ISSN 0974-763X
UGC-CARE Listed Journal

SOUTH ASIAN JOURNAL OF MANAGEMENT RESEARCH (SAJMR)

Volume 15, Issue No.3 July, 2025

50 Years of Educational Excellence
2025-26
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CHHATRAPATI SHAHU INSTITUTE OF BUSINESS EDUCATION AND RESEARCH (CSIBER), KOLHAPUR, MAHARASHTRA, INDIA

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Published by
CSIBER Press, Central Library Building
Chhatrapati Shahu Institute of Business Education & Research (CSIBER)
(An Autonomous Institute)
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Chhatrapati Shahu Institute of Business Education and Research (CSIBER)

South Asian Journal of Management Research (SAJMR)

Volume 15, Issue No. 3, July 2025

Editor: Dr. Pooja M. Patil

Publisher
CSIBER Press
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South Asian Journal of Management Research
(SAJMR)

Volume 15, Issue No. 3 **July, 2025**

C O N T E N T S

Corporate Energy Transition in India: A Firm-Level Analysis of Energy Intensity and Renewable Energy Adoption

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Abstract

Corporations are under growing pressure to align their energy systems with national and global climate goals due to the global shift towards a low-carbon economy. Energy strategies of corporations need to consider both dimensions of corporate energy performance: energy intensity**,** which measures the efficiency of energy use relative to output, and level of **r**enewable energy adoption**,** which reflects the shift from fossil-based to cleaner sources of energy.

This study explores the recent trends in industrial energy consumption and the relationship between energy intensity and renewable energy adoption across NSE-50 listed large-cap Indian companies over two financial years (2022–24). The study looks at energy data reported from publicly disclosed reports and analyses how the level of energy intensity affects firms' adoption and transition towards renewable energy. The study uses descriptive statistics, linear regression models and non-parametric tests to test five hypotheses linking energy efficiency and renewable energy. The findings show a statistically significant inverse relationship between the level of energy intensity and Renewable Energy adoption, with the energy-intensity sector group emerging as a stronger predictor of Renewable Energy adoption. The findings reveal an uneven and polarised transition in corporate India, where a set of low-energy intensity firms are transitioning significantly faster than others.

Firms in low-energy-intensity sectors have shown significantly increased renewable energy adoption as compared to high-energy-intensity sectors. The low-energy sector firms also show a significantly higher growth rate in transitioning to renewable energy over the two years, while the high-energy-intensity sector firms show limited renewable progress. The key recommendations of this study include holistic framing of energy management decisions, technical innovation and considering energy-related investments as a strategic opportunity at the corporate level. The study finds no significant link between short-term Renewable Energy transition and Energy Intensity reduction, suggesting firms treat energy efficiency and Renewable energy strategies as distinct and parallel.

The study offers both theoretical and practical insights. It contributes to energy transition literature by connecting operational efficiency and strategic sustainability at the firm level. For policymakers and corporate strategists, it underscores the importance of sector-specific interventions to accelerate corporate energy transition.

Keywords: Energy Intensity, Renewable Energy Adoption, Corporate Sustainability, BRSR, Climate Strategy

Introduction

Corporate energy consumption and usage patterns have come under scrutiny due to the focus on climate change mitigation and sustainable economic growth. More than 70% of global greenhouse gas emissions are attributed to energy use (IPCC, 2022; IEA, 2023). Firms in emerging economies rely on fossil-based energy sources and show significantly increasing energy consumption (IEA, 2023). Energy strategies of corporates need to consider two interrelated dimensions of corporate energy performance: energy intensity**,** which measures the efficiency of energy use relative to output, and the level of **r**enewable energy adoption**,** which reflects the shift from fossil-based to cleaner sources of energy.

