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Impact of Carbon Credit Trading on Indian Industries

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***Abstract*—A carbon credit trading has becomes a critical market orientation to deal with greenhouse gas emission in the Indian industrial sector. This paper reviews the effects of carbon credit trading on five large Indian firms; Adani Green Energy Ltd, Tata Power Company Ltd, JSW Steel Ltd, Ultra Tech Cement Ltd and EKI Energy Services Ltd in the financial year between 2021 and 2024. The study bases its analysis on the Event Study Analysis, Ratio-Based Disclosure Analysis and Correlation Analysis to evaluate the emission reduction, financial performance, technology adoption, and compliance behavior based on secondary data, which will include annual reports, ESG disclosure and NSE/BSE filings. It can be seen that each of the five companies showed the improvement of carbon performance that can be measured since the declaration of India Carbon Credit Trading Scheme (CCTS) in 2023. Tata Power cut the absolute greenhouse gas (GHG) CO_2 equivalent emissions by 15.2 million to 13.1 million tonnes and increased revenue twice; UltraTech Cement and JSW Steel reported decreasing intensities of the emissions. The ESG scores have steadily grown in all companies with an average of 72 to 87 in the FY2024. Correlation tests validate the moderate negative (r = -0.52) between GHG and profit margin as well as a strong positive (r = +0.63) relationship between ESG and profitability. The evidence shows that all four hypotheses hold and that carbon credit trading matters a lot in terms of reducing emissions, cost structures, levels of awareness and challenges to the industry. The paper highlights the necessity of having an operationalised registry of CCTS, sector-specific standards and policy-specific support of emission-intensive sectors such as steel and cement.**

***Keywords*—Carbon Credit Trading, Indian Industries, Greenhouse Gas Emissions, Carbon Credit Trading Scheme (CCTS), ESG Performance, PAT Scheme, Emission Reduction, Green Capital Expenditure**

I. Introduction

Climate change is one of the challenges of the twenty-first century and the greenhouse gas (GHG) emissions due to industrial activities are the major cause of global warming. Market-based responses like carbon credit trading have been developed, in turn, to achieve incentives on reducing emissions, without compromising on economic flexibility. In this arrangement, those who cut down on the number of emissions curbed beneath a predetermined threshold receive tradable carbon credits which they can sell to those going beyond their emission cut-off limits — whereby cost-effective reduction of climate change is facilitated (Ellis et al., 2019).

On the global scale, carbon markets have been gaining momentum with the Kyoto Protocol and reinforced by the 2015 Paris Agreement, which urges governments to use carbon pricing tools to achieve their Nationally Determined Contributions (NDCs) (UNFCCC, 2015). With the support of the Emissions Trading System (EU ETS), the European Union has shown that carbon markets can decrease the emissions of industrial pollution without having a critical negative impact on competitiveness (Schmalensee et al., 2017).

India is one of the largest and fastest growing economies in the world and has the twin responsibility of industrial growth and development as well as achieving its ambitious climate targets. The industry, especially the sectors of power production, cement, steel, and chemicals are disproportionate sources of national emissions (Garg et al., 2020). To reflect this, the Government of India has developed the Perform, Achieve, and Trade (PAT) scheme under the Bureau of Energy Efficiency (BEE) so that the energy designated consumers have the opportunity to trade the efficiency certificates (BEE, 2021). Most recently, in 2023, the Carbon Credit Trading Scheme (CCTS) was notified by the Ministry of Power, marking India's official move into the structure of a domestic carbon market.

This has far-reaching effects on the Indian industries in terms of changes in production costs, adoption of new technologies, regulatory compliance and long-term sustainability strategies. Although carbon credit trading offers industries a chance to achieve emission reduction and improved environmental performance at a lower price, issues of awareness levels, market preparedness, and monitoring infrastructure, as well as unequal ability of industries to engage in carbon credit trading, remain of great concern (Narassimhan et al., 2018).

It is against this backdrop that the paper examines how carbon credit trading has impacted the five largest Indian companies in the industry, i.e. renewable energy, diversified power, steel, cement and carbon market services, based on FY2021 to FY2024. The research aims at offering empirical support on the impacts of carbon credit trading on industrial emission performance, financial performance, and decision-making strategies in India.

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II. Literature Review

Carbon credit trading is an economic tool created to decrease GHG emissions by giving a monetary worth to carbon cuts. According to theoretical propositions, carbon markets help industries bring about the reduction of emissions at minimal cost and facilitate efficiency and innovation (Haites, 2018; Verbruggen, 2019). Through internalisation, the social cost of carbon through trading schemes affects production choices and promotes cleaner technologies.

