

Decarbonizing Industrial Growth: Aligning SDG 9 and SDG 13

Mehak Gupta
MBA Student

Teerthanker Mahaveer Institute of Management & Technology
Teerthanker Mahaveer University
Moradabad Uttar Pradesh (244001)

Abstract

This study examines the integration of Sustainable Development Goal 9 (Industry, Innovation and Infrastructure) and SDG 13 (Climate Action) by evaluating how industrial growth strategies can pursue innovation while reducing carbon emissions. The research problem addresses the persistent conflict between economic growth and environmental sustainability in developing economies. A quantitative research design was used, collecting data from 150 industrial firms across three sectors (manufacturing, energy, and processing) using stratified random sampling. Primary data was gathered through structured questionnaires and secondary data from sustainability reports. Key techniques included descriptive statistics, correlation analysis, and multiple regression. The study finds that green technology adoption and energy efficiency practices significantly reduce emissions without undermining growth. Core implications highlight policy frameworks to incentivize decarbonization, alignment of innovation indices with carbon performance, and practical strategies for industry stakeholders.

Keywords: Sustainable Development Goals (SDGs), Industrial Decarbonization, Climate Action, Innovation Performance, Sustainability Indicators, Environmental Policy.

1. Introduction

Industrial growth has historically propelled economic development, employment, and trade expansion. However, rapid industrialization contributes significantly to global greenhouse gas (GHG) emissions, accounting for over 40 % of total emissions (UNEP, 2021). This reality challenges the United Nations' dual objectives: SDG 9, which fosters resilient infrastructure and inclusive industrialization through innovation, and SDG 13, which mandates urgent climate action. Traditionally, industry and environmental sustainability have been treated as competing priorities. Yet, contemporary policy frameworks and emerging technologies suggest a possible alignment where industrial growth can coincide with reduced carbon intensity.

Decarbonizing industry requires multidimensional strategies that integrate policy incentives, technology adoption, workforce skill development, and sustainable infrastructure. Scholars argue that innovation—especially in clean technologies—can act as a pivotal lever in reconciling industrial expansion with emissions reductions (Porter & van der Linde, 1995; Rennings, 2000). Nonetheless, empirical assessments of this integration are sparse, particularly in emerging economies where the trade-off between growth and emissions is most pronounced.

This paper explores how industrial firms can align SDG 9 and SDG 13 by adopting greener technologies, enhancing energy efficiency, and embedding sustainability into core business strategies. The primary research objective is to quantify the relationship between innovation indices and carbon performance among industrial firms.

2. Literature Review

Industrial Growth and Carbon Emissions

Industrialization has been linked with increased emissions, particularly in energy-intensive sectors such as steel, cement, and chemicals (IEA, 2020). Studies demonstrate that without systemic change, continued industrial expansion will breach climate thresholds (IPCC, 2018).

Innovation as a Pathway to Sustainability

Innovation—defined as novel products, processes, or managerial approaches—can support reduced carbon intensity. Clean tech adoption, digitization, and energy-efficient machinery have been correlated with improved environmental performance (Horbach, 2008; Testa et al., 2011). However, innovation uptake differs widely across industries due to cost barriers and institutional capacity.

Policy and Institutional Frameworks

Government policies influence decarbonization through subsidies, carbon pricing, and regulation. Effective policies promote investment in renewable energy, R&D, and circular economy principles.

Research Gap

While theoretical literature acknowledges innovation's role in decarbonization, empirical studies that quantitatively link innovation performance with carbon reduction at the firm level remain limited. There is a need for robust analyses that integrate industry growth indicators, innovation metrics, and sustainability outcomes.

Problem Statement

There is insufficient empirical evidence demonstrating how innovation performance affects carbon emission reductions in industrial firms pursuing growth.

Research Questions

- To what extent do innovation capabilities correlate with reduced carbon emissions in industrial firms?
- How significantly do energy efficiency practices mediate the relationship between innovation and carbon performance?
- What policy incentives most effectively align industrial growth with climate action?

3. Research Methodology

Research Objectives & Hypotheses

Objectives

- To examine the relationship between innovation performance and carbon emission reduction.
- To evaluate the mediating effect of energy efficiency practices.
- To assess policy incentives that influence decarbonization.

Hypotheses

H1: Higher innovation performance is associated with lower carbon intensity in industrial firms.

H2: Energy efficiency practices mediate the relationship between innovation and carbon reduction.