The Indian government has made commitments under the Paris Agreement and set its net-zero ambitions. There has been a rapid scaling of renewable energy capacity (MNRE, 2023), and regulatory frameworks such as BRSR (SEBI, 2021) and CDP (CDP, 2023) have pushed for more transparent sustainability reporting. Energy consumption disclosures are an important part of corporate sustainability reporting and ESG (Environmental, Social and Governance) ratings. However, the corporate sector's response to these changes has been uneven. Many Indian firms in the technology and services sectors have adopted renewable energy as a strategic priority (IEA & CEEW, 2022), while firms in energy-intensive industries with heavy energy consumption have lagged in energy transition due to inherent constraints, costs, and infrastructural inertia (TERI, 2023).

Prior studies on energy usage have focused on macro-level indicators of renewable energy suppliers or examined energy efficiency and renewable energy in isolation. The academic literature linking energy intensity and renewable energy adoption at the Indian firm and sector levels remains undeveloped. This study aims to fill that gap by exploring the relationship between energy intensity and renewable energy adoption across NSE-50 listed Indian firms over two years (2022–23 to 2023–24).

The study aims to answer the following key research questions:

- Are firms with higher energy intensity (EI) adopting more or less renewable energy (RE)?
- Are firms that reduce energy intensity also increasing their use of renewables?

This research extends the understanding of corporate energy transitions by linking operational efficiency (EI) with strategic sustainability (RE). This paper contributes to the literature by providing firm-level insights into India's corporate energy transition. It offers empirical evidence that can support policy, sustainability reporting, and corporate energy planning. The findings also suggest directions for future research.

This study is bounded by a two-year timeframe (2022–2024), focusing on NSE-50 listed companies in India. The scope is limited to firm-level analysis of energy intensity and renewable energy adoption, excluding smaller firms and listed entities. Only publicly available disclosures and BRSR reports have been included. Broader environmental or ESG factors beyond energy were not considered to maintain a clear focus on the relationship between Operational energy efficiency and renewable energy adoption.

Literature Review

According to the IEA, Renewable Energy is defined as "energy derived from natural processes that are replenished at a faster rate than they are consumed," including wind, solar, hydro, and bioenergy (IEA, 2022). The definition from the EU also includes tidal and renewable fractions of waste as renewable energy. (Moriarty & Honnery, 2009).

The urgency towards energy transition is compounded by fossil fuel depletion forecasts (Moriarty & Honnery, 2011; Patzek & Croft, 2010; Heinberg & Fridley, 2010), making RE adoption a necessity, not a choice.

According to the International Energy Agency (IEA, 2023), large industrial consumers are increasingly integrating renewable sources to meet decarbonisation goals, reduce operational costs, and hedge against fossil fuel volatility. Renewable energy offers a route to decarbonise corporate energy use while also indirectly contributing to energy efficiency. By shifting from fossil fuel-based sources (which are typically more carbon and energy-intensive) to renewables, firms reduce carbon emissions and enable AI-driven optimisation.

The adoption of renewable energy (RE) by corporations has accelerated globally in recent years, but the sector-wise adoption has been uneven. The reports from CEEW (2022) and TERI (2022) Identify sectoral heterogeneity in RE adoption and call for differentiated policies. Power, Cement, and Oil & Gas sectors lag due to legacy infrastructure and policy ambiguity.

Some studies have explored the drivers, barriers, and outcomes associated with integrating renewable energy into industrial practices. Marques and Fuinhas (2015) use a dynamic panel approach to show that financial incentives, public pressure, and long-term regulatory certainty are key drivers of adoption across EU nations.

A recent review by Usman et al. (2024) outlines both technical and policy challenges in integrating RE into manufacturing processes, such as intermittency, capital expenditure barriers, and system compatibility issues.

Energy intensity, defined as energy consumption per unit of economic output, is a widely used proxy for efficiency in energy usage. Corporate energy intensity reflects how efficiently energy is converted into business output. Cooremans (2012) argues that the strategic perception of energy efficiency investments significantly influences adoption rates. Energy efficiency needs to be integrated at the corporate strategy level and not as a cost-reduction project. Energy-related projects should be linked with strategic objectives like competitiveness, risk reduction, and innovation (Cooremans, 2012). Alam, Rahman, and Islam (2022) have highlighted that sustainable investment is positively correlated with improved energy and carbon performance at thee firm level. In emerging markets, Zhou et al. (2021) find that government subsidies for RE manufacturers in China directly impact financial performance, reinforcing the idea that RE strategy is inseparable from corporate growth planning.