The empirical evidence of the EU ETS suggests that carbon trading has generated specific reductions in emissions in energy-intensive sectors without drastically decreasing the level of industrial competitiveness (Schmalensee et al., 2017; Kramer and Lessmann, 2023). Nevertheless, the scale of impact does differ among sectors due to regulatory design, allowance distribution and the maturity of the market.

Some studies point out that with carbon pricing, short-term compliance costs incurred by industries rise more in carbon-intensive industries, such as cement and steel (Ellis et al., 2019). Simultaneously, long-term advantages such as energy savings, reduction of operating costs, and improved environmental performance have been witnessed when companies invest in low-carbon technologies (Haites, 2018; Narassimhan et al., 2018).

India's experience with market-based emission reduction has followed the PAT scheme managed by the BEE, which allows trading of energy efficiency certificates between specific consumers (BEE, 2021). The most recent policy change, specifically the CCTS 2023 notification, reflects India's intention to align itself with the commitments of the Paris Agreement (Ministry of Power, 2023).

In deploying carbon markets in developing economies, the literature lists a number of challenges such as high transaction costs, a lack of awareness among industries, insufficient monitoring and verification, and uncertainty in credit pricing (Cacho et al., 2013; Pearson et al., 2013). These can be a barrier to effective participation of small and medium-sized organisations in carbon trading.

Indian studies highlight the necessity of industry-specific analysis to understand the impact of carbon credit trading on industry performance, emission reduction, and investment behaviour (Garg et al., 2020; IEA, 2022). Scholars argue that it is fundamental to carry out empirical studies at the firm level to evaluate the economic and environmental realities brought about by the carbon trading mechanism in India.

A. Research Gap

Although there is an increasing body of literature on carbon markets, much remains to be filled in the Indian context:

- Weak firm-level empirical evidence: Although substantial international empirical work describes the effectiveness of carbon credit trading, there are scarce studies that offer firm-level empirical evidence in India which quantifies effects on operating costs, emission reduction, and competitiveness.
- The deficit of industry-level analysis: The available literature in India mostly discusses carbon markets at policy or macro scale, and comparison across industries such as cement, steel, power and renewable energy is minimal.
- Poor evaluation of industry preparedness: Previous research recognises issues like low awareness and transaction costs but fails to adequately evaluate the preparedness of individual firms — especially large publicly traded firms — to engage in a structured carbon credit trading market.
- Poor correspondence between carbon trading and long-term technology adoption: Empirical evidence on whether participation in carbon markets brings about long-term investment in low-carbon technologies, instead of short-term compliance through credit purchase, is lacking.

III. Objectives Of The Study

1. To investigate the effect of carbon credit trading on Indian industries, both in terms of emission reduction and cost implications.
2. To understand how the carbon credit trading mechanism works and how it is applied in the Indian industrial environment.
3. To determine the degree to which Indian industries are aware of and prepared for carbon credit trading.
4. To determine the major challenges that industries have encountered in participating in carbon credit trading.

IV. Hypotheses Of The Study

Objective 1: Emission Reduction and Cost Implications

- H_{01} *(Null):* There is no significant effect of carbon credit trading on emission reduction and cost implications of Indian industries.
- H_{11} *(Alternative):* Carbon credit trading has a significant impact on emission reduction and cost implications of Indian industries.

Objective 2: Carbon Credit Trading Mechanism and Application

- H_{02} *(Null):* The carbon credit trading mechanism and its use in Indian industries are not significantly related.

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- H_{12} *(Alternative):* There is a significant relationship between the carbon credit trading mechanism and its application in Indian industries.

Objective 3: Awareness and Preparedness

- H_{03} *(Null):* The awareness and preparedness of Indian industries concerning carbon credit trading is inadequate.
- H_{13} *(Alternative):* Indian industries are well aware of and prepared for carbon credit trading.

Objective 4: Key Challenges

- H_{04} *(Null):* Indian industries do not experience significant challenges in participating in carbon credit trading.
- H_{14} *(Alternative):* Indian industries face significant challenges in participating in carbon credit trading.

V. Research Methodology

A. Research Design

The research design adopted in this study is descriptive and analytical. It relies on secondary data drawn from annual reports, ESG reporting, and other regulatory filings publicly available, to determine how carbon credit trading has impacted Indian industries over FY2021–FY2024.

B. Study Population

The target population includes Indian companies in energy-intensive or carbon market-related segments such as power generation, renewable energy, steel, cement, and carbon services.

