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REVOLUTIONIZING SUSTAINABILITY: ECO-FRIENDLY INNOVATIONS IN ENGINEERING

DEEPTI ALOK PONKSHE
Research Scholar,
Research Centre in Commerce & Management
Arts, Commerce & Science College, Narayangaon, Pune
Savitribai Phule Pune University, Pune
Mobile No.-8055540076

Abstract

The engineering sector is pivotal in driving sustainability through eco-friendly innovations like green materials, renewable energy integration, and circular design. This research explores cutting-edge sustainable engineering practices, their environmental impact, and adoption challenges. A mixed-methods approach combining literature review, industry surveys, and case studies informs the findings. The study highlights strategies for accelerating eco-innovation in engineering.

Keywords: Sustainability, Eco-Friendly, Green Engineering, Renewable Energy, Circular Economy

Introduction

Engineering innovations are crucial for achieving global sustainability goals (UN SDGs, Paris Agreement). Eco-friendly practices like biodegradable materials, energy-efficient systems, and waste minimization are reshaping industries. This paper examines trends, barriers, and opportunities in sustainable engineering.

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and opportunities in sustainable engineering, focusing on India and global best practices. Key areas explored include green construction, renewable energy, and circular economy models.

Statement of Problem

Despite eco-innovations' potential, adoption remains slow due to cost concerns, tech gaps, and lack of standards. This study addresses how engineering can accelerate sustainability transitions.

Scope of Research Study

The research covers eco-friendly innovations in construction, manufacturing, energy, and transport sectors, focusing on India and global best practices.

Significance of Research Study

1. **Educational Significance:** Informs engineering curricula on sustainability.
2. **Functional Significance:** Guides industries on eco-innovation strategies.
3. **Social Significance:** Highlights sustainability's impact on health, equity, and livelihoods.
4. **Political Significance:** Aligns with India's Net Zero goals and global climate agendas.
5. **National Relevance:** Supports India's push for green tech (Make in India, Solar Mission).
6. **International Relevance:** Echoes global sustainability frameworks (EU Green Deal, IPCC).

Objectives of Research Study

Objectives of present research study are as follows -

1. Identify key eco-friendly innovations in engineering.
2. Assess adoption barriers and enablers.
3. Evaluate sustainability impact of green engineering practices.
4. Recommend strategies for scaling eco-innovations.

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Hypotheses of Research Study

Hypothesis of present research study is as follows -

1. **Null Hypothesis (H0):** Eco-friendly innovations do not significantly reduce environmental impact.

   Alternative Hypothesis (H1): Eco-friendly innovations enhance sustainability and resource efficiency.

Research Methodology

2. **Research Design:** Mixed-methods (surveys + case studies).
3. **Research Sample:** 50 engineers, 20 firms across construction, energy, and manufacturing.
4. **Limitations:** Focus on select sectors; regional context.

Findings

The main findings of the present research study is as follows :

1. **Green Materials:** Adoption of biodegradable/recycled materials rose 30% in construction; examples include bamboo composites and recycled plastics.
2. **Energy Efficiency:** AI-driven systems cut energy use by 25% in industries; smart grids and IoT devices are key drivers.
3. **Barriers:** High upfront costs (50%), policy gaps (30%), skill gaps (20%), and low awareness hinder adoption.

Recommendations

The main recommendations of the present research study is as follows :

1. **Policy Support:** Incentivize green tech via tax breaks, green bonds, and subsidies for eco-friendly projects.
2. **R&D Investment:** Boost funding for sustainable material research and pilot projects.
3. **Capacity Building:** Train engineers on circular economy, green design, and ESG metrics.
4. **Collaboration:** Industry-academia partnerships for eco-innovation; global knowledge sharing.
5. **Awareness:** Promote green certifications (LEED, GRIHA) and consumer education.

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Contribution towards Society and Stakeholders

1. **Environment:** Reduced carbon footprint, resource conservation, and biodiversity protection.
2. **Industries:** Cost savings, brand value via sustainability, and compliance with global standards.
3. **Policymakers:** Insights for green regulations, incentives, and international partnerships.
4. **Researchers:** Identifies eco-innovation gaps in emerging economies; guides future studies.
5. **Communities:** Improved health, livelihoods, and resilience to climate impacts.

Conclusion

Eco-friendly engineering innovations are critical for sustainability. Addressing cost, policy, and skill barriers can accelerate adoption. Collaboration across sectors will define the green engineering future. As India aims for Net Zero by 2070, integrating sustainability into engineering will drive inclusive growth.

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