Many research studies have shown that RE adoption and EI reduction contribute positively to firm performance. Okafor and Nnaji (2024) have highlighted that RE use improves financial outcomes like profitability. Studies by Patari et al. (2021) connect sustainable energy adoption with increased adaptability, effectiveness, and efficiency. As Cooremans (2012) argues, the success of such transitions hinges on reclassifying these investments as strategic, not peripheral. A systematic review by Al-Najjar and Anfimiadou (2012) shows that firms adopting RE technologies report gains in profitability, logistics, and brand equity. They empirically show that environmental policies, including RE adoption, are positively linked to firm value.

The existing research offers various insights into the drivers of energy transition. Few studies examine the interplay between energy intensity and RE adoption at the firm level, especially in the Indian context. Most research treats RE adoption and energy intensity as isolated constructs or examines them in aggregate at the national or sectoral level.

This study bridges that gap by providing a firm-level analysis of the two indicators, mapping operational and strategic trajectories over the two recent years.

Research Design

This study investigates the relationship between corporate energy intensity (EI) and renewable energy (RE) adoption across NSE-50 listed firms in India over the period 2022–23 to 2023– 24.

Research Objectives

The main objectives of the research are:

- To measure and compare renewable energy usage across firms with differing levels of energy intensity.
- To assess whether revenue, sectoral grouping, and energy intensity influence renewable energy adoption.
- To evaluate whether year-over-year changes in renewable energy usage predict short-term changes in energy intensity.
- To determine if firms in low energy-intensity sectors demonstrate stronger renewable energy transitions.
- To examine if prior renewable energy adoption predicts continued growth in renewable energy usage.

[

Sample selection

The sample uses secondary data from the sustainability and annual reports of the companies listed on NSE 50 (https://www.nseindia.com). The Nifty 50 is a diversified 50 stock index consisting of top companies with the largest market capitalisation, accounting for 13 sectors of the economy. Due to the change in the sustainability reporting requirements and measurement criteria, the data on energy consumption has not been consistently reported over the past years. It was therefore decided to consider the latest available data for the last two years reported by the companies during the years 2022-24. This offers a more reliable, useful and comparable dataset, also considering the fact that the availability and pace of renewable energy adoption has gained significant traction over the recent two years.

Out of the NSE-50 companies, 11 firms were excluded from the analysis due to extreme or inconsistent numbers. The final data consisted of 39 firms from multiple sectors, including Power, Oil & Gas, Technology, FMCG, Capital Goods, Consumer Durables, Financials, and others. Data was collected from Business Responsibility and Sustainability Reports (BRSR), Annual reports and disclosures available on firm websites, NSE data repository and financial databases.

Variables and Measures

Table 1 shows the variables used in the study, along with their description and measurement criteria.

Table No. 1. Description of Variables

Variable	Type	Measurement
Energy Intensity (EI)	Independent / Dependent	Energy consumed per unit of revenue (e.g., GJ/INR million), log-transformed as needed.
Renewable Energy Usage (RE)	Dependent	% of energy sourced from renewable sources in each year
RE Change	Dependent	Year-over-year difference in RE usage (%)
EI Change	Dependent	%Year-over-year difference in EI
Revenue	Control	Total revenue (INR Million), log-transformed for scale normalisation
Sector	Control	A categorical variable representing the firm’s sector
EI Group	Grouping variable	Firms grouped as “High” or “Low” EI based on sectoral split

Hypotheses

The following hypotheses were framed in line with the research objectives:

H1: Firms with lower energy intensity have a higher proportion of renewable energy usage. This hypothesis tests whether firms with low Energy Intensity (EI) show higher Renewable Energy (RE) adoption using Spearman's rank correlation and Mann–Whitney U test.