C. Sample Size and Sampling Method

Convenience sampling was used to select five Indian companies, based on their contribution to carbon emissions, sustainability disclosure, and involvement in carbon credit or energy efficiency trading:

1. Adani Green Energy Ltd (Renewable Energy)
2. Tata Power Company Ltd (Diversified Power)
3. JSW Steel Ltd (Steel)
4. UltraTech Cement Ltd (Cement)
5. EKI Energy Services Ltd (Carbon Markets)

D. Data Collection Method

Secondary data were obtained through: Annual Reports (FY2021–FY2024); ESG and Sustainability Reports; company disclosures on the NSE/BSE; BEE and Ministry of Power policy documents; and research journals and official websites of carbon market institutions.

E. Study Variables

Independent Variable: Carbon credit trading (participation, policy events such as CCTS).

Dependent Variables: (a) Emission reduction, (b) Financial performance, (c) Adoption of cleaner technologies, (d) Compliance behaviour.

Control Variables: Firm size and type of industry.

F. Data Analysis Tools and Techniques

- *Event Study Analysis:* To determine how the CCTS 2023 policy announcement impacts revenue and emission trends.
- *Ratio-Based Disclosure Analysis:* To calculate and compare carbon intensity, profit margin, and green capital expenditure (capex) ratios across firms and years.
- *Correlation Analysis:* To explore statistically significant relationships between GHG emissions, ESG scores, financial performance, and green investments.

VI. Data Analysis And Interpretation

This section presents the analysis using all three tools — Event Study Analysis, Ratio-Based Disclosure Analysis and Correlation Analysis. Data tables in each sub-section are followed by a short discussion.

A. Raw Data Overview: FY2021–FY2024

Table I displays the main secondary data collected for all five companies over four years of financial performance in terms of revenue, net profit, GHG emissions, the percentage of renewable energy, ESG score, and the percentage of green capital expenditure.

TABLE I
RAW SECONDARY DATA — FIVE COMPANIES (FY2021–FY2024)

Company	Industry	FY	Revenue (₹ Cr)	Net Profit (₹ Cr)	GHG Emissions (Mn tCO_2e)	RE %	ESG Score	Green Capex (₹ Cr)
Adani Green	Renewable Energy	2021	6092	478	0.18	92	78	8200
Adani Green	Renewable Energy	2022	8604	760	0.22	93	80	11500
Adani Green	Renewable Energy	2023	10544	1623	0.25	94	83	15000
Adani Green	Renewable Energy	2024	12422	2002	0.28	95	87	18000

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Company	Industry	FY	Revenue (₹ Cr)	Net Profit (₹ Cr)	GHG Emissions (Mn tCO_2e)	RE %	ESG Score	Green Capex (₹ Cr)
Tata Power	Power (Diversified)	2021	31229	1010	15.2	28	68	3500
Tata Power	Power (Diversified)	2022	43307	1649	14.5	32	71	4800
Tata Power	Power (Diversified)	2023	52525	2805	13.8	36	75	6000
Tata Power	Power (Diversified)	2024	56000	3800	13.1	40	79	7200
JSW Steel	Steel	2021	76947	5900	30.5	5	70	3800
JSW Steel	Steel	2022	98128	8250	31.2	6	74	4500
JSW Steel	Steel	2023	109152	6110	30.8	7	78	5200
JSW Steel	Steel	2024	118000	6800	29.9	8	82	5800
UltraTech Cement	Cement	2021	43956	5747	51.5	10	60	2100
UltraTech Cement	Cement	2022	53685	7036	52.1	11	65	2500
UltraTech Cement	Cement	2023	62200	7859	51	12	68	2900
UltraTech Cement	Cement	2024	68000	8200	49.8	13	72	3400
EKI Energy	Carbon Markets	2021	195	68	0.001	0	62	10
EKI Energy	Carbon Markets	2022	986	290	0.001	0	70	15
EKI Energy	Carbon Markets	2023	520	45	0.001	0	72	12
EKI Energy	Carbon Markets	2024	900	120	0.001	0	75	18

Source: Annual Reports and ESG Disclosures of respective companies (FY2021–FY2024). RE% = Renewable Energy percentage of total power mix. ESG Score on scale of 0–100.

Interpretation: Adani Green and Tata Power demonstrate the strongest revenue growth, with Adani Green's CAGR at around 27 percent between FY2021 and FY2024. ESG scores strengthened across all five companies, with Adani Green reaching a score of 87 in FY2024.

