

Green Supply Chains in Manufacturing Sub-Sectors—Taking the New Energy Vehicle Industry Chain as an Example

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Abstract. The ESG importance of the new energy vehicle supply chain has become extremely important under the national dual carbon goals. Nevertheless, there is limited research on the stream of ESG differences and synergies between the battery-to-vehicle segments. It focuses on Contemporary Amperex Technology Co (CATL) and GAC Toyota Group and applies the case analysis according to the Huazheng ESG rating to study the performance differences in ESG of the company and find possible avenues of cooperation. Studies further show that CATL attention is on carbon reduction and recycling of wastebatteries in the environmental aspect whereas GAC Group is sharp on setting up of zero-carbon factories and supply chain environmental regulation. In the social aspects, CATL has improved training on the supply chain, but GAC Group has comparatively loose social management regulations and a high level of charitable donations. In terms of the governance aspects both the businesses have adopted three level organisational structure. In creating a joint business framework which incorporates elements of technology sharing, exchange of information and alignment of policies, every section of the value chain in the industry must be aware of its unique attributes and the proprietorship of the same. Lack of representativeness of the chosen case studies and the depth of information will also be noted in this paper, which will serve as reference points in the future development of the ESG studies in industrial chains.

Keywords: Green supply chain, ESG, New energy Vehicle.

1. Introduction

Driven by both the national dual carbon goals and the strategy to build a manufacturing powerhouse, the new energy vehicle industry has emerged as a benchmark sector for the green transformation of manufacturing. In the first half of 2025, China's new energy vehicle production and sales grew by 37.9% and 39.8% year-on-year respectively, with the industrial chain's scale exceeding five trillion yuan [1]. However, insufficient coordination in ESG practices across the upstream and downstream segments of the industrial chain has directly impacted the efficiency of value transmission within green supply chains.

Today the studies that examine the interconnection between green supply chains and corporate development have assumed a multidimensional approach. Although China Association of Automobile Manufacturers white paper provides the basic operational environment of the industry

in 2025, the supply chain optimisation models are excessively utopian as specified by Ke Yutong and Zhang Yinan. Secondly, ESG research studies are not methodologically rigorous [1-3]. Guan Xin et al. make use of data to show the driving impact of the standardisation of unified performance on the act of green innovation, whereby the dynamic game-theoretic game is statified [4]. Jiang Enlu et al. present a digital technology, which can break this constraint, but they do not take into account the financial problems of applying blockchain to SMEs and data sovereignty conflicts [5]. Thirdly, the relevance of technology based solutions is doubted. In research by Roh et al. the mediating role of green marketing was confirmed in the electronic sector in South-Korea but their results do not consider a case of institutional shock due to subsidy phase-outs in implementation of the same strategy to the Chinese policy-driven market [6]. Rashid et al., emphasize the situation of the developing countries and consider big data and AI as black boxes without decomposing their role in the life cycle assessment algorithms embedded within the procurement decision-making processes, making their solution too inadequately implementable [7]. Overall this is an area which needs to be discussed in terms of all dimensions as it would ensure that research is not disconnected with the reality of industrial practice.

The research focuses on ESG performance and synergistic processes of new energy vehicle suppliers on both sides of the chain in this paper. It chooses CATL which is privately-owned battery manufacturer and is a representative of the upstream sector and GAC Group that is a state-owned vehicle manufacturer and is a representative of the downstream sector as the research subjects following a cross- case analysis approach [8-10]. Based on the Huazheng ESG Rating Framework, this paper examines the personal and cooperative ESG performance of both organizations in the environmental, social, and governance aspects [11]. The Huazheng ESG Rating Framework uses three pillars namely the Environmental (E), Social (S) and Corporate Governance (G). It includes 16 themes and 44 key indicators with ratings on nine levels, which are AAA to C (0-100) according to the set standards, real-time changes include market feedback and experts panel contribution. This research will explore the technological advantages of each of the companies and condense ESG synergistic models that can be emulated and, thus, serve as a point of reference in the formation of green industrial chains and eventually the green supply chain.

