Corporate Pathway to Net-Zero: A System Dynamics Study of India's top companies' Decarbonisation Strategies

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Abstract

The transition to a low-carbon economy has placed corporate decarbonisation at the center of global climate action, particularly in emerging economies such as India. This study examines the pathways adopted by leading Indian firms to achieve net-zero emissions using a system dynamics perspective. Drawing on case evidence from top companies across manufacturing and service sectors, the research analyzes how internal capabilities, external pressures, and feedback mechanisms interact to shape decarbonisation strategies. The study integrates insights from systems theory to model the dynamic relationships between regulatory frameworks, stakeholder expectations, technological innovation, and corporate decision-making processes towards carbon emissions. The findings reveal that corporate pathways to net-zero are characterized by nonlinear interactions and feedback loops, where policy incentives, market pressures, and organizational capabilities jointly influence emissions reduction trajectories. While firms demonstrate significant progress in renewable energy adoption, energy efficiency, and sustainability governance, challenges remain in addressing Scope 3 emissions, technological constraints, and data transparency. The analysis highlights the importance of system-level coordination, including technological investments, clean energy adoption, and alignment with global climate initiatives, in achieving meaningful decarbonisation outcomes. This study contributes to the literature by offering a systems-based framework for understanding corporate climate strategies in emerging economies and provides managerial and policy implications for accelerating the transition to net-zero.

Keywords

Decarbonization initiatives, Causal Loop Diagram, Renewable energy investment, Net Zero Targets

1. Introduction

Corporate decarbonisation has become central to global climate mitigation efforts, particularly following the Paris Agreement. Businesses are increasingly adopting net-zero targets and aligning their strategies with frameworks such as the Science Based Targets initiative (SBTi), which encourages firms to set emissions-reduction targets consistent with limiting global warming to 1.5°C. Research on corporate sustainability stresses the need to integrate environmental objectives into core business strategies, rather than viewing them merely as compliance tasks. Porter and van der Linde (1995) suggest that environmental innovation can increase a company's competitiveness, while more recent studies highlight the strategic value of carbon reporting and the management of climate-related risks.

Emerging economies occupy a pivotal position in the global decarbonisation agenda, attributable to their expanding industrial sectors and escalating energy requirements. Academic discourse concerning developing nations contends that firms operating within these environments encounter distinctive obstacles, such as technological deficiencies, limited access to finance, and regulatory ambiguities (Newell & Paterson, 2010). Nevertheless, these economies are also presented with opportunities to implement advanced clean technologies and bypass conventional, carbon-intensive developmental trajectories.

In nations such as India, the process of corporate decarbonisation is shaped by the interplay of national climate policy frameworks, ongoing energy transitions, and competitive imperatives arising from integration into global supply chains (Lee, 2012). The growing engagement with international sustainability reporting mechanisms, exemplified by initiatives like the Carbon Disclosure Project (CDP), has incentivised corporations to systematically disclose greenhouse gas emissions and to formulate explicit climate-related objectives. India has set up its ambitious target of becoming Net Zero by 2070; which implies that various corporations aspire to contributing to this target by adopting climate mitigation strategies. Companies across sectors such as steel, cement, energy, automobile, and IT are implementing measures, including renewable energy procurement, energy-efficient manufacturing processes, the electrification of operations, and carbon capture technologies, to achieve their Net Zero targets. The leading corporations in these sectors, such as, Mahindra & Mahindra (Net Zero targeted by 2040), Infosys (Net Zero targeted by 2040), Tata Consultancy Services (Net Zero targeted by 2030), and JSW Steel (Net Zero targeted by 2050) have set up ambitious targets before 2070 for becoming net zero. These ambitious targets and investments towards these targets raise the need for this study, where we attempt to study the decarbonisation strategies of these leading companies from the system dynamics perspective.

This study attempts to deep dive into the following research questions:

RQ1: What are the major initiatives by leading Indian companies for implementing decarbonisation strategies?

RQ2: How are major decarbonisation strategies interlinked to achieve net zero targets of the leading Indian companies?

2. Theoretical Background

Climate change has emerged as one of the most pressing global challenges, prompting governments, international organizations, and businesses to adopt strategies aimed at reducing greenhouse gas (GHG) emissions. The private sector plays a critical role in global climate mitigation because corporations account for a substantial share of global emissions through their production processes, energy consumption, and supply chains (Hoffmann, 2018). Consequently, corporate decarbonisation has become a key component of global climate governance. The adoption of net-zero commitments by corporations has accelerated significantly following the Paris Agreement, which established the global goal of limiting temperature rise to well below 2°C and pursuing efforts to limit warming to 1.5°C. Net-zero commitments typically involve reducing emissions as much as possible and neutralizing residual emissions through carbon removal or offset mechanisms (Fankhauser et al., 2022). Over the past decade, an increasing number of companies have pledged to achieve net-zero emissions by mid-century, reflecting growing pressure from investors, regulators, consumers, and civil society (Black et al., 2021).