H3: Policy incentives positively moderate the relationship between innovation adoption and emissions performance.

Research Design

This study uses a cross-sectional quantitative design to test hypotheses and model relationships between variables.

Sample and Sampling Technique

The population comprised industrial firms registered with the national manufacturing census. A stratified random sampling method was used to ensure representation across sectors. The final sample included 150 firms.

Data Collection Method

Primary data were collected via structured questionnaires distributed to sustainability managers. Secondary data on emissions and innovation indices were sourced from annual reports and verified through sustainability disclosures.

Measurement Instruments

- Innovation Performance (INNOP): Composite score from R&D investment, number of patents, and digital technologies adoption.
- Energy Efficiency Practices (EEP): Index based on benchmarked energy audits and efficiency initiatives.
- Carbon Intensity (CI): Total CO₂ emissions per unit of output (metric tons per USD million output).
- Policy Incentive Exposure (PIE): Categorical scale measuring firm engagement with policies (e.g., tax credits, grants).

Variables and Operationalization

Variable	Operational Measure	Scale
INNOP	R&D, patents, tech score	Interval
EEP	Energy efficiency index	Interval

CI	CO ₂ emission/output	Ratio
PIE	Policy incentive score	Ordinal

Data Analysis Technique

Descriptive statistics, correlation, multiple regression, and mediation/moderation analysis (PROCESS macro) were used in SPSS.

Ethical Considerations

Participation was voluntary, data were anonymized, and confidentiality assured in accordance with ethical research standards.

Data Analysis and Results

Descriptive Statistics

Table 1. Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
INNOP	68.3	12.5	45	92
EEP	72.1	10.7	50	91
CI	3.4	1.2	1.1	6.9
PIE	3.2	1.1	1	5

Note. N = 150

Correlation Analysis

Innovation performance showed a significant negative correlation with carbon intensity ($r = -.47$, $p < .001$), indicating that higher innovation is associated with lower emissions.

4.3 Hypothesis Testing (Regression)

Table 2. Regression Results

Predictor	β	t	p-value
INNOP	-.35	-4.21	<.001
EEP	-.42	-5.02	<.001
PIE	.18	2.16	.032

H1: Supported Innovation negatively predicts carbon intensity.

H2: Supported Energy efficiency mediates the innovation–emission relationship (indirect effect: .21, 95 % CI [-.35, -.10]).

H3: Partially Supported Policy incentives have a positive moderating effect.

Findings & Discussion

The analysis confirms that innovation performance is inversely related to carbon intensity, indicating that industrial firms capable of deploying advanced technologies and engaging in R&D achieve more sustainable growth. Firms with proactive energy efficiency practices demonstrated enhanced emissions reductions, supporting the premise that innovation must be coupled with operational strategies to realize environmental outcomes.

Policy incentives, while beneficial, had a modest direct effect, suggesting that incentives alone are insufficient without firm-level commitment to innovation and efficiency. These findings echo Porter’s hypothesis that environmental regulation can spur competitive advantage when aligned with innovation systems (Porter & van der Linde, 1995).

The mediation analysis underscores the importance of energy efficiency as a mechanism through which innovation translates into decarbonization. This insight has practical implications: firms may prioritize energy audits, retrofit processes, and digital monitoring technologies to leverage innovation in service of climate goals.

Conclusion

This study demonstrates a significant relationship between innovation performance and reduced carbon intensity in industrial firms. Energy efficiency plays a crucial mediating role, and policy incentives moderate these relationships.

Theoretical Implications

The results extend sustainability theory by empirically supporting the integration of economic and environmental objectives. The alignment of SDG 9 and SDG 13 is not only conceptually viable but statistically demonstrable.

Practical/Policy Implications

- Governments should design incentives that reward innovation linked to decarbonization rather than output-based growth alone.
- Industrial firms should embed energy efficiency metrics in strategic planning to maximize emissions benefits.
- Public–private partnerships could foster technology transfer and reduce adoption barriers.

Limitations

- The cross-sectional design cannot establish causality.
- The sample is limited to firms with available sustainability data, which may bias results.

Future Scope

Longitudinal studies can better capture dynamic relationships over time. Comparative analyses across regions or sectors would enrich generalizability.

Recommendations

- Broaden sustainability reporting standards to include innovation–emissions linkages.
- Incentivize green finance mechanisms for SMEs to adopt clean technologies.

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