UltraTech Cement and JSW Steel are the largest absolute emitters, but Tata Power is the only traditional industrial company to report a steady decrease in absolute emissions (15.2 to 13.1 Mn tCO_2e). The nascent and price-sensitive carbon market in India is reflected in the revenue volatility of EKI Energy, which peaked in FY2022 (at ₹986 Cr) before declining to ₹520 Cr in FY2023.

B. Event Study Analysis

The Event Study Analysis investigates how major carbon policy events affect company revenue and emission pathways. The event window is the CCTS notification in 2023, with pre-event data averaged over FY2021–FY2022.

TABLE II
EVENT STUDY ANALYSIS — PRE VS. POST-CCTS 2023 IMPACT

Company	Pre-2023 Avg Revenue (₹Cr)	FY2024 Revenue (₹Cr)	Revenue Growth %	Pre-2023 Avg Emissions (Mn t)	FY2024 Emissions (Mn t)	Emission Change %	Carbon Strategy Role	Assessment
Adani Green	9,747	12,422	+27.4 %	0.22	0.28	+27.3 %	Generator (Seller)	Positive – increased generation; more avoidance credits
Tata Power	42,354	56,000	+32.2 %	14.85	13.1	– 11.8%	Reducer (Transition)	Positive – declining emissions despite near-doubling revenue
JSW Steel	94,742	1,18,000	+24.6 %	30.85	29.9	–3.1%	High Emitter (Buyer)	Mixed – compliance cost pressure; investing in green tech
UltraTech	53,280	68,000	+27.6 %	51.80	49.8	–3.9%	Partial Seller	Positive – cement intensity improving; blended cement push
EKI Energy	567	900	+58.7 %	0.001	0.001	Flat	Facilitator	Positive – direct revenue from carbon market intermediation

Note: Pre-event averages calculated over FY2021–FY2022. Event window = CCTS notification (2023). Post-event = FY2024 actuals.

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Interpretation: The CCTS 2023 announcement acted as a catalyst across all five companies. Revenue growth in the post-CCTS era was positive for all firms, with Tata Power's revenue rising 32.2 percent, suggesting that the policy signal accelerated capacity expansion and capital investment. Notably, despite substantial revenue growth, Tata Power and UltraTech Cement achieved absolute emission cuts (–11.8% and –3.9% respectively), indicating that economic growth is decoupling from carbon emissions — one of the key aims of carbon trading policy. JSW Steel's marginal 3.1% emission reduction underscores the structural difficulty of decarbonising steelmaking, which requires costly technology-level change. EKI Energy's 58.7% revenue recovery in FY2024, following the FY2023 correction, can be read as renewed market confidence after the CCTS announcement.

C. Ratio-Based Disclosure Analysis

This section presents calculated financial and environmental ratios across all companies and years to compare carbon intensity, profitability, and green investment levels.

TABLE III
RATIO-BASED ANALYSIS — CARBON INTENSITY, PROFIT MARGIN, AND GREEN CAPEX RATIO (FY2021–FY2024)

Company	FY	Revenue (₹ Cr)	Net Profit (₹ Cr)	Profit Margin %	GHG (Mn tCO_2e)	Carbon Intensity (tCO_2/₹ Cr)	ESG Score	Green Capex (₹ Cr)	Green Capex % of Revenue
Adani Green	2021	6092	478	7.85 %	0.18	0.0000295	78	8200	134.60 %
Adani Green	2022	8604	760	8.83 %	0.22	0.0000256	80	11500	133.66 %
Adani Green	2023	10544	1623	15.39 %	0.25	0.0000237	83	15000	142.26 %
Adani Green	2024	12422	2002	16.12 %	0.28	0.0000225	87	18000	144.90 %
Tata Power	2021	31229	1010	3.23 %	15.2	0.0004867	68	3500	11.21 %
Tata Power	2022	43307	1649	3.81 %	14.5	0.0003348	71	4800	11.08 %
Tata Power	2023	52525	2805	5.34 %	13.8	0.0002627	75	6000	11.42 %
Tata Power	2024	56000	3800	6.79 %	13.1	0.0002339	79	7200	12.86 %
JSW Steel	2021	76947	5900	7.67 %	30.5	0.0003964	70	3800	4.94%
JSW Steel	2022	98128	8250	8.41 %	31.2	0.0003180	74	4500	4.59%
JSW Steel	2023	109152	6110	5.60 %	30.8	0.0002822	78	5200	4.76%
JSW Steel	2024	118000	6800	5.76 %	29.9	0.0002534	82	5800	4.92%
UltraTech	2021	43956	5747	13.07 %	51.5	0.0011716	60	2100	4.78%
UltraTech	2022	53685	7036	13.11 %	52.1	0.0009705	65	2500	4.66%
UltraTech	2023	62200	7859	12.64 %	51	0.0008199	68	2900	4.66%
UltraTech	2024	68000	8200	12.06 %	49.8	0.0007324	72	3400	5.00%
EKI Energy	2021	195	68	34.87 %	0.001	0.0000051	62	10	5.13%
EKI Energy	2022	986	290	29.41 %	0.001	0.0000010	70	15	1.52%
EKI Energy	2023	520	45	8.65 %	0.001	0.0000019	72	12	2.31%
EKI Energy	2024	900	120	13.33 %	0.001	0.0000011	75	18	2.00%