Academic literature on corporate climate action highlights the growing integration of decarbonisation strategies into core business operations, corporate governance, and long-term strategic planning (Kolk & Pinkse, 2005). These developments have led to the emergence of multiple global initiatives that provide guidance for corporate emissions measurement, target setting, disclosure, and climate governance. Research suggests that corporate climate action typically focuses on three areas: improving energy efficiency, transitioning to renewable energy, and transforming supply chains (Bansal & Roth, 2000; Hoffman, 2018). Scholars also highlight the role of stakeholder pressure, regulatory frameworks, and investor expectations in shaping corporate climate strategies.

Strategic management literature suggests that environmental challenges can create opportunities for innovation and competitive advantage. The natural resource-based view of the firm argues that environmental capabilities such as pollution prevention, product stewardship, and sustainable development can generate long-term competitive benefits (Hart, 1995). Similarly, research on environmental innovation indicates that environmental regulation can stimulate technological innovation and enhance competitiveness (Porter & van der Linde, 1995). More recent studies suggest that corporate climate strategies are shaped by multiple drivers, including regulatory pressures, market expectations, stakeholder demands, and reputational considerations (Bansal &

Roth, 2000). As a result, climate strategies have evolved from isolated environmental initiatives to integrated corporate sustainability strategies encompassing operational efficiency, technological innovation, and supply chain transformation (Weinhofer & Hoffmann, 2010).

A number of global initiatives have emerged to guide corporate climate action and provide standardized frameworks for emissions measurement, reporting, and target setting. These initiatives collectively form an institutional ecosystem that supports corporate decarbonisation efforts. One of the most influential initiatives is the Science Based Targets initiative (SBTi), which provides companies with methodologies to set emissions reduction targets consistent with climate science. The SBTi Corporate Net-Zero Standard requires companies to achieve deep decarbonisation across value chains and align corporate emissions trajectories with pathways that limit global warming to 1.5°C (Science Based Targets Initiative, 2021). The initiative has gained significant traction among multinational corporations seeking to demonstrate credible climate commitments (Weinhofer and Hoffmann, 2010). Corporate climate transparency is also supported by reporting platforms such as the Carbon Disclosure Project (CDP), which enables companies to disclose emissions data, climate risks, and sustainability strategies. The increasing use of CDP disclosures by investors reflects the growing importance of climate-related financial risks in investment decision-making (Tang & Luo, 2014).

Another key framework supporting corporate decarbonisation is the Greenhouse Gas Protocol, which provides globally accepted standards for measuring corporate emissions. The protocol categorizes emissions into three scopes: direct operational emissions (Scope 1), indirect emissions from purchased electricity (Scope 2), and emissions across the value chain (Scope 3). This accounting framework forms the foundation for most corporate emissions reporting systems (WRI & WBCSD, 2015).

Corporate climate initiatives also include sector-specific and thematic commitments. The RE100 initiative encourages companies to transition to 100 percent renewable electricity for their operations. Since its launch, RE100 has attracted participation from hundreds of global corporations committed to accelerating renewable energy adoption (Climate Group, 2022). Global coalitions such as the United Nations Global Compact and the We Mean Business Coalition further support corporate climate action by mobilizing business leaders, facilitating knowledge sharing, and advocating climate-friendly policy frameworks.

Corporate decarbonisation initiatives face some challenges, one major challenge is the lack of consistent definitions and standards for net-zero commitments. Corporate targets often differ in terms of emissions coverage, reduction timelines, and reliance on carbon offsets, making it difficult to compare corporate climate commitments (Black et al., 2021). Another challenge relates to the risk of greenwashing, where companies announce ambitious climate commitments without implementing meaningful operational changes. Critics argue that some firms rely excessively on

carbon offsets rather than pursuing deep emissions reductions within their core operations (Hale et al., 2021). Implementation challenges also remain significant. Although many companies have adopted long-term net-zero targets, relatively few have developed detailed transition plans outlining the technological and operational transformations required to achieve these goals (Fankhauser et al., 2022). Achieving deep decarbonisation often requires substantial investments in renewable energy, low-carbon technologies, and supply chain transformation. Furthermore, measuring emissions across global supply chains remains technically complex. Scope 3 emissions, which include emissions generated by suppliers and product use, are often difficult to quantify due to data limitations and inconsistent reporting practices (Tang & Luo, 2014).

