iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** V **Month of publication:** May 2026

DOI: https://doi.org/10.22214/ijraset.2026.82581

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue V May 2026- Available at www.ijraset.com

Green Technology and Sustainable Development in India: Progress, Challenges, and the Role of Industries

Amey Pingale
Assistant professor, K.T.H.M. college, Nashik, Maharashtra

Abstract: ***This research paper provides a comprehensive review of sustainable development initiatives in India, focusing on the critical role of green technology (GT) and renewable energy (RE) in achieving the 2030 Sustainable Development Goals (SDGs). By synthesizing a systematic review of 40 articles on Indian sustainability initiatives with global technological frameworks such as Industry 4.0, the study evaluates India's current progress across various sectors, including sustainable cities, urban rail, and rural solar energy. The analysis identifies significant milestones in the adoption of feasible green technologies like solar PV and biogas, while also highlighting critical research gaps in social SDGs such as gender equality and reduced inequality. Key findings suggest that while technological feasibility is advancing, successful long-term adoption depends on "institutional work" and the alignment of national policies with international green growth standards.***
Keywords: Sustainable Development Goals, industry, energy, industries

I. INTRODUCTION

Sustainable development is defined as progress that meets contemporary needs without compromising the ability of future generations to meet theirs. In the face of a mounting global climate crisis—where fossil fuels currently account for over 75% of greenhouse gas emissions—the transition to low-carbon economies has become a global imperative. This vision is encapsulated in the 17 Sustainable Development Goals (SDGs) adopted by UN members in 2015, specifically Goal 7 (Clean Energy) and Goal 13 (Climate Action).

Green technology (GT) and renewable energy (RE) are acknowledged as primary catalysts for this transition, offering tools for pollution control, energy efficiency, and sustained economic growth. Concurrently, the fourth industrial revolution is transforming the technological landscape through digitalization, smart systems, and the Internet of Things (IoT), providing a backbone for modern sustainable manufacturing.

India has emerged as a key player in this arena, recognized as one of the top-10 renewable-attractive economies globally. Significant progress has been made in sectors such as sustainable urban rail, groundwater management, and decentralized rural energy systems like biogas. However, systematic reviews indicate that research on India's sustainability initiatives remains limited, with several SDGs related to social equality and responsible consumption remaining largely unexplored. Furthermore, many early initiatives, particularly in forestry, faced challenges regarding long-term economic sustainability.

This paper aims to bridge these gaps by synthesizing existing literature on Indian initiatives within the context of global technological drivers. It evaluates how the integration of Industry and green innovations can address current barriers and identifies the most promising "niches" for future research and development to ensure India's long-term sustainable growth.

II. METHODOLOGY

This study employs a systematic review and qualitative synthesis of existing research to evaluate the intersection of sustainable development and green technology in India. The research design is structured around a three-pillar thematic framework that transitions from the global strategic context of renewable energy to specific technological drivers like Industry 4.0, and finally to localized Indian sectoral progress. Data collection involved identifying and reviewing peer-reviewed articles and government reports published, focusing on key Sustainable Development Goals (SDGs).

©IJRASET: All Rights are Reserved

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue V May 2026- Available at www.ijraset.com

III. LITERATURE REVIEW

The following literature review synthesizes current research on sustainable development and green technology, transitioning from global frameworks to specific initiatives within the Indian landscape.

1) The Global Strategic Context and Green Energy

Global discourse has increasingly framed green energy as a strategic imperative for sustainable development. The transition away from fossil fuels—which currently account for over 75% of global greenhouse gas emissions—is essential for meeting the 2030 Agenda and the Paris Agreement targets.(Caglar & Dastan, 2023)

Green technologies (GT) and renewable energy (RE) are widely recognized as catalysts for energy efficiency and tools for combating environmental degradation while simultaneously fostering economic growth. Recent studies in the top-10 renewable economies demonstrate that GT and RE consumption significantly contribute to ecosystem sustainability, although trade can sometimes increase the ecological deficit. (Zhironkin & Cehlár, 2023)

2) Technological Drivers: Green Tech and Industry 4.0

The Fourth Industrial Revolution, or Industry 4.0, serves as a major technological driver for achieving the Sustainable Development Goals (SDGs). This revolution is built on digitalization, smart systems, and the Internet of Things (IoT), transforming enterprises into smart and sustainable entities. (Caglar & Dastan, 2023)