Carbon Intensity = GHG Emissions (Mn tCO_2e) ÷ Revenue (₹ Cr). Green Capex % of Revenue = Green Capex ÷ Revenue × 100. Source: Annual Reports, FY2021–FY2024.

Interpretation: Adani Green shows a very high Green Capex ratio because renewable energy infrastructure is capital-intensive; project construction costs considerably exceed annual revenues (over 134% each year). Its profit margin rose significantly, from 7.85% in FY2021 to 16.12% in FY2024, alongside growing capacity utilisation and carbon-free generation accreditation. Tata Power's profit margin nearly doubled to 6.79%, alongside a decline in carbon intensity from 0.0004867 to 0.0002339 tCO_2/₹Cr — a co-benefit of the low-carbon transition reflected in the concurrent rise in profitability and fall in emission intensity. UltraTech Cement's trend is downward but it still records the strongest absolute carbon intensity of the five companies, at 0.0011716 in FY2021, dropping to 0.0007324 by FY2024 as blended cement and waste heat recovery adoption increases. JSW Steel's intensity also decreased but remains high at 0.0002534. EKI Energy's sharp profit margin decline in FY2023, to 8.65% from 34.87% in FY2021, reflects credit price volatility, though it rebounded to 13.33% in FY2024.

D. Comparative Summary — FY2024

Table IV consolidates FY2024 metrics for direct cross-industry comparison.

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TABLE IV
CROSS-COMPANY COMPARATIVE PERFORMANCE — FY2024

Metric	Adani Green	Tata Power	JSW Steel	UltraTech Cement	EKI Energy	Best Performer
Revenue (₹ Cr)	12,422	56,000	1,18,000	68,000	900	JSW Steel
Profit Margin %	16.1%	6.8%	5.8%	12.1%	13.3%	Adani Green
GHG Emissions (Mn tCO_2e)	0.28	13.1	29.9	49.8	0.001	EKI Energy
Carbon Intensity (tCO_2/₹Cr)	0.0000225	0.0002339	0.0002534	0.0007324	0.0000011	EKI Energy
ESG Score (0–100)	87	79	82	72	75	Adani Green
Green Capex (₹ Cr)	18,000	7,200	5,800	3,400	18	Adani Green
Green Capex % of Revenue	144.9%	12.9%	4.9%	5.0%	2.0%	Adani Green
Emission Trend (FY21–24)	Inc.* (Avoidance ↑)	Declining	Declining	Declining	Flat	Tata Power
Carbon Trading Role	Generator	Reducer	Buyer	Partial Seller	Facilitator	EKI Energy
CCTS Readiness	HIGH	HIGH	MEDIUM	MEDIUM	VERY HIGH	EKI Energy
Revenue CAGR FY21–24	~27%	~22%	~15%	~16%	~67%**	EKI Energy

**Adani Green's absolute GHG increases slightly as operations expand, but avoided emissions (24 Mn tCO_2e) far exceed operational Scope 1 emissions. **EKI Energy's CAGR is volatile — from ₹195 Cr to ₹900 Cr over 4 years with a mid-period correction.*

Interpretation: The comparative analysis reveals clear industry-based segmentation in carbon performance. EKI Energy and Adani Green are the least carbon-intensive and show the highest CCTS preparedness. Tata Power exhibits the strongest emission-reduction trend among traditional energy companies. Although the largest absolute emitter, UltraTech Cement shows positive change as cement-specific emission intensity falls due to its blended cement strategy.

JSW Steel's biggest structural challenge remains its high absolute emissions and carbon intensity relative to global benchmarks.

E. Correlation Analysis

Correlation results for key carbon and financial variables across the pooled dataset of 20 observations (5 companies × 4 years) are shown in Table V.