Despite the growing body of literature on corporate climate strategies and net-zero commitments, several important gaps remain in the academic understanding of corporate decarbonisation. Existing studies largely focus on theoretical frameworks and empirical evidence from developed economies, particularly North America and Europe (Fankhauser et al., 2022; Hoffmann, 2018). While these studies provide valuable insights into corporate climate governance, they may not fully capture the institutional, regulatory, and market dynamics influencing firms in emerging economies. One significant gap relates to the limited empirical research examining how firms operationalize net-zero commitments in practice. Many studies document the rapid increase in corporate net-zero pledges following the Paris Agreement, yet there is comparatively little evidence on how these commitments translate into concrete operational changes within firms (Hale et al., 2021). In particular, the extent to which companies implement deep emissions reductions versus relying on carbon offsets remains insufficiently explored (Wright and Nyberg, 2017). Another important research gap concerns the integration of global climate initiatives such as the Science Based Targets initiative and the Carbon Disclosure Project into corporate strategy. While these frameworks provide standardized approaches for emissions disclosure and target setting, academic research has not fully examined how participation in these initiatives influences firm-level decision making, investment strategies, and innovation outcomes.

Furthermore, existing research often focuses on emissions reduction within firm boundaries, with limited attention to value chain decarbonisation. However, a substantial share of corporate emissions arises from upstream suppliers and downstream product use. Measuring and managing these Scope 3 emissions remains a major challenge for companies, and there is limited empirical research on effective supply chain decarbonisation strategies.

Another gap in the literature relates to sectoral differences in decarbonisation pathways. Industries such as energy, steel, cement, and transportation face significant technological and economic barriers to emissions reduction. Yet much of the existing research treats corporate climate action as a homogeneous phenomenon, overlooking important differences in technological feasibility, capital intensity, and regulatory exposure across sectors.

3. Research Methodology

This study uses systems theory to understand the feedback mechanisms of various decarbonisation strategies that impact net-zero carbon-emission targets. As decarbonisation requires systemic transformation of energy, industrial production, and supply chains, corporate climate initiatives are part of broader transitions supported by global frameworks such as the Science Based Targets initiative, which aligns corporate emissions-reduction targets with global climate goals. Systems theory helps explain how these various decarbonisation initiatives influence firm-level investments and actions towards carbon emission reduction and adaptation. We employed Casual Loop Diagrams (CLDs) to capture the integration of various decarbonisation initiatives. Two sample industries are chosen for this study: the automobile industry, representing the manufacturing sector, and Tata Consultancy Services (TCS), representing the services sector. The secondary published reports, such as sustainability reports, annual reports, and BRSR (Business Responsibility Sustainability Report), and the news articles[1].

4. Case Studies

4.1 Case Study 1: Mahindra & Mahindra

Mahindra & Mahindra (M&M) Limited, which was established in 1945, began its journey in the automotive sector by launching India's first utility vehicle. In the last seven decades, the automotive arm has developed into a multinational corporation that dominates the Indian sport utility vehicle (SUV) and light commercial vehicle segments and operates on six continents. From focusing solely on manufacturing internal combustion engine vehicles to embracing green mobility, M&M has gradually woven environmental, social, and governance (ESG) goals into its corporate strategy. Net Zero Targets and Strategic Framework Members of M&M have pledged to become a carbon neutral entity within their entire business group by the year 2040, which is ten years earlier than the Paris Agreement deadline. To ensure the target is truly science-based, the company aligned itself with the Science Based Targets initiative (SBTi) framework. In particular, M&M is targeting a 47% reduction in its Scope 1 and Scope 2 greenhouse gas (GHG) emissions per equivalent production unit and a 30% reduction in its Scope 3 emissions per unit sold by the year 2033, compared to its 2018 levels.

Decarbonization Strategies of M&M

M&M was the first Indian company to introduce an *internal carbon price*, at the rate of USD 10 per ton of carbon emitted. This tool channels the funds toward low-carbon technologies and support for renewable energy infrastructures. In addition, M&M was the first global signatory of

[1] Large Language Models (LLMs) are used to synthesise the data on the tangible impact of these initiatives.

the EP100 initiative, committing to doubling its energy productivity by 2030, a goal that the automotive division reached 12 years ahead of schedule.

Phase 1: Governance & Financial Engineering

i. **Implement Internal Carbon Pricing (ICP):** M&M established an ICP mechanism & applied a shadow price on carbon (initially set at $10 per ton of CO_2e with updates to higher levels in some reports) for capital expenditure proposals. This causes high-carbon projects to have reduced ROI steering investments toward lower-emission technologies.

ii. **Commit to Science-Based Targets (SBTi):** M&M set targets to reduce Scope 1 and 2 GHG emissions by 47% per equivalent product unit by 2033 (from a 2018 base year) and Scope 3 emissions by 30% per sold product unit by 2033 (from 2018).

iii. **Adopt "Double Materiality":** M&M adopted double materiality principles, assessing both financial risks from climate change and its own impacts on the planet. They identified risks across the value chain from procurement to end-of-life.