2. Contemporary Amperex Technology Co

Huazheng applies a "core issue priority" weighting rule to the new energy vehicle sector, assigning highest weightings to high-impact, short-term metrics (such as carbon reduction and green factories), while non-core issues receive zero weighting. CATL's strategic positioning precisely aligns with these high-weighting indicators, creating a positive feedback loop of "strategy-practice-scoring" [9,10].

2.1. Environmental dimension (E)

The Huazheng Environmental Dimension comprises five major themes and twelve key indicators, with the new energy vehicle sector's core weightings concentrated across climate change, resource utilisation, and environmental management. CATL leads in high-weighting metrics through technological innovation and full-cycle management, guided by its objectives of achieving operational carbon neutrality by 2025 and full value chain carbon neutrality by 2035. Regarding climate change, CATL independently developed its Carbon Cloud System to track 342 carbon nodes, making it accessible to vehicle manufacturers. It also formulated the "Guidelines for Calculating the Carbon Footprint of Power Batteries throughout Their Entire Life Cycle" and issued green bonds to

support suppliers' green electricity conversion initiatives. These measures have reduced emissions intensity per unit of product by 20.97% year-on-year. Nine factories have obtained PAS 2060 carbon neutrality certification, with green electricity usage reaching 74.51%. Green financing exceeding RMB 50 billion has been allocated to zero-carbon technology R&D. Regarding resource utilisation, CATL provides technical assistance for waste recycling to cathode material suppliers, achieves 95% water reuse in production, and increases Kirin battery material utilisation to 72%. In 2024, it recycled 120,000 tonnes of spent batteries and regenerated 15,000 tonnes of lithium carbonate, with circular production capacity accounting for 30% of total output. Concurrently, it established the Bangpu Recycling Alliance with other automakers, achieving over 60% coverage for battery repurposing. Regarding environmental pollution, CATL achieved 100% compliance in exhaust gas treatment and 100% safe disposal of hazardous waste, with no environmental penalty records. In environmental management, its core factories obtained ISO 14001 certification, while conducting carbon reduction audits on 60 key suppliers. CATL's breakthroughs in high-weighting indicators such as "carbon reduction" and "resource recycling" have significantly boosted its ESG scores. Its green technologies have influenced and spearheaded a value-added effect: "corporate emissions reduction → collaborative progress across the supply chain → establishment of new industry standards." This further solidifies CATL's industry-leading ESG performance while fully leveraging the advantages of private enterprises in terms of greater financial flexibility and freedom in research direction [9,10].

2.2. Social dimension (S)

The Huazheng Social Dimension is aimed at the weightings of the new energy vehicle sector to the supply chain management, human capital and social contribution. The main deliverable of CATL to the social facet is the institutional design and resource allocation [5,9]. In terms of the supply chain management, CATL has set up system of CREDIT sustainable audit. It uses its leadership in the industry to commit its significant suppliers to meet a green electricity consumption rate of at least 50 percent by 2026, and collaborated with Nangang Steel and Fangda Group to develop a zero-carbon supply chain. At the same time, they held 90 supplier ESG trainings and a program designed as Supply Chain Green Financing. Using their credit status, CATL helps to cut down the financing expenses of small and medium suppliers, hoping to overcome the credit issues of borrowing and financing among SMEs. In terms of the human capital, CATL created a training system termed as, Three-Capabilities Model, which trains role specific competencies to increase core talent retention rates. Such partnerships with college vocationals had created the training bases of practical training that helped decongest the shortages of labour in the industrial chain. Wellbeing of the employees is a priority area and the flexible working arrangements are considered to have positive effect on employee wellbeing, and the suppliers are checked against the labour rights as an element of procurement scoring. There are social contributions which are creating an energy technology excellence foundation to develop new talent in the area, and collaborating with automaker companies in the Rural Charging Network project to increase the uptake of electric vehicles in the lower-end markets. With respect to data security and privacy, CATL has developed data classification and grading system. In addition to securing its own activities, it has created battery safety data interfaces and invented the so-called digital twin technology to prevent the chances of misusing user data. The supply chain responsibility management and human capital investment of CATL directly corresponds to the need of Huazheng Securities in its high impact + medium timeframe indicator, which brings synergistic effects between the organizational responsibility of CATL and its supply chain management and human capital dimension [9,10].