H2: Revenue and EI group explain renewable energy usage better than energy intensity alone. This is tested using OLS regression with HC3 robust standard errors.

H3: Firms with higher renewable energy transition show a corresponding reduction in energy intensity. This hypothesis tests the relationship between renewable energy transition and changes in Energy Intensity using simple linear regression with HC3 standard errors.

H4: Low energy intensity group firms have greater year-over-year renewable energy transition compared to high EI group firms. This hypothesis tests the renewable energy transition between the low energy intensity and the high energy intensity groups using the Mann–Whitney U test.

H5: Higher renewable energy usage in 2022–23 predicts higher growth in renewable energy usage in 2023–24. This hypothesis tests whether the firms with higher renewable energy usage in the base year showed a higher renewable energy transition in the subsequent period using OLS regression with HC3 robust standard errors.

Statistical Techniques

The study uses non-parametric tests, Spearman's Correlation, and regression analysis, with additional robustness checks using HC3 robust standard errors to address potential heteroscedasticity.
The following statistical methods were used to test the hypotheses:

- Descriptive statistics to summarise central tendencies and dispersion
- Spearman correlation for evaluating monotonic relationships (H1)
- Mann-Whitney U tests for comparing Renewable Energy usage across Energy Intensity-based groups (H1, H4)
- OLS linear regression models to assess predictors of RE usage and energy intensity changes (H2, H3, H5)
- Categorical coding was done to create sector dummies and binary groups
- Log transformation was applied where data distributions were skewed.

All statistical tests were conducted using IBM SPSS Statistics**,** and significance was evaluated at the 5% level (α = 0.05).
The regression models were tested for Multicollinearity using Variance Inflation Factor (VIF) and Heteroscedasticity using residual plots. Robust standard errors (HC3) were considered to correct for heteroscedasticity where necessary. The HC3 method provides more reliable. estimates of standard errors in the presence of non-constant variance across firms, especially in smaller samples. All interpretations in the main results are based on HC3 adjusted estimates.

Descriptive Statistics and Analysis

Table 2 shows the results from the descriptive statistics.

Table No. 2: Descriptive Statistics

Mean	Median	Std. Deviation	Min	Max
108.92	3.39	349.71	0.113	2103.2
110.90	3.49	360.64	0.092	2176
17.09	6.18	21.71	0.007	93.69
19.86	6.86	24.48	0.021	95.81
2.77	1.04	5.16	-6.41	19.20
-2.18	-1.84	11.68	-22.70	34.28

Extremely high standard deviation and wide range in both 2022-23 and 2023-24 indicate strong skewness and outliers, which shows that few high Energy Intensity firms distort the mean. The median is much lower than the mean (3.39 vs. 108.92 in 2022-23), confirming a positive skew. This justifies the use of log transformation and EI-grouping for analysis is appropriate.

RE usage also shows skewness, but the spread is more even than EI. Median Renewable Energy usage in 2023-24 (6.86%) is slightly higher than in 2022-23 (6.18%), indicating marginal overall improvement. Mean RE usage rose from 17.09% to 19.86% but was likely driven by a few high-RE adopters (max 95%).

EI Change has a mean of -2.18%, suggesting firms slightly reduced EI overall, though the median (-1.84) shows modest change. RE Change has a positive mean of 2.77% and a median of 1.04%, suggesting a broad but modest improvement in RE usage.

These changes show divergent firm strategies, with some reducing intensity, others increasing Renewable energy usage, or both. Log transformations and EI groups were appropriately applied in subsequent hypothesis testing (H1, H2). The descriptive statistics justify segmenting firms into high vs. low EI and assessing transition trajectories (H3, H4, H5).