Phase 2: Operational Decarbonization (Scope 1 & 2)

i. **EP100 (Energy Productivity):** M&M was the first company globally to commit to doubling its energy productivity (economic output per unit of energy) by 2030 from a 2008-09 baseline. It achieved significant progress ahead of schedule in various sectors through upgrades like HVAC systems, motors, heat recovery & process innovations such as intelligent air handling in paint shops. These are the highest energy consumers in auto plants. For example, it reported substantial increases (e.g., 94% in the automobile sector and 87% in the farm sector in certain updates).

ii. **Transition to RE100 (Renewable Energy):** The company advanced toward renewable energy goals (aligned with RE100 principles in group efforts), investing in captive solar, wind, and hybrid renewable projects to enhance energy price stability and minimize Scope 2 emissions.

iii.**Zero Waste to Landfill (ZWL):** M&M certified numerous locations (e.g. 83 by FY25) as Zero Waste to Landfill (ZWL), recycling and reusing industrial waste to eliminate methane emissions from landfills and promote circularity.

Phase 3: Product Portfolio Transformation (Scope 3 - Downstream)

i. **Develop dedicated EV Architectures:** M&M shifted its drivetrain mix. It developed dedicated EV architectures like the INGLO platform, an electric-origin skateboard design with modular & scalable features for optimized battery placement, lower weight, better range & improved handling rather than relying solely on retrofitted ICE platforms. This supports faster consumer adoption of electric vehicles.

ii. **Diversify Last-Mile Solutions:** M&M diversified last-mile solutions by prioritizing electrification in commercial logistics fleets (such as 3-wheelers and small vans) where total cost of ownership parity is achieved sooner than in passenger cars, delivering immediate emissions reductions in logistics.

iii. **Bridge Technologies (CNG/Hybrid):** As a bridge, the company deployed lower-carbon technologies like CNG or hybrids for commercial vehicles in markets with limited EV infrastructure

Phase 4: Value Chain & Circularity (Scope 3 - Upstream & End-of-Life)

i.**Establish Organized Vehicle Scrapping:** M&M established organized vehicle scrapping through its CERO joint venture (with MSTC), India's first authorized recycler. This recovers steel (65-70% of a vehicle), aluminium, rare earth metals, and other materials, re-entering them into the supply chain and avoiding the high energy costs of virgin extraction.

ii. **Green Procurement Policies:**

o **Green Steel:** M& Commit to purchasing near-zero emission steel (Green Steel) for body structures.

o **Recycled Content:** Set targets for recycled content in non-structural parts (e.g., 20-40% recycled content in polymers & aluminium).

iii.**Supplier Decarbonization:** The company implemented supplier decarbonization programs, using purchasing power to enforce a Supplier Code of Conduct mandating environmental reporting, while building capabilities to help Tier 1 and Tier 2 suppliers establish their own carbon neutrality targets.

Phase 5: Nature-Based Solutions

i. **Afforestation at Scale:** M&M invested in large-scale afforestation through Project Hariyali, an ongoing tree-planting initiative (targeting millions of trees annually since 2007, with expansions to regions like Araku for coffee and fruit trees). This serves as a carbon sink and supports ecological restoration and livelihoods, applied only after maximizing direct reduction levers.

Table 1: M&M Automotive Division: 5-Year Decarbonization Progress

Initiative	FY 21	FY 22	FY 23	FY 24	FY 25

Strategic Targets (SBTi)	Committed to reduce Scope 1+2 emissions by 47% and Scope 3 by 30% by 2033 (Base 2018).	4% reduction in Scope 1+2 emission intensity achieved vs baseline.	43.6% reduction in Scope 1+2 emission intensity achieved vs baseline.	49% reduction in Scope 1+2 emission intensity achieved vs baseline.	56% reduction in Scope 1+2 emission intensity achieved vs baseline.
Energy Productivity (EP100)	Doubled energy productivity (100% improvement) against F09 baseline.	Achieved 74% increase in energy productivity vs F09 baseline.	Achieved 2.7x increase in energy productivity vs F09 baseline.	Achieved 64% increase in energy productivity vs F09 baseline.	Achieved 120% increase in energy productivity vs F09 baseline.
Renewable Energy (RE100)	10.12% share of renewable energy in the total electricity mix.	12% cumulative RE share; Commissioned 60 MWp captive solar plant.	Increased renewable electricity consumption by 221% year-on-year.	33% share of renewable energy in the total electricity mix.	30% share of renewable energy in the total electricity mix.
Green Mfg (Scope 1&2)	Igatpuri plant certified as India's first Carbon Neutral & Zero Waste to Landfill (ZWL) factory.	>80% of M&M locations certified as Zero Waste to Landfill (ZWL).	20 out of 23 manufacturing sites certified as Zero Waste to Landfill.	2.27 million sq. m of M&M sites certified as Zero Waste to Landfill.	83 locations across the Group certified as Zero Waste to Landfill.
Product Decarbonization (EVs)	Launched Treo Zor (Electric 3-wheeler cargo).	Announced Born Electric (BE) vision; Launched Alfa CNG (Passenger & Cargo).	Launched XUV400 (First e-SUV); Unveiled BE.05 & XUV.e9 concepts.	1.6% volume share for EVs and 1.8% for alternate fuels achieved.	Unveiled BE 6e and XEV 9e (Electric Origin SUVs).