Information and communication technology is driving innovation and efficiency across all sectors, providing the necessary potential to share information and create new sustainable opportunities. Furthermore, specific "feasible" green technologies such as solar photovoltaic (PV), wind energy, and biogas have emerged as practical tools for increasing resource efficiency without increasing carbon emissions. (Berawi, 2019)

3) The Indian Landscape: Progress and Sectoral Initiatives

A systematic review of literature focused on India reveals significant progress in several key sectors:

- Sustainable Infrastructure: Research has highlighted the evolution of sustainable urban rail systems and the modernization of bus services, such as in Patna, which evaluate quality parameters to improve public transit efficiency. (Androniceanu & Sabie, 2022)
- Energy and Rural Electrification: India shows vast potential for decentralized energy, particularly through biogas, with a capacity for an estimated 12 million plants that convert agricultural waste into fuel and fertilizer. Additionally, micro-solar energy systems are playing a vital role in the sustainable development of rural areas like North East India. (Shafiei & Abad, 2017)
- Resource Management: The application of geoinformatics for groundwater potential mapping in Southern India has become a critical tool for sustainable water management, addressing the targets of SDG 6. (Choudhuri, 2019)

IV. IDENTIFIED RESEARCH GAPS AND CHALLENGES

Despite these advancements, critical gaps remain in the Indian research landscape. Most existing literature focuses on environmental and economic goals, leaving social SDGs—such as gender equality, reduced inequality, and responsible consumption—largely unexplored. Furthermore, the transition to green technology is often hindered by "innovative uncertainties" and a lack of regulatory adoption. Research emphasizes that technological feasibility alone is insufficient; green-tech ventures must engage in "institutional work" to influence government policies and establish the legitimacy necessary for long-term diffusion. Additionally, early forestry projects under the Clean Development Mechanism (CDM) in India were found to be economically unsustainable, highlighting the need for better alignment between technology selection and localized country-specific strengths.

V. DISCUSSION

The integration of green technology (GT) and renewable energy (RE) in India presents a complex landscape of significant progress balanced against systemic challenges. As one of the top-10 renewable-attractive economies globally, India is at a critical juncture where technological innovation must be matched by institutional and social evolution to achieve its 2030 Sustainable Development Goals (SDGs).

A. The Positive Impact: Progress and Potential:

India has demonstrated remarkable initiative in several "green" sectors that directly contribute to both economic and environmental sustainability:

©IJRASET: All Rights are Reserved

1) Renewable Energy Milestones: India's potential for decentralized energy is vast, with an estimated capacity for 12 million biogas plants. These systems provide a double benefit by utilizing agricultural waste to produce both fuel and high-quality fertilizer. (Shafiei & Abad, 2017)
2) Sustainable Infrastructure: Significant advancements have been made in urban rail and sustainable bus services in cities like Patna, which serve as models for reducing the carbon footprint of India's rapidly growing urban population.
3) Rural Empowerment: Innovative designs in micro-solar energy systems are actively facilitating sustainable development in remote regions like North East India, providing essential electrification that supports local economies. (Habanik, Grencikova, & Krajco, 2019)
4) Natural Resource Management: The application of geoinformatics for groundwater potential mapping in Southern India is a critical step toward ensuring water security—a vital component of SDG 6.

B. The Negative Impact: Challenges and Gaps:

Despite these successes, several "brown" legacies and systemic hurdles remain:

1) Economic Unsustainability of Early Projects: A review of selected Forestry Clean Development Mechanism (CDM) projects in India revealed that many were economically unsustainable and relied on plant species that had adverse ecological and social impacts over the long term.
2) Neglected Social SDGs: While environmental and economic goals receive significant attention, research on India's progress in "social niches"—such as gender equality, reduced inequality, and responsible consumption—remains critically limited. (Choudhuri, 2019)
3) Technological and Regulatory Barriers: The adoption of green innovation is often hindered by a lack of "institutional work". For technologies to be successful, ventures must do more than prove technical feasibility; they must actively influence government policies to establish legitimacy and avoid regulatory hurdles. (Hall, Matos, & Bachor, 2017)
4) Industrial Pollution: Rapid industrialization along major riverbanks like the Yamuna and Kosi continues to pose severe challenges to environmental protection and sustainable management. (Choudhuri, 2019)