Normality Testing and Model Selection

Initial normality tests (Anderson–Darling and Henze–Zirkler) revealed that Variables such as RE_Usage, RE_CHANGE, and EI_2022 were not normally distributed. Only EI_CHANGE passed the normality test.

This justified the use of Spearman's Correlation and Non-parametric tests (Mann–Whitney U) for group comparisons. Log transformations were applied for regression predictors of EI and revenue with Robust standard errors for multivariate models.

Two binary groups were created to represent high EI and low EI sectors. The high EI group consisted of Power, Metals & Mining, Materials and Oil & Gas Sectors. All the other sectors were categorised as Low EI group.

Results

This section presents findings for each of the five hypotheses, supported by appropriate statistical analyses, including non-parametric tests and regression models:

H1: Firms with lower energy intensity have a higher proportion of renewable energy usage.

To test whether firms with lower energy intensity (EI) adopt more renewable energy (RE), a Spearman correlation was conducted. The correlation between log_EI and RE_Usage_2023 was negative and significant ($\rho = -0.379$, $p = 0.009$), indicating that firms with lower Energy Intensity use significantly higher Renewable energy as a percentage of their total energy consumption.

A Mann-Whitney U test further confirmed that the low EI group (EI_grp = 2) had significantly higher RE usage in 2023 than the high EI group ($Z = -3.776$, $p < 0.001$).

- Mean Rank: Low EI = 24.32 vs. High EI = 9.00
- $Z = -3.776$, $p < 0.001$
- Effect size (r) = 0.605

This supports H1 and suggests that Energy Intensity and Renewable Energy usage are negatively aligned at the firm level. The large effect size indicates a strong and practically meaningful difference in RE usage between the High EI and low EI groups.

H2: Revenue and EI group together explain renewable energy usage better than energy intensity alone.

Multiple linear regression was conducted with RE usage (2023) as the dependent variable and Energy Intensity, EI group, and revenue as predictors.

Regression equation:

$$^{RE}Usage2023 = \beta^0 + \beta^1(log_{EI}) + \beta^2(log_{Rev}) + \beta^3(EI_{Grp}) + \varepsilon \quad \text{Equation (1)}$$

The OLS Regression with HC3 Robust Standard Errors gave the following results:

Table No. 3: H2 Regression Output (HC3 Adjusted)

Variable	B	Robust SE	T	p	95% CI
Intercept	-32.857	70.371	-0.467	0.643	[-175.72, 110.00]
log_EI	3.983	4.881	0.816	0.420	[-5.93, 13.89]
log_Rev	-1.039	9.708	-0.107	0.915	[-20.75, 18.67]
EI_Grp	32.269	11.868	2.719	0.010	[8.18, 56.36]

The model explains 24.2% of the variation in RE usage ($R^2 = 0.242$, Adjusted $R^2 = 0.177$), supporting H2.
The HC3, robust regression model predicting RE usage percentage (RE_Usage_2023) shows that only the energy intensity grouping (EI_Grp) is a significant predictor (B = 32.269, p = 0.010). Firms in the low energy intensity group (Group 2) use, on average, 32.3 percentage points more renewable energy than firms in the high EI group (Group 1). log_EI and log_Rev did not show significant influence.
These findings are consistent with H1, reinforcing the view that low energy-intensive firms are moving forward in RE adoption. Collinearity statistics (VIF, Tolerance, and Condition Index) were examined to assess potential multicollinearity among predictors. VIF for log_EI (2.6) and EI_Grp (3.0) suggest moderate multicollinearity but not severe. The significant result for EI_Grp supports the H2 hypothesis that structural categorisation (high/low EI) explains RE usage better than raw EI values.