Water Security	Water Positive at Group level.	44% of water recycled and reused; continued Water Positive status.	94% reduction in specific water withdrawal (Auto Sector) vs F22.	1.65 million m^3 groundwater recharged; 38.7% hazardous waste recycled.	91% Water Positive Index achieved; 33% of Group's water recycled & reused.
Afforestation (Carbon Sink)	19.08 million trees planted cumulatively under Project Hariyali.	20.65 million trees planted cumulatively (1.32 million in F22).	22.86 million trees planted cumulatively (2.21 million in F23).	1.8 million trees planted by M&M in F24.	Project Hariyali continues to expand green cover (Total cumulative count ongoing).

(Note: Data has been summarised based on previous years' integrated reports from Mahindra Group using the NotebookLM Tool)

Causal-Loop Diagram of M&M Decarbonisation Strategies

This CLD reinforces the integration of M&M initiatives into internal carbon pricing, energy mix, investments in carbon-offset technologies, and capital expenditures. Figure 2 presents the interlinkages of these initiatives and the feedback loops.

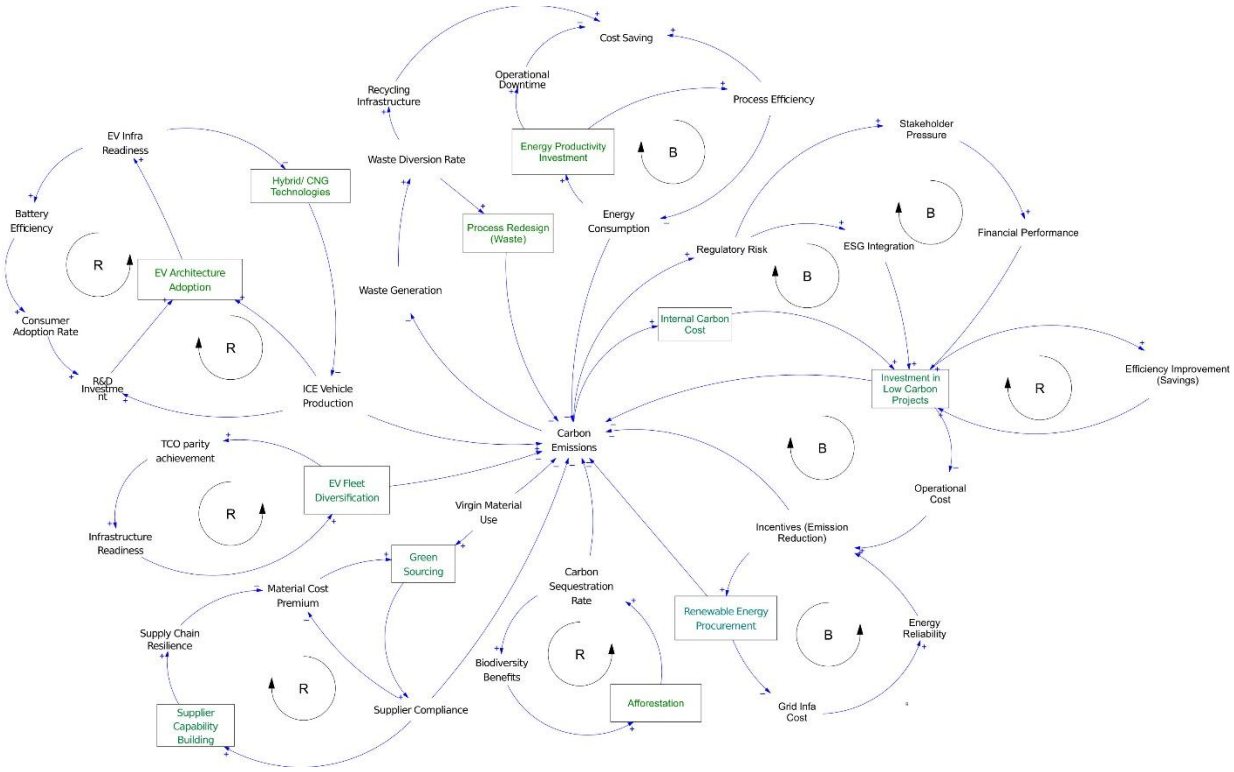

Figure 1: CLD of M&M Decarbonization Strategies

4.2 Case Study 2: Tata Consultancy Services

Tata Consultancy Services (TCS), a global leader in IT services and part of the Tata Group, has integrated a robust decarbonization strategy into its "Building on Belief" philosophy, aiming to achieve net zero emissions by 2030 for its direct operations and by 2045 across its entire value chain. The company's environmental stewardship is anchored by four key pillars: carbon footprint mitigation, water conservation, waste reduction, and biodiversity preservation. Central to this strategy is an aggressive transition to renewable energy, which already accounts for 74% of its total energy use, alongside the deployment of proprietary technology like TCS Clever Energy - an IoT-based platform that optimizes energy efficiency across its global campuses. By combining rigorous absolute emission reduction targets with "Sustainability by Design," TCS not only minimizes its own environmental impact but also provides digital solutions to help its global clients navigate their own green transformations