2.3. Governance dimension (G)

The Huazheng Governance Framework encompasses six major themes and 19 key indicators, with core weightings concentrated on governance structure, disclosure quality, and business ethics. CATL delivers its primary contribution through a "three-tier governance structure coupled with digitalised oversight". Regarding governance structure, CATL has established a three-tier framework comprising the Board of Directors, the Sustainability Committee, and subsidiary working groups to strengthen internal ESG management. It spearheaded the formation of the New Energy Industry Chain ESG Alliance and integrated an ESG risk assessment matrix covering eight domains including supply chain and technological iteration, thereby driving ESG management across the industry chain. Regarding disclosure quality, CATL publishes ESG reports adhering to the GRI Standards Core option, issues the "Supply Chain ESG Disclosure Guidelines", and leads the industry in collective compliance to enhance coordination capabilities. In business ethics, CATL conducts integrity education, operates a whistleblowing platform, and promotes supplier signings of the "Business Ethics Charter". Rationale for Score Improvement: CATL's ESG governance framework and disclosure quality align with Huazheng Securities' "high impact + short timeframe" core metrics. By enhancing its own governance capabilities and extending these standards throughout the industrial chain, CATL not only safeguards its own governance quality but also elevates the governance levels of other enterprises within the chain. This creates a virtuous cycle of "governance benchmarking – standard dissemination – ecosystem optimization" [9,10].

2.4. Total

The chosen green industrial chain strategy of CATL focuses on green technological breakthroughs, joint environmental programmes and exporting standards exactly conforms to the ESG score logic of Huazheng Securities to accomplish a closed cycle of environmental strategies implementation, metric improvement and ratings improvement. On the basis of being a private enterprise and strong upstream supply chain, CATL preemptively determines new technologies and innovative ways to minimise pollution and emission and shares the strategies with other firms in the industrial chain. At the same time, through its central position in leadership, the firm leads in the development of many codes of conduct, strictly applying it themselves and monitoring it among other supply chain stakeholders.

3. GAC Toyota

The weighting rule implemented by Huazheng Securities takes into consideration a more weighting to supply chain collaboration and policy responsiveness with vehicle manufacturers represented by the GAC Group, where the weight indicator of high impact and short timeframe occupy more than 60 percent of the weighting. The strategic location of GAC Group is exactly logical and the system of policy adoption and practical implementation and score improvement constitutes the closed circle [9,11].

3.1. Environmental dimension (E)

The Huazheng Environmental Dimension has six major themes and 16 key indicators, and the core of weightings of the automotive manufacturing industry is concentrated into three themes, namely climate change, resource circulation, and environmental management. The pioneering innovations have anticipated carbon neutrality in production and closed loop recycling systems that demonstrate

GAC Group centred around its GLASS Initiative has enjoyed breakthroughs in high-weighting indicators. In relation to climate change, GAC Group has created carbon emissions accounting interfaces with the battery suppliers, jointly created end-to-end carbon footprint standards with CATL on the "vehicle-battery" lifecycle and has adopted a three-tier accounting system, which has helped the company to achieve much lower emissions per unit of product. At the same time, it also published its 14th Five-Year Plan of carbon neutrality, which stated that it had already attained 0-carbon factory commissioning, and three of its plants received ISO 50001 energy management certification. In terms of resource utilisation, GAC Group created the Youpai Energy project that will allow battery repurposing by assisting industry leaders in creating a new battery regeneration system and improving the resource recovery rate. At the same time, it has enhanced the recycled water use and innovated lightweight material technologies that are owned by them which are marketed among colleagues and minimized material wastage throughout the supply chain. GAC Group established supply chain ESG audit system and Supply Chain Green Procurement Guidelines to the environment management, with the metrics of carbon reduction included in the supplier qualification weighting. In terms of environmental friendliness, GAC Group obtained RMB 8 billion green credit funding on the construction of zero-carbon factories. At the same time, it entered into an agreement with GAC Financial Services to subsidise the interest of suppliers on their loans, which are green financing [9,11].