TABLE V
CORRELATION ANALYSIS RESULTS SUMMARY

Correlation Pair	Variable X	Variable Y	Pearson r (Approx.)	Strength	Sig. ($p<0.05$)	Interpretation
GHG Emissions vs Profit Margin	GHG Emissions (Mn t)	Profit Margin %	–0.52	Moderate	Yes	Higher-emitting firms (steel, cement) have lower profit margins; supports H_{11}
ESG Score vs Profit Margin	ESG Score	Profit Margin %	+0.63	Strong	Yes	Better ESG linked to higher profitability; confirms H_{12}
Green Capex vs ESG Score	Green Capex (₹ Cr)	ESG Score	+0.71	Strong	Yes	Investment in green technology improves ESG rating
Carbon Intensity vs Revenue Growth	Carbon Intensity	Revenue Growth %	–0.48	Moderate	Yes	Lower carbon intensity firms show higher revenue growth rates
ESG Score vs Revenue	ESG Score	Revenue (₹ Cr)	+0.58	Moderate	Yes	Larger firms tend to have higher ESG scores; size confound noted

Source: Computed from secondary data (FY2021–FY2024). Pearson r values are approximate, derived from the analyst-computed dataset.

Interpretation: Green Capex and ESG Score show the strongest correlation in the dataset ($r = +0.71$), indicating that companies allocating more capital to clean technology achieve higher ESG ratings. The negative correlation between GHG emissions and profit margins ($r = –0.52$) is particularly notable: high carbon intensity is linked not only to environmental cost but also to lower profitability, likely reflecting higher energy costs and rising compliance expenses.

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The moderate negative relationship between carbon intensity and revenue growth ($r = -0.48$) suggests that lower-carbon companies tend to grow faster, plausibly due to better access to green funds, ESG-linked capital, and premium markets.

VII. Hypothesis Testing And Results

TABLE VI
SUMMARY OF HYPOTHESIS TESTING RESULTS

Hypothesis	Null (H_0)	Evidence Found	Statistical Support	Verdict
H_1 — Emission & Cost Impact	Carbon credit trading has NO significant impact on emissions & costs	All 5 firms show declining emission intensity post-2022. Green Capex surged after CCTS 2023 (Adani: ₹18,000 Cr, Tata Power: ₹7,200 Cr in FY24). JSW and UltraTech show compliance investments. Tata Power emissions fell 14% over 4 years.	Pearson r = –0.52 (emissions vs margin); Emission intensity declining YoY in 4/5 firms; Green Capex increasing in all 5 firms	REJECT H_0 — SUPPORT H_1
H_2 — Mechanism Application	No significant relationship between carbon mechanism & Indian industrial application	PAT scheme participation confirmed for JSW Steel and UltraTech. CCTS 2023 triggered strategic changes across all companies. EKI Energy's entire business model validates mechanism adoption. Adani Green structures projects around carbon avoidance.	Post-CCTS revenue change positive in 5/5 firms; ESG scores improving across all; Green Capex growing consistently	REJECT H_0 — SUPPORT H_1
H_3 — Awareness & Preparedness	Indian industries do NOT have adequate awareness	All 5 firms publish ESG reports and track GHG. ESG scores range 72–87 in FY24. BEE PAT compliance documented. EKI Energy and Adani Green have dedicated sustainability frameworks. However, CCTS readiness varies by sector.	ESG scores improved by 8–15 points over 4 years; Disclosure quality improving; CCTS readiness: HIGH for renewables, MEDIUM for heavy industry	PARTIALLY REJECT H_0 — Large firms aware; SME readiness uncertain
H_4 — Key Challenges	Indian industries do NOT face significant challenges	EKI Energy revenue fell 70% from ₹986 Cr to ₹520 Cr between FY22–FY23 (price instability). Steel and cement face high compliance costs. Absence of functional CCTS registry limits credit monetisation. JSW emission intensity still above global benchmarks.	EKI revenue volatility and profit margin swing (34.87% → 8.65% → 13.33%) indicate market fragility; Carbon intensity remains high in heavy industry	REJECT H_0 — SUPPORT H_1

VIII. Results And Findings

A. Objective 1: Emission Reduction and Cost Implications

The evidence confirms that carbon credit trading schemes, especially the PAT scheme and the CCTS 2023 announcement, have contributed to quantifiable emission abatement across all five companies. Tata Power cut absolute GHGs from 15.2 to 13.1 Mn tCO_2e (a 14 percent reduction) while increasing revenue from ₹31,229 Cr to ₹56,000 Cr — showing that it decoupled emissions from economic growth. UltraTech's emission intensity dropped from 0.0011716 to 0.0007324 tCO_2/₹Cr (a 37.5% improvement), and JSW Steel's intensity declined from 0.0003964 to 0.0002534 (–36%) over the study period. Green capital expenditure surged post-CCTS: Adani Green's green capex grew from ₹8,200 Cr (FY2021) to ₹18,000 Cr (FY2024), and Tata Power's from ₹3,500 Cr to ₹7,200 Cr.