Decarbonization Strategies of TCS

The company's decarbonization efforts are executed through four primary "levers" designed to address specific emission factors.

i. Renewable Energy (RE) Transition (Direct Scope 2 Impact)

Accelerating the RE mix is the most powerful causal factor for absolute emission reductions.

- Quantitative Progress: The RE share in the total energy mix has scaled aggressively from 15.6% in FY 2021 to 79% by FY 2025.
- Implementation Mechanisms: This is achieved through a combination of onsite rooftop solar (cumulative capacity of 10.2 MWp), Power Purchase Agreements (PPAs), and Green-Tariff schemes with state utility providers. As of FY 2025, renewable sources account for 85% of total electricity consumption.

ii. Infrastructure and Operational Efficiency (The Building Lever)

With a real estate footprint of 40.6 million sq. ft., optimizing the energy intensity of physical campuses is critical.

- Green Building Standards: 71% of the India office space (28.8 million sq. ft.) is certified to IGBC standards, prioritizing energy-efficient architectural design.
- Technical Interventions: Key structural changes include upgrading to VRF systems with inverter technology, deploying modular UPS units (maintaining 90-95% efficiency at low loads), and using high-efficiency VFD-based chillers.
- AI-Native Optimization: The TCS Clever Energy platform utilizes IoT and AI/ML algorithms for real-time monitoring and predictive control of HVAC and lighting. In FY 2025, this platform resulted in 3.12 million kWh in avoided energy consumption.

iii. Green IT and Data Center Optimization (The Tech Lever)

Data centers are a high-density energy demand factor. The strategy focuses on improving Power Usage Effectiveness (PUE).

- Efficiency Gains: The weighted average PUE at main data centers was improved from 1.7 in FY 2024 to 1.59 in FY 2025.
- Virtualization and Consolidation: By consolidating servers and utilizing high-degree virtualized hosting, the company has reduced the physical power and cooling footprint of its 54 equipment rooms.
- Low-Carbon Compute: All data centers are now powered by 100% renewable electricity.

iv. Value Chain Management (Scope 3 Lever)

Addressing the footprint of suppliers and employees accounts for the majority of the organization's climate impact.

- Vision 25x25: This strategic operating model aims to have only 25% of the workforce in offices at any time, which delinks business growth from campus expansion and reduces commute-related emissions.
- Responsible Sourcing: The Supplier Sustainability Assessment Platform (launched FY 2023) profiles partners on environmental criteria. By FY 2025, 23.8% of value chain partners by spend had been successfully assessed.

Table 2: Investments in Technological Innovation by TCS

Fiscal Year	R&D Investment (Consolidated)	Capex for Environmental & Social Impact	Key Decarbonization Investment Focus
FY 2021	₹19.17 billion	₹31.39 billion	LED lighting transition, IoT energy management (Clever Energy), and 8.1 MWp solar capacity.
FY 2022	₹22.42 billion	₹29.64 billion	Modular UPS deployment, HVAC retrofits, and scaling solar to 10.2 MWp.
FY 2023	₹25 billion	₹30.63 billion	Green building certifications (64.6% of India portfolio) and cloud-based sustainability IP development.
FY 2024	₹27.51 billion	₹26.50 billion	Renewable energy procurement (Open Access PPAs) and AI-native energy optimization.
FY 2025	₹26.30 billion	₹49.77 billion	AI data center efficiency, hydrogen fuel systems research, and 71% green building certification.

Strategic Outcome

1. Infrastructure and Building Efficiency (The "Green Infrastructure" Lever)

Investment in physical assets is a direct causal driver for reducing Scope 2 emissions.

- Green Buildings: Major capital is deployed toward designing new campuses to IGBC/LEED standards and retrofitting older facilities. By FY 2025, investments reached a peak of ₹4,977 crore for environmental/social projects, supporting a portfolio where 71% of office space is green-certified.
- Technical Retrofits: Specific Capex is directed toward HVAC system upgradation (VRF systems with inverter technology), high-efficiency VFD chillers, and modular UPS units that maintain 90-95% efficiency even at low loads.

2. Technological Innovation (The "Green IT" and R&D Lever)

Research investments (reaching ₹2,630–₹2,751 crore annually) drive the development of intellectual property used to optimize the energy intensity of digital services.