3.2. Social dimension (S)

The Huazheng Social Dimension is a set of five large themes and 13 key indicators where the core weightings of vehicle manufacturers were put on supply chain management, social contribution and product responsibility. By using its state-owned enterprise benefits, the GAC Group has made rural revitalisation + supply chain empowerment its priority initiatives, although improvement in social dimension management is still wanting. Concerning supply chains, GAC Group has created an ESG risk grading system on suppliers and opened its ESG risk database to small and medium-sized suppliers and offered compliance diagnostic assessment services. At the same time, they introduced the platform, called the Supply Chain ESG Empowerment Programme, and collaborated with CATL to create a base of battery recycling training, with a total of more than 1,000 technicians of the supply chain being trained every year. In terms of social contribution, in 2024, GAC Group spent more than RMB 50 million on the community welfare programs, which cumulatively spent over RMB 3.433 billion on charitable activities. They also carry out the public welfare programs to facilitate the development of agriculture in the aided region, using their status as state-owned enterprises and the terminal distribution channels at their disposal [6]. In terms of human capital, the Group offers extensive training of employees and has a significant focus on employee wellbeing post which the occupational health coverage is 100%. It is also in partnership with vocational institutions in order to create new energy training bases combating the labour shortages and employment issues that graduates present. GAC Group has established 50 carbon-neutral 4S dealerships in product stewardship as its dealers are being prompted by carbon-neutral goals to deliver on end-user low-carbon experiences [9,11].

3.3. Governance dimension (G)

The Huazheng Governance Framework encompasses four major themes and twelve key indicators, with core weightings for vehicle manufacturers focused on board independence, compliance and risk management, and business ethics. Leveraging the dual governance advantages inherent in state-

owned enterprises (Party Committee oversight + Board decision-making), GAC Group employs a "compliance-first + digital risk management" approach. However, there remains scope for improvement in the depth of disclosure regarding governance framework details. Regarding board and ESG governance, GAC Group maintains a 45% proportion of independent directors. The board receives quarterly ESG progress reports and incorporates KPIs such as carbon emissions and compliance incidents into executive performance contracts, with a weighting of no less than 20%. For compliance and risk management, the Group has established a "1+7" digital compliance platform enabling T+1 day alerts for external regulatory changes. Across 1,847 compliance reviews at all levels, no penalties were incurred. Concurrently, the "Sky Eye" audit system was launched, achieving 100% online spot checks in three high-risk areas: procurement, tendering, and fund management. This identified 112 issues annually, with a 100% rectification closure rate [6]. Regarding business ethics and anti-corruption, GAC revised eight systems including the Rules of Procedure for the Discipline Inspection Committee and the Real-Name Reporting Reward Measures, establishing a "five-department coordination" oversight system (Discipline Inspection, Audit, Finance, Legal, Risk Control). Concurrently, integrity training was conducted, and during supply chain supervision, seven suppliers were blacklisted or restricted from transactions, recovering economic losses of RMB 32 million. Regarding information disclosure and investor communication, GAC Group has received an A-grade evaluation for information disclosure from the Shanghai Stock Exchange for twelve consecutive years. It actively convenes earnings briefings and investor open days. Furthermore, it pioneered the industry's first "visualised" ESG data platform, disclosing 128 underlying indicators across ten categories to investors, ensuring corporate data is traceable and verifiable [9,11].

3.4. Total

GAC Group's green industrial chain strategy, centred on "policy alignment, technological synergy and ecosystem co-creation", precisely aligns with Huazheng Securities' ESG scoring logic. This forms a positive feedback loop between strategy, metrics and ratings while clarifying areas for optimisation. Leveraging its state-owned enterprise status and leading position in the downstream sector, GAC Group can provide comprehensive oversight and a safety net for the entire industrial chain. Its SOE identity lends greater authority to the regulations and codes it spearheads, encouraging more enterprises to voluntarily comply. Furthermore, its dominant downstream position means that by focusing on internal operations alone, it can significantly bolster the development of green industrial chains. In essence, similar enterprises can emulate its approach: internally implementing stringent high standards to achieve low-carbon environmental protection while simultaneously driving other enterprises within the chain; externally, leveraging its SOE status to spearhead the establishment of standards and codes of conduct, and overseeing their implementation.

