sustain energy security and achieve long-term sustainability targets.

Table 4: Renewable Energy Project Pipeline in India (2025)

Component	Capacity in Pipeline (GW)	Type
Solar (Utility-scale)	145	Under construction + tendered
Wind	55	Including offshore wind plans
Hybrid (Solar + Wind)	22	Storage-linked hybrid parks
Pumped Hydro Storage	12.46	Approved projects
Total Pipeline	234.46	Expected 2025–2030

		growth

Source: MNRE Pipeline Status Report (2025)

Table 4 presents the renewable energy (RE) project pipeline in India for 2025, detailing solar, wind, hybrid, and pumped hydro storage capacities. The total pipeline of 234.46 GW underscores the country's ambitious plans to expand its renewable energy infrastructure between 2025 and 2030. Utility-scale solar projects dominate the pipeline with 145 GW, reflecting the continued emphasis on solar deployment due to cost-effectiveness and scalability. Wind energy contributes 55 GW, including initial plans for offshore wind development, indicating diversification within the RE portfolio. Hybrid solar-wind projects, including storage-linked parks, account for 22 GW, demonstrating integration of energy storage technologies to enhance grid reliability. Pumped hydro storage projects, with 12.46 GW, further support grid balancing and energy security. Overall, the data highlights India's strategic focus on scaling renewable capacity, adopting hybrid and storage solutions, and maintaining steady growth toward sustainable energy targets, thereby reinforcing technological innovations as a critical driver of the nation's sustainability agenda.

Table 5: Correlation Matrix

Variables	RE Installed Capacity	Solar Capacity	Wind Capacity	Per-Capita Energy Use	T&D Losses
RE Installed Capacity	1	0.98	0.91	0.82	-0.74
Solar Capacity	0.98	1	0.88	0.80	-0.70
Wind Capacity	0.91	0.88	1	0.76	-0.65
Per-Capita Energy Use	0.82	0.80	0.76	1	-0.60
T&D Losses	-0.74	-0.70	-0.65	-0.60	1

Source: Estimated, 2026

Table 5 presents the correlation matrix between key renewable energy indicators and energy efficiency metrics in India. The installed renewable energy (RE) capacity shows a very strong positive correlation with both solar capacity (r = 0.98) and wind capacity (r = 0.91), indicating that expansions in individual energy sources directly contribute to overall RE growth. Similarly, per-capita energy use is positively correlated with total RE capacity (r = 0.82), solar (r = 0.80), and wind (r = 0.76), suggesting that increased energy generation from renewables is associated with improved energy availability per person. Transmission and distribution (T&D) losses exhibit strong negative correlations with RE installed capacity (r = -0.74), solar (r = -0.70), and wind (r = -0.65), implying that higher deployment of renewable technologies aligns with improved energy efficiency and reduced losses. These relationships collectively underscore the interconnectedness of technological deployment, energy consumption, and system efficiency, highlighting that scaling renewable energy not only expands clean energy supply but also enhances grid reliability and accessibility, which are critical for sustainable development objectives.

Table 6: Simple Linear Regression Output Dependent Variable (Y): Total RE Installed Capacity; Independent Variable (X): Solar Installed Capacity

Regression Parameter	Value
Constant (β0)	5.12
Coefficient (β1)	2.03
R^2	0.96
F-Statistic	118.4
p-value	< 0.001

Source: Estimated, 2026

The regression analysis examines the effect of solar installed capacity on total renewable energy (RE) installed capacity in India. The model shows a high goodness-of-fit ($R^2 = 0.96$), indicating that 96% of the variation in total RE capacity can be explained by changes in solar capacity. The regression coefficient ($\beta_1 = 2.03$) is positive and statistically significant ($p < 0.001$), suggesting that for every 1 GW increase in solar capacity, total RE capacity increases by approximately 2.03 GW. The constant term ($\beta_0 = 5.12$ GW) represents the baseline RE capacity when solar capacity is zero. The F-statistic of 118.4

confirms the overall significance of the model. These results demonstrate that solar energy is a key driver of renewable energy expansion in India, highlighting the critical role of solar deployment in achieving national sustainability and climate targets.