- TCS Clever Energy: Sustained R&D investment in this IoT-based platform allows for real-time monitoring and predictive control of HVAC and lighting, resulting in 12,470 MWh of saved energy in FY 2025 alone.
- Data Centr Efficiency: Investments in server consolidation and advanced cooling technologies improved the weighted average Power Usage Effectiveness (PUE) from 1.7 in FY 2024 to 1.59 in FY 2025.
- Decarbonization Solutions: Investments have yielded a suite of IP, including:
    - TCS Software Carbon Footprinting Framework: Estimates energy consumption during the software development lifecycle to provide "Green Ratings".
    - TCS ESG Integrator: Tracks and manages Scope 1, 2, and 3 emissions across supply chains.
    - TCS DigiFleet: Provides real-time insights to optimize fleet operations for fuel efficiency.
    - TCS GoZero Hub: A research center focused on carbon management and circular economy solutions

3. Renewable Energy Transition (The "Energy Mix" Lever)

While the cost of renewable energy is often categorized within operating expenses (green tariffs), the company invests Capex in onsite rooftop solar, which remained constant at a capacity of 10.2 MWp through the latter reporting years.

These combined investments in efficiency and RE procurement increased the renewable energy share from 15.6% in FY 2021 to 79% in FY 2025.

Table 3: 5-Year Decarbonization Progress (FY 2021 – FY 2025)

Strategy Lever	FY 2021 Progress	FY 2022 Progress	FY 2023 Progress	FY 2024 Progress	FY 2025 Progress

Absolute GHG Emissions (Scope 1+2)	48.8% YoY reduction; specific emissions at 0.54 tCO2e/FTE.	66% cumulative reduction against FY 2016 baseline.	71% cumulative reduction (138k tCO2e); met initial 2025 target early.	80% cumulative reduction (96k tCO2e); overachieved near-term goals.	84% cumulative reduction (76k tCO2e); aligned with new 90% SBTi target.
Renewable Energy (RE) Mix	15.6% RE share in total electricity; 8.1 MWp onsite solar capacity.	37.2% RE share (112 GWh consumed); augmented Adibatla and Kochi solar.	55.2% RE share of total energy; switched to green tariffs in 6 Indian states.	74% RE share of total energy; increased green tariff and open access PPAs.	79% RE share of total energy (85% of total electricity).
Data Centre & IT Efficiency	1.66 weighted average PUE; 21 centers reached 1.65 target; 0.4 Mn kWh saved via consolidation.	1.65 PUE at corporate data centers; replaced 20 UPS and 30 cooling units.	1.66 weighted average PUE; 100% RE at Yantra Park data center.	1.70 weighted average PUE; reduced equipment room PUE from 1.88 to 1.76.	1.59 weighted average PUE; achieved 100% renewable power for all data centers.
Energy Saving Interventions	Defined "New Normal" via cognitive AI/ML; all offices transitioned to LED.	3,200 tCO2e avoided via building retrofits and modular UPS deployment.	4,219 MWh saved (3,016 tCO2e avoided) through Clever Energy and Resource Optimization.	16,301 MWh saved (11,671 tCO2e avoided) via HVAC and lighting optimization.	5.10 Mn kWh savings and 3.12 Mn kWh avoided consumption via Clever Energy.
Value Chain & Scope 3 Impacts	234.6k tCO2e footprint; business travel and commute emissions fell by >95%.	358.4k tCO2e footprint; became Jaguar Racing title partner to catalyze EV value chain.	366.6k tCO2e footprint; Assessment Platform launched; 20% of top 80% suppliers assessed.	471k tCO2e footprint; 17% of value chain partners (by spend) successfully assessed.	524k tCO2e footprint (32% reduction vs FY20); 23.8% of spend assessed for ESG.
Infrastructure & Circularity	60% India office space certified LEED Green Building; 100% recycling of e-waste.	64.4% India office space certified IGBC Green Building (28.2 Mn sq. ft).	64.6% India office space certified IGBC; pilot Zero Waste to Landfill (ZWL) at Hyderabad.	67.3% India office space certified IGBC; pilot ZWL facility achieved 99% waste diversion.	71% India office space certified (28.8 Mn sq. ft); 9 campuses achieved ZWL Certification.