4. Comprehensive analysis and research implications

4.1. Collaborative outcomes and methods

The CATL and GAC Group worked together to reach an average of 19.5% in terms of carbon emission intensity reduction along the supply chain, use of more green electricity i.e. 35% and recover an average of 150,000 tonnes of materials and recycle 15,000 tonnes of lithium carbonate respectively through their various initiatives. More than 200 suppliers were involved in ESG

training where 60 core suppliers were starting green electricity upgrades. On the metrics of carbon footprint, they standardised the definitions of data, low cost of coordination and stability of supply chains by joint risk alerts. There exists a very strong strategic alliance between GAC Group and CATL in the construction of green industrial chains. Both enterprises increase the upstream-downstream synergy with the help of green finance. CATL makes its Carbon Cloud system and battery recycling technology available, GAC enables vehicle carbon accounting and recycling networks. They collaboratively set standards, resulting in closed-loop battery management, talent development and data standardisation to drive supply chain decarbonisation and facilitate the dual carbon strategy. Under this collaborative system, the two companies work together in three fundamental areas namely, technological innovation, supply chain integration and sustainable development. CATL is a globally best battery manufacturer and industry dominant thus it offers high performance as well as high safety batteries to GAC Group in the context of technological innovation. In their turn, GAC Group incorporates these innovated battery technologies in their new energy vehicles and supplement each other with technological advantages and forms of mutually beneficial development. Related to synergy in supply chains, the partners have incorporated a closed loop mechanism of collaboration system that views the realm of procurement of raw materials, manufacturing and recycling. This has the benefit of minimising carbon emissions in the chain of industries, as well as improving efficiency in resource utilisation.

4.2. Research implications

The deep collaboration between GAC Group and CATL offers significant research insights for establishing green supply chains in the new energy vehicle sector. Their technological co-innovation has disrupted the linear relationships inherent in traditional supply chains. Through a partnership model centred on "leading enterprises + core suppliers", they have contributed innovative solutions across three key areas: technological research and development, supply chain integration, and ESG. Firstly, the two companies have established a comprehensive collaborative mechanism spanning from R&D to application, constructing a networked system. Secondly, through joint laboratories and technology-sharing platforms, they have collectively advanced green industrialisation. Concurrently, they have integrated ESG principles into their collaborative supply chain management. By establishing standardised environmental and sustainability benchmarks, they enable the entire industrial chain to achieve greener transformation. Enterprises sharing similar ownership structures or industrial characteristics can emulate this three-dimensional collaborative mechanism: "technology alliances + standard-setting + shared green benefits". Enterprises positioned upstream in the industrial chain may advance shared technological R&D by establishing collaborative R&D platforms. Midstream enterprises should comply with industry procurement regulations, implementing green and low-carbon procurement practices. Downstream service providers, meanwhile, should jointly establish rational, standardised, and efficient recycling platforms. This ultimately achieves a closed-loop ESG enhancement for green supply chains, propelling the entire industry towards efficient, low-carbon, and sustainable development. Practically, enterprises may explore establishing closed-loop collaborative mechanisms to achieve efficient resource recycling or unify ESG production standards for peer enterprises. Shared R&D platforms should be developed to advance environmental technology innovation. All companies must commit to high-level data disclosure to facilitate unified monitoring and regulation by leading enterprises and government bodies.

5. Conclusion

Two firms considered in this paper include CATL, which is a privately-owned company located at the upstream of the supply chain of new energy vehicles, and GAC Group, which is a state-owned company located at the downstream of the supply chain. By employing the Huazheng ESG rating system, ESG performance and collaborative mechanisms of enterprises in the two ends of the supply chain are revealed. The research fills the information void in the current literature on the lack of collaborative analysis and cross-case studies on the supply chain new energy vehicle, which provides most of the relevant enterprises with a reference framework of synergistic mechanisms. The already existing companies can tap into the three-dimensional collaborative framework that is comprised of technology alliances + regulatory establishment + green mutual benefit.

There are three weaknesses of the study. To begin with, there is limited representativeness in the cases since only top-most private enterprises and state-owned enterprises have been covered. Second, it does not include the changing variables like technological change and the change in policies and it is challenging to show the evolutionary logic in the long term. Future studies can be improved to make the results more generalisable, with the inclusion of the enterprises of different sizes and in different geographical regions. The use of internal company data would enhance the research on social and governance aspects, and the case would be tracked on a long-term basis to complement dynamic views. Further building of green supply chain research framework would be achieved by extending research into ESG synergies to other parts of the supply chain, including lithium mining and component manufacturing.

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