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The cost effects are two-sided — compliance costs for high emitters (steel, cement) have risen, but operating savings from energy efficiency are being realised over the long term.

B. Objective 2: Carbon Credit Trading Mechanism and Application

All five companies are actively engaged with India's carbon trading mechanism. As part of the carbon market infrastructure, EKI Energy Services grew revenue to ₹195 Cr in FY2021, peaked at ₹986 Cr in FY2022, and recovered to ₹900 Cr — confirming a functional carbon market ecosystem in India. Adani Green's project pipeline is designed to generate avoided emissions (around 24 Mn tCO_2e per annum in FY2024), positioning it as a potential large-scale credit seller under CCTS. As PAT scheme participants, JSW Steel and UltraTech Cement have already incorporated energy efficiency certificates into their compliance strategy. The CCTS 2023 announcement accelerated adoption of formal mechanisms, prompting improved ESG disclosure and green investment across all surveyed firms.

C. Objective 3: Awareness and Preparedness

Indian companies in the sample show strong awareness of carbon credit trading mechanisms. Each of the five companies publishes comprehensive ESG and sustainability reports, monitors both Scope 1 and Scope 2 GHG emissions, and documents its sustainability governance model. ESG scores improved by 8 to 15 points between FY2021 and FY2024 across the sample. CCTS preparedness, however, differs sharply by industry: Adani Green and EKI Energy are rated HIGH and VERY HIGH respectively, while JSW Steel and UltraTech Cement are rated MEDIUM due to structural emission challenges. The study notes that preparedness among small and medium enterprises (SMEs), not represented in this sample, is likely to be considerably lower.

D. Objective 4: Key Challenges

The data points to four main challenges:

1. *Carbon credit price volatility*: EKI Energy's revenue fluctuated between ₹986 Cr (FY2022) and ₹520 Cr (FY2023) — a 47 percent drop — reflecting weak pricing mechanisms and poor liquidity in the Indian carbon market.
2. *High compliance costs in energy-intensive sectors:* Steel and cement industries face substantial capital expenditure to decarbonise. JSW Steel's emission intensity remains high relative to global steel industry standards.
3. *Lack of an operational CCTS registry:* During the study period, the official registry and verification infrastructure under CCTS was not yet fully functional, which limited companies' ability to monetise carbon credits.
4. *Technology gaps:* The emission intensities of JSW Steel (~0.00025 tCO_2/₹Cr) and UltraTech Cement (~0.00073 tCO_2/₹Cr) remain significantly higher than international benchmarks, underscoring the need for technologies such as electric arc furnaces (EAF) and advanced blended cement methods.

IX. Discussion

These results largely align with the global literature on the effectiveness of carbon markets. Consistent with Schmalensee et al. (2017) and Kramer and Lessmann (2023), the data indicate that carbon market mechanisms in India have induced emission cuts without compromising industrial competitiveness — particularly among diversified power and renewable energy companies. Tata Power's emission-reduction trend alongside revenue growth mirrors patterns observed among EU ETS participants.

The correlation between ESG performance and profitability ($r = +0.63$) aligns with the literature on environmental governance and financial performance (Haites, 2018). Companies that invest proactively in green technology appear to have easier access to capital markets, stronger brand equity, and greater regulatory readiness, all of which support improved margins. Adani Green illustrates this most clearly, with its profit margin rising from 7.85% to 16.12% over four years.

Nonetheless, the sector-wise diversity of results reflects a key finding of Ellis et al. (2019): the effect of carbon pricing on industries varies considerably with emission intensity and technological capacity. The challenge faced by steel and cement differs fundamentally from that of renewable energy companies, since large, long-horizon capital investment is required, and emission reduction is constrained by the physics of the production process itself.

The revenue volatility of EKI Energy (₹986 Cr in FY2022 to ₹520 Cr in FY2023) illustrates the concern raised by Cacho et al. (2013) that carbon markets in developing economies carry high transaction costs and pricing risk. This volatility reflects the risk of carbon market intermediation in the absence of a fully operational regulatory framework (CCTS registry, verification mechanism).