(Note: Data has been summarised based on previous years' integrated reports from Tata Consultancy Services using the NotebookLM Tool)

Causal Loop Diagram of TCS

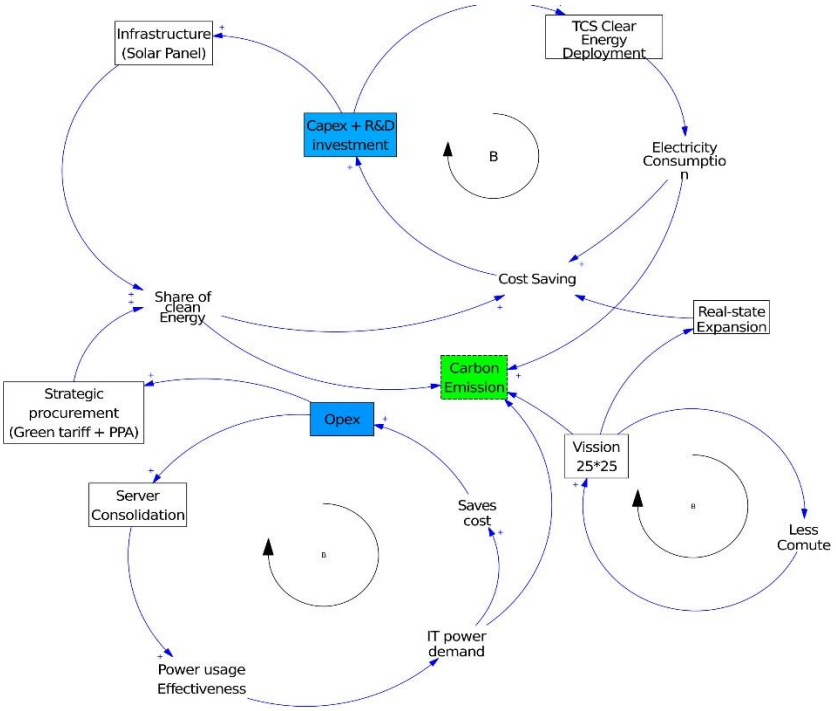

Figure 2: CLD of TCS Decarbonization Strategies

5. Discussions

This study examined corporate decarbonisation strategies through the lens of two leading Indian companies—Mahindra & Mahindra (M&M) and Tata Consultancy Services (TCS)—representing distinct sectors: manufacturing and information technology. The findings highlight both common patterns and sector-specific differences **i**n corporate approaches to decarbonisation, offering important insights into how firms in emerging economies operationalize climate commitments.

Convergence Toward Strategic Integration of Decarbonisation

A key finding is that both firms have moved beyond compliance-driven environmental practices toward strategic integration of decarbonisation into core business models**.** This aligns with prior literature suggesting that corporate climate strategies are increasingly embedded in long-term strategic planning rather than treated as peripheral sustainability initiatives (Kolk & Pinkse, 2005; Hoffmann, 2018). For instance, M&M has incorporated sustainability into its manufacturing strategy through investments in electric mobility, renewable energy adoption, and energy-efficient production processes. Similarly, TCS has integrated decarbonisation into its operational strategy by focusing on energy-efficient IT infrastructure, green buildings, and renewable energy sourcing. This convergence supports the Natural Resource-Based View (NRBV)**,** which posits that environmental capabilities can serve as sources of competitive advantage (Hart, 1995). Both firms

demonstrate that decarbonisation is not merely a compliance requirement but a strategic capability linked to long-term value creation.

Sectoral Differences in Decarbonisation Pathways

Despite similarities in strategic intent, the analysis reveals significant sectoral variation in decarbonisation approaches**.** M&M, as a manufacturing firm, faces higher direct emissions (Scope 1 and Scope 2) due to energy-intensive production processes. Consequently, its decarbonisation strategy emphasizes: electrification of vehicles, energy-efficient manufacturing, adoption of renewable energy, and exploration of green technologies. In contrast, TCS, as a service-oriented firm, has relatively lower direct emissions but a greater focus on Scope 2 and Scope 3 emissions, particularly related to data centers, office infrastructure, and employee travel. Its strategies emphasize on renewable energy procurement, green IT infrastructure, digital solutions for sustainability. These differences highlight the importance of industry context, supporting prior research that decarbonisation pathways are highly sector-specific (Weinhofer & Hoffmann, 2010). Hard-to-abate sectors require technological innovation and capital-intensive solutions, whereas service sectors can achieve rapid emissions reductions through energy efficiency and renewable energy transitions.

Systems Perspective: Interconnected Nature of Decarbonisation

The study also highlights the relevance of a systems perspective in understanding corporate decarbonisation. Both firms operate within complex ecosystems involving suppliers, customers, regulators, and technology providers. Decarbonisation efforts extend beyond firm boundaries, particularly in addressing Scope 3 emissions across supply chains. For instance, M&M must engage with suppliers to reduce emissions embedded in automotive components, while TCS must address emissions related to client operations and service delivery. This supports Systems Theory**,** which conceptualizes organizations as open systems interacting with multiple external actors. Decarbonisation is therefore not an isolated firm-level activity but part of a broader socio-technical transition toward a low-carbon economy.

6. Conclusion

This study makes an attempt to integrate decarbonization strategies with system theory and causal loop diagrams to provide a blueprint for other manufacturing and service firms to pave their decarbonization pathway to contribute to the net zero targets of India and the Nationally Determined Commitments towards clean energy, carbon offset technologies, and energy mix management.

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