a) Sector-Specific Innovations and Water Security

Beyond energy production, India’s sustainable development is increasingly tied to technological interventions in natural resource management and infrastructure. For instance, the use of geoinformatics for groundwater potential mapping in Southern India has become a vital tool for ensuring water security, directly addressing the targets of SDG 6. Similarly, the modernization of urban transport through sustainable bus services in mid-sized cities like Patna and the expansion of urban rail systems across emerging Indian metros demonstrate a shift toward resource-efficient public infrastructure. These localized technological applications—such as micro-solar energy systems specifically designed for the rural North East show that "frugal innovation" tailored to India's unique geographic and social needs is as critical as large-scale high-tech projects for achieving broad-based sustainability.

b) The Role of Digitalization and Future Governance

The transition toward a green economy in India is further accelerated by the principles of Industry 4.0, which leverages digitalization, smart manufacturing, and information technology to minimize waste and maximize resource efficiency. This digital transformation is not merely an industrial upgrade but a strategic necessity for achieving SDG targets related to climate action (Goal 13) and affordable energy (Goal 7). However, the successful integration of these technologies into the national economy requires a robust framework for international cooperation and updated legislative acts that follow recognized global standards. To sustain current momentum, India must prioritize increasing public and private investment in clean energy while simultaneously addressing the lack of research in social "niches" like gender equality and reduced inequality to ensure that the technological revolution leaves no one behind.

c) The Labor Paradigm Shift and Digital Competencies

A critical yet often overlooked dimension of India’s transition to a green economy is the shifting demand in the labor market. Historically, India’s industrial sector has benefited from a large pool of low-skilled labor; however, the integration of Industry 4.0 and green manufacturing processes is rendering traditional manual roles obsolete. As manufacturing becomes increasingly digitized and data-driven, there is an urgent need to bridge the "digital skill gap" to ensure that the workforce remains competitive.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

This transition poses a significant challenge: without proactive national vocational training programs focused on green-tech competencies, the technological revolution risks exacerbating existing social inequalities, contradicting the "leave no one behind" philosophy of the 2030 Agenda.

d) Regulatory Alignment and Green Entrepreneurship

Furthermore, the success of green innovation in India depends heavily on the ability of entrepreneurs to navigate and influence the country's complex legislative landscape. While many Indian startups have proven the technological feasibility of localized solutionssuch as advanced water purification or sustainable forestry management—the diffusion of these technologies often stalls due to regulatory "lock-ins" and high institutional hurdles. The discussion must therefore emphasize the necessity of "institutional work," where green-tech ventures actively collaborate with policymakers to establish new standards and legitimacy. Only by aligning niche technological breakthroughs with national environmental regulations can India transform experimental sustainability projects into scalable, market-ready national standards.