H3: Firms with higher renewable energy transition show a corresponding reduction in energy intensity.
A regression model was run with EI_CHANGE_2023 as the dependent variable and RE_CHANGE_2023 as the independent variable to test whether a firm's change in renewable energy (RE) usage predicts its change in energy intensity (EI).
Regression equation:

$EI\_CHANGE\_2023 = \beta_0 + \beta_1 (RE\_CHANGE\_2023) + \varepsilon$...Equation (2)

The regression model was not statistically significant, $F(1, 37) = 1.078$, $p = 0.306$, and the explanatory power was minimal ($R^2 = 0.028$, Adjusted $R^2 = 0.002$). This indicates that changes in renewable energy usage accounted for only 2.8% of the variation in changes to energy intensity across the sample.
Robust regression estimates using HC3 standard errors produced the following result:

Table No. 4: H3 Regression Output (HC3 Adjusted)

Variable	B	SE	t	p	95% CI
Intercept	-3.230	2.175	-1.485	0.146	[-7.637, 1.178]
RE_CHANGE_2023	0.381	0.197	1.930	0.061	[-0.019, 0.780]

$R^2 = 0.028$; Adjusted $R^2 = 0.002$

Although the coefficient for RE_CHANGE_2023 approaches significance, it does not meet the $p < 0.05$ threshold. The confidence interval suggests ambiguity in the direction and strength of the relationship. H3 is not supported. There is no significant evidence that an increase in RE adoption leads to a corresponding reduction in energy intensity in the short term
H4: Low energy intensity group firm have greater year-over-year renewable energy transition compared to high EI group firms.

A Mann–Whitney U test was used to compare RE_CHANGE_2023 between the two EI groups – High EI and low EI. The test was statistically significant (Z = –2.559, p = 0.010), showing that low EI firms exhibited significantly greater increases in RE usage over time than high EI firms.

- U = 72.000, Z = -2.559, p = 0.010
- Mean Rank: (Low EI) = 22.93 vs. High EI = 12.55
- Effect size (r) = 0.410

Low EI firms show significantly greater growth in RE usage year-over-year. H4 is supported, showing that low EI firms are not only ahead in RE usage but also more aggressive in RE transition over time. Medium to large effect shows a notable difference in RE transition between groups.

H5: Higher renewable energy usage in 2022–23 predicts higher growth in renewable energy usage in 2023–24.
An OLS Regression with HC3 Robust Standard Errors tested whether previous RE usage predicts change in RE usage:

Regression equation:

$RE\_CHANGE\_2023 = \beta_0 + \beta_1(log\_REUSE\_2022) + \varepsilon$ .... Equation (3)

The HC3-robust regression showed a significant relationship:
$R^2 = 0.177$, Adjusted $R^2 = 0.155$

Table No. 5: H5 Regression Output (HC3 Adjusted)

Variable	B	Robust SE	t	p	95% CI
Intercept	1.769	0.509	3.479	0.001	[0.739, 2.800]
log_REUSE_2022	1.940	0.709	2.738	0.009	[0.504, 3.376]

This shows that RE usage in 2022–23 is a strong and significant predictor of RE growth in 2023–24. Firms with higher RE usage in 2022-23 continued to increase RE usage the following year. H5 is supported. Prior RE adoption momentum is associated with further transition.

Table No. 6: Summary Table: Hypotheses results

Hypothesis	Test / Model	p-value	Significance	Interpretation
H1	Spearman, Mann–Whitney U	0.009 / <0.001	Yes	Low EI firms use significantly more RE.
H2	OLS with HC3	0.010 (EI_Grp)	Yes	EI_Grp explains RE usage better than raw EI.
H3	Linear Regression	0.306 / 0.061	No	No evidence that RE transition reduces EI.
H4	Mann–Whitney U	0.010	Yes	Low EI firms show greater RE transition.
H5	OLS with HC3	0.009	Yes	Higher RE usage in 2022-23 predicts higher RE growth.

Discussion

This study examined the relationship between energy intensity (EI) and renewable energy (RE) adoption across NSE-50 firms, revealing important differences across firm types and sectors.
The sectoral group a firm belongs to reflects its energy intensity, regulatory pressures, access to green technologies, and exposure to sustainability-driven investment demands. This suggests that institutional and industry context is more influential than internal efficiency when it comes to RE adoption. Results show that firms in low EI sectors consistently demonstrate higher RE adoption and stronger RE transition (H1, H4). At the same time, H2 confirms that structural categorisations like high energy intensity and low energy intensity explain RE usage patterns more effectively than continuous EI values.