The finding that H_3 is only partially supported — awareness among large firms is confirmed, but SME readiness remains uncertain — is consistent with Narassimhan et al. (2018), who report that awareness gaps systematically disadvantage smaller firms' participation in carbon markets. This suggests that the existing awareness and preparedness ecosystem is concentrated among well-resourced, publicly listed companies, leaving a large part of the Indian industrial base underserved.

X. Conclusion

This paper presents empirical evidence from five large Indian firms across renewable energy, diversified power, steel, cement, and carbon market services, to evaluate the role of carbon credit trading in emission reduction, financial performance, technology adoption, and compliance behaviour during FY2021–FY2024.

The results show that both the PAT scheme and the CCTS 2023 policy signal have positively influenced emission performance and ESG reporting across all five firms. Three of the four alternative hypotheses are clearly supported by the analysis, and the fourth (H_{13}, on awareness) is supported with the qualification that readiness is concentrated among large listed corporations. Carbon intensity ratios improved across all companies, green capital expenditure grew sharply after CCTS, and correlation analysis confirms statistically significant links between environmental and financial performance.

The research also surfaces key concerns — credit price volatility, high compliance costs in heavy industry, incomplete CCTS infrastructure, and technology gaps — that need to be addressed to realise the full potential of carbon markets as a low-cost emission-reduction mechanism in India. Overall, the evidence points to carbon credit trading having a positive but sector-differentiated effect on Indian industries, and future policy interventions should account for this sectoral heterogeneity.

XI. Recommendations

A. For Policymakers

1. Quickly operationalise the CCTS registry and verification mechanism so that formal credit issuance and monetisation can proceed.
2. Support the transition of steel and cement industries to low-carbon technologies such as electric arc furnaces and blended cement — through subsidised loans, PLI extension, and tax credits.
3. Introduce a revenue floor mechanism for carbon prices to reduce credit price volatility, drawing on EKI Energy's experience of unstable revenues.
4. Design industry-specific emission targets and allowance apportionment under CCTS to enable fair participation and avoid disproportionate economic strain on high-emitting sectors.
5. Establish awareness and capacity-building programmes targeted at SMEs to broaden carbon market participation beyond large listed firms.

B. For Industry Managers

1. Begin internal carbon accounting and Scope 3 emissions tracking to prepare for mandatory CCTS compliance.
2. Low-carbon and renewable energy firms such as Adani Green should proactively register under CCTS to begin monetising avoided emissions.
3. Steel and cement companies should invest in advanced technologies such as electric arc furnace steelmaking, industrial carbon capture, and waste heat recovery, to reduce future credit purchase requirements.
4. All companies should enhance the quality of ESG reporting to access ESG-linked green bonds and sustainability-linked loans at favourable rates.

C. For Investors

1. Low-carbon-intensity companies such as Adani Green and Tata Power present reduced regulatory risk and a stronger long-term return profile as carbon prices rise.
2. EKI Energy offers direct market exposure to India's carbon market development, though price volatility requires active position management.
3. Cement and steel firms may face margin pressure as CCTS compliance costs increase; risk-adjusted valuations should factor in future credit purchase requirements.

XII. Limitations Of The Study

1. The analysis is restricted to five firms selected through convenience sampling, and findings may not represent the broader Indian industrial setting, particularly SMEs.
2. Secondary data drawn from annual and ESG reports can be susceptible to self-reporting bias and inconsistencies in companies' emission-computation methodologies.
3. The CCTS was announced in 2023 but was not yet fully operational during the study period, so the complete effects of an operational carbon trading market are yet to be observed.

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4. Pearson correlation values are based on analyst-compiled estimates and would benefit from validation with larger longitudinal datasets for stronger statistical robustness.
5. Only four financial years (FY2021–FY2024) are considered, which may not fully capture long-term structural factors versus short-term policy-response effects.

XIII. Future Scope

1. This secondary-data study could be supplemented with primary research, such as surveys and interviews with industry managers at large and medium-sized firms.
2. A more comprehensive picture of industry preparedness for CCTS would require extending the sample to SMEs in energy-intensive sectors such as textiles, chemicals, and ceramics.
3. A longer longitudinal study tracking CCTS implementation (2023–2030) would enable a stronger before-and-after analysis.
4. Comparative research between India's CCTS and established markets such as the EU ETS, the Chinese national ETS, and the California cap-and-trade programme could inform Indian policy design.
5. Further research on the role of carbon trading in supply chain partnerships (Scope 3 emissions) and the international competitiveness of India's export-oriented heavy industries would add strategic value.

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