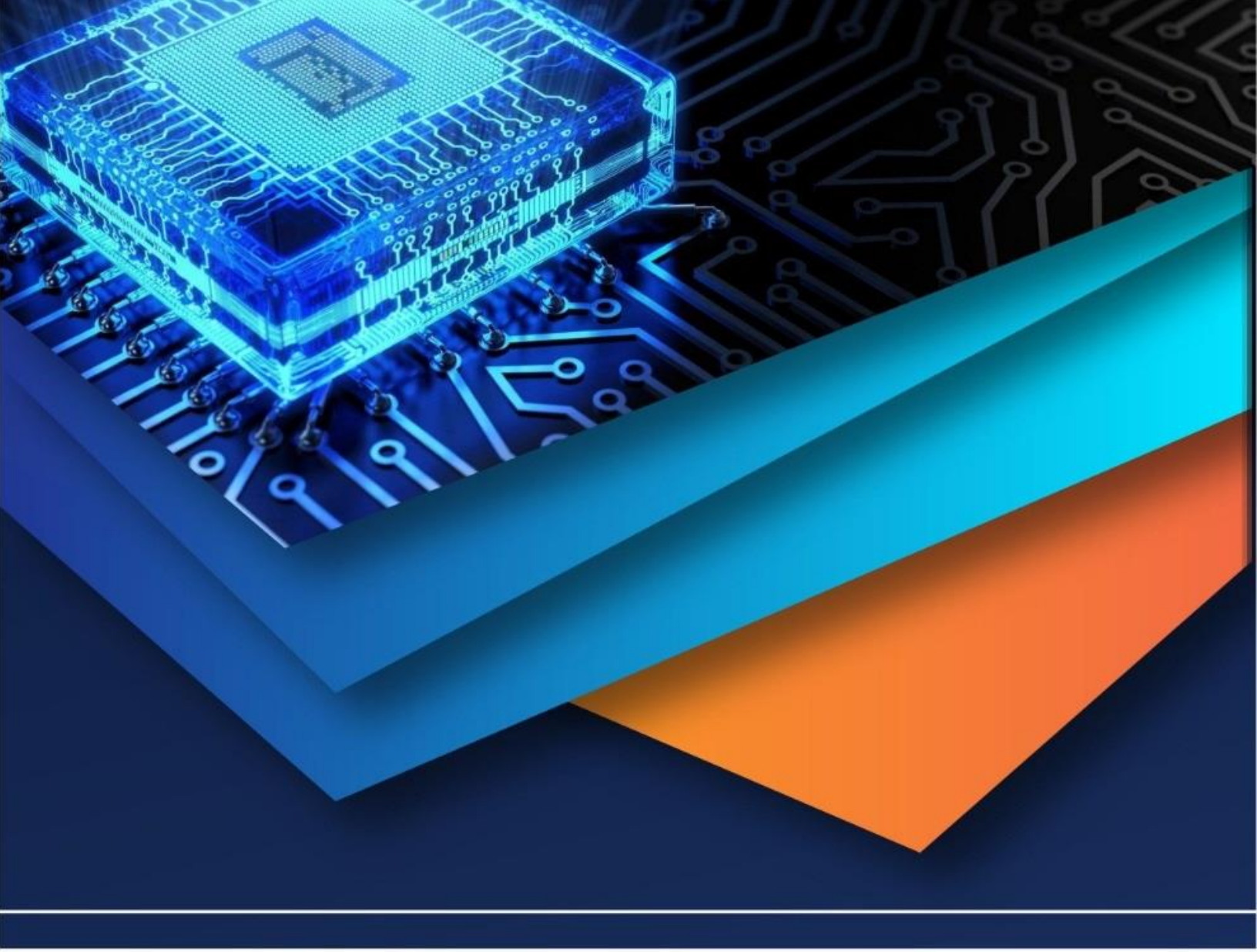
VI. CONCLUSION

The transition to a truly green economy in India requires more than just high-tech solutions like Industry 4.0; it demands a "frugal innovation" approach that is adaptable to local conditions. Future success depends on intensifying the dialogue on national green policies and fostering international co-operation to harmonize standards and secure the necessary private and public investment. While India has the technological tools to be a global leader in sustainability, the primary challenge lies in bridging the gap between national policy and localized, economically viable implementation.

REFERENCES

[1] Androniceanu, A., & Sabie, O. M. (2022). Overview of Green Energy as a Real Strategic Option for Sustainable Development. doi:https://doi.org/10.3390/en15228573
[2] Berawi, M. A. (2019). THE ROLE OF INDUSTRY 4.0 IN ACHIEVING SUSTAINABLE DEVELOPMENT GOALS. International Journal of Technology. doi:https://doi.org/10.14716/ijtech.v10i4.3341
[3] Caglar, A. E., & Dastan, M. (2023). The synergy of renewable energy consumption, green technology, and environmental quality: Designing sustainable development goals policies. Wiley. doi:10.1111/1477-8947.12577
[4] Choudhuri, S. (2019). A Research on Sustainable Development in India. International Journal of Recent Technology and Engineering (IJRTE). doi:10.35940/ijrte.B1226.0782S319
[5] Habanik, J., Grencikova, A., & Krajco, K. (2019). The Impact of New Technology on Sustainable Development. Inzinerine Ekonomika engineering economics, 41-49. doi:http://dx.doi.org/10.5755/j01.ee.30.1.20776
[6] Hall, J., Matos, S., & Bachor, V. (2017). From green technology development to green innovation:. Springer. doi:https://doi.org/10.1007/s11187-017-9940-0
[7] Shafiei, M. M., & Abad, H. (2017). The Importance of Green Technologies and Energy Efficiency for Environmental Protection. International Journal of Applied Environmental Sciences, 937-951.
[8] Zhironkin, S., & Cehlár, M. (2023). Economic and Technological Advances of Green Energy and Sustainable Development: The Overview. doi:https://doi.org/10.3390/

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)