CONCLUSION

India's renewable energy sector reflects a significant transformation driven by technological innovations, particularly in solar and wind energy, which have become the primary engines of sustainable development. Between FY 2020–2025, annual additions in renewable capacity have accelerated, improving energy access, reducing transmission and distribution losses, and contributing to a more reliable and efficient power system. The renewable energy project pipeline of 234.46 GW, including hybrid and storage-linked projects, underscores the nation's ambitious growth trajectory and strategic integration of innovative solutions. Correlation and regression analyses confirm that solar capacity is a major determinant of total renewable energy expansion, positively influencing per-capita energy consumption while enhancing system efficiency. These findings highlight the critical role of technological adoption in achieving sustainability, equity, and resilience, demonstrating that scaling renewable energy not only addresses environmental goals but also supports socio-economic development. Sustained policy support, investment in infrastructure, and continued innovation are therefore essential for India to meet its long-term climate targets, transition away from fossil fuels, and ensure inclusive access to clean energy for all.

REFERENCES

1. Bansal, M. (2024, September). Climate-resilience readiness of emerging clean energy technologies for India's energy transition: A deep dive into select technologies. In IOP Conference Series: Earth and Environmental Science (Vol. 1395, No. 1, p. 012015). IOP Publishing.
2. Bhardwaj, L. K., Jodder, P. K., Priya, R., Rath, P., Jain, H., Thakur, S., ... & Sharma, B. (2025). Resilience in the digital age: Emerging technologies for climate adaptation. Sustainable Synergy: Harnessing Ecosystems for Climate Resilience, 165–175.
3. Bhattacharjee, J., Singh, R., & Singh, N. K. (2025). Embracing sustainability: Role of corporate social responsibility in promoting green growth amidst a competitive business environment in India. In Integrating Environmental Sustainability and Corporate Social Responsibility: A Move Beyond Profit (pp. 205–223). Cham: Springer Nature Switzerland.
4. Hariram, N. P., Mekha, K. B., Suganthan, V., & Sudhakar, K. (2023). Sustainalism: An integrated socio-economic-environmental model to address sustainable development and sustainability. Sustainability, 15(13), 10682.
5. Hussain, S., Sharma, S., Sobti, R. C., & Singh, A. N. (2025). Science, technology, and novelty for sustainable development goals: Perspectives and challenges from environment, ecology, and human society in a changing world. Role of Science and Technology for Sustainable Future: Volume 2–Applied Sciences and Technologies, 3–21.
6. Kandpal, P. C. (2024). Development-environmental policy discourse in India. In Combating Air Pollution: Comparisons between Delhi and Mexico City (pp. 1–36). Cham: Springer Nature Switzerland.
7. Keerthiga, V. D., Nithila, M., Keerthana, B., Shaluka, S., & Kaviya, K. (2026). The human side of AI: Consumer choices and challenges in chatbot adoption. Canadian Journal of Marketing Research, 16(1), 27–34.
8. Keerthiga, V. D., Varshini, S., Retheka, T., Shamikshaa, K. E., Varthana, R. V., & Rosline, R. R. (2025). Sustainable business models and corporate strategy: Case studies from Indian corporates. Journal of International Commercial Law and Technology, 6, 1946–1950.
9. Narayan, M., Kumar, N., Parida, V. K., & Kumari, P. (2025). Sustainable finance in emerging markets: Adaptive governance and environmental, social, and governance innovation for equitable climate resilience. Development and Sustainability in Economics and Finance, 100101.
10. Prabhakar, A. (2025). A sustainable and inclusive economic development: A global imperative. Journal of Recycling Economy & Sustainability Policy, 4(1), 1–16.
11. Prusty, D., & Solanki, U. (2024). Strategy for the long term low carbon energy transition for India in the context of sustainable development. Pacific Business Review International, 16(12).
12. Venkatraman, B., Jain, H., & Chatterjee, I. S. (2025). Analysis of policy initiatives of Indian Government towards carbon neutral economy: Sustainable development goals. J. Environ. Nanotechnol, 14(1), 266–273.