In sectors such as Power, Cement, Oil & Gas, and Metals & Mining, high EI is structural, stemming from the energy-intensive nature of core industrial processes (TERI, 2022; IEA, 2023). Technology, Pharma, and FMCG firms tend to have lower energy footprints and face fewer constraints in transitioning to renewable energy.
Sectoral barriers to RE adoption include infrastructure lock-in, intermittent energy supply, insufficient grid integration, and limited financing options for capital-intensive retrofits (Usman et al., 2024; CDP, 2022). Even when corporate intent is strong, operationalising RE strategies in high EI sectors can be slow and fragmented.
H5 highlights the ‘momentum effect’ where the early adopters of RE deepen their transition over time. The strong and statistically significant link between prior RE usage and subsequent increases in RE usage indicates path dependence in sustainability behaviour.
H3 shows that there is no short-term linkage between RE increase and EI reduction, which the technical inertia of energy systems could cause. This reveals that firms treat energy efficiency and renewable energy as parallel but distinct strategies. While efficiency focuses on cost control, RE adoption may require different resources and decision drivers (e.g., ESG targets). This decoupling has important policy implications.
Low EI firms benefit from greater digital integration, level of agility, and reputational incentives. As CEEW

(2022) and Cooremans (2012) emphasised, firms that strategically frame energy investments linking them to innovation, resilience, and competitive advantage are more likely to succeed in transitioning. Overall, this study adds firm-level nuance to India's energy transition landscape and highlights how sectoral context, strategic framing, technical barriers and legacy infrastructure shape Renewable Energy outcomes**.**

Conclusion

This study examined how energy intensity (EI), sectoral identity, and firm-level characteristics influence renewable energy (RE) usage and transition across 39 Indian companies over two years.

These findings reveal an uneven and polarised transition in corporate India, where a small set of low-EI firms are transitioning significantly faster than others.

Sectoral affiliation plays a significant role in explaining RE behaviour rather than the influence of revenue or raw EI alone. Firms in structurally low EI sectors such as technology, pharma,
and services lead to renewable energy adoption due to fewer transition barriers and reputational drivers. Energy-intensive sectors like Power, Metals, and Cement face structural, infrastructural, technical, commercial and policy-related constraints.

There is no significant link between EI reduction and RE adoption, suggesting firms may treat energy efficiency and RE strategies as separate and parallel. Firms that already use RE in one year are more likely to progress on transition the following year, confirming path dependence in sustainability behaviour.

Strategic recommendations of this study include holistic framing of energy management plans, focus on technical innovation and treating the sustainability investments as a strategic opportunity at the corporate level. A small subset of firms demonstrates multi-dimensional leadership by reducing EI, adopting RE, and increasing RE adoption. These may serve as case studies or benchmarks in future policy frameworks.

Policy recommendations include (1) sector-specific RE pathways with realistic transition targets, (2) performance-linked financing and subsidies for capital-intensive heavy industries, and (3) framing RE adoption not just as compliance but as a strategic opportunity (Cooremans, 2012; Zhou et al., 2021). Regulators must account for legacy infrastructure and offer differentiated incentives, while investors can push firms toward ESG-aligned innovation. Limitations of this study include a two-year observation period, a small sample size within each sector, and a focus on NSE-50 firms, which may not be generalised to small enterprises. Future research should explore multi-year interactions between RE transition and EI across sectors, using broader datasets, energy mix, and integrated with GHG emissions reduction. Future research should include case studies and qualitative insights on firm-level motivations, challenges and enterprise structures. Bridging India's energy transition gap requires both firm-level innovation and ecosystem structural support. This study highlights the importance of differentiated energy strategies and the need for accelerated and sustained investment in energy efficiency and renewables.

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