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Strategies of Green Transformation in Production Operation of Power Battery Enterprises Under the Dual-Carbon Target

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ABSTRACT

Following the Paris Climate Agreement, global efforts to reduce carbon emissions have shifted from policy commitments to practical implementation. Electricity generation and transportation remain two of the largest sources of carbon emissions. Although new energy vehicles (NEVs) contribute to the decarbonization of the transportation sector, the production of power batteries continues to generate substantial emissions. This study examines the green transformation strategy of CATL under China's "dual-carbon" targets. As a global leader in the power battery industry and the first company in the sector to introduce a carbon neutrality plan, CATL provides a valuable case for analysis. Using a literature review and case study approach, this research explores the company's transformation through green corporate culture, management practices, and production processes. The findings indicate that CATL has successfully reduced carbon intensity, improved energy efficiency, increased the use of recycled materials, and strengthened supply chain resilience.

Keywords: Carbon Neutrality; Green Transformation; Power Battery; SustainableDevelopment; CATL

INTRODUCTION

Since the signing of the Paris Climate Agreement in December 2015, green development has evolved from a global consensus to global action. In September 2020, Chinese President Xi Jinping declared the nation's ambitious timeline: to reach peak CO_2 emissions by 2030 and to realize carbon neutrality by the year 2060. In response to this national strategy, Chinese enterprises have successively carried out green transformation to move towards the "dual carbon" goals.

The majority of worldwide carbon output stems from power generation and transport. Consequently, deploying New Energy Vehicles (NEVs) is vital for conserving energy and curbing emissions within the transportation landscape. The NEV industry has become a pillar force for achieving carbon neutrality in the transportation field. However, the contribution of NEVs to carbon emission reduction is often limited to the usage phase. In the production phase, NEVs remain major carbon polluters, with the most significant emissions coming from the production of power batteries, which accounts for a substantial portion of the vehicle's total lifecycle emissions. According to relevant research, “According to relevant research, carbon emissions from power battery production account for about 50% of the total carbon emissions from the entire NEV production process (ICCT, 2021)”, making the green transformation of power battery enterprises a critical link in the global decarbonization chain that cannot be ignored.

As a leading enterprise in China's power battery field, “As a leading enterprise in China’s power battery field, CATL has developed into the world’s largest power battery manufacturer. Data shows that in 2022, CATL ranked first in global sales for eight consecutive years (SNE Research, 2023)”, with an installed capacity of 191.6 GWh and a market share of 37%. Furthermore, Furthermore, “CATL announced its carbon neutrality plan, aiming to achieve carbon neutrality in core operations by 2025 and carbon neutrality across the entire value chain by 2035 (Contemporary Amperex Technology Co., Limited, 2022)”. This marks CATL's commitment to becoming the world's first leading battery enterprise to achieve carbon neutrality, and its green transformation practices have important reference significance for the entire power battery industry.

Despite the importance of this sector, Despite the importance of this sector,” domestic research on the power battery industry often focuses on value evaluation and strategic expansion rather than green transformation specifically (Li et al., 2020)”. Additionally, research on green transformation tends to be empirical at the regional or industrial level, with few in-depth case studies on corporate green transformation paths, especially lacking systematic analysis of the motivation mechanisms, implementation paths, and multi-dimensional effect evaluation of leading enterprises' green transformation. This research aims to fill these gaps by answering the following questions: What are the specific motivations and paths for CATL's green transformation? What are the environmental, economic, and social effects of these strategies? How do CATL's green transformation practices drive the green development of the entire power battery industry chain? And what lessons can the wider power battery industry learn from CATL's experience?

LITERATURE REVIEW

Concept of Green Transformation

“Scholars characterize industrial green transformation not merely as a static event, but as an ongoing evolutionary journey impacting every segment of the industrial value chain. Fundamentally, this transition manifests as a shift toward optimizing resource and energy efficiency, whilst simultaneously minimizing the discharge of pollutants, improving labor productivity, and enhancing sustainable development capacity. (Fan

& Yi, 2021) For resource-based companies, green transformation is essentially a strategic action consistent with the external environment's evolutionary trend, subverting traditional development models for sustainable ones. It is a dynamic process covering innovation and production, applied to all value chains of the enterprise.

In the context “In the context of the power battery industry, green transformation has more specific connotations. It not only requires enterprises to reduce carbon emissions and pollutant discharge in the production process but also involves the green design of products, the green management of the supply chain, and the recycling and reuse of waste batteries. Different from the green transformation of traditional manufacturing industries, the green transformation of power battery enterprises is also closely linked to the development of the NEV industry and the achievement of national 'dual-carbon' goals,with stronger policy relevance and industrial driving effects. (Wang et al., 2007)”

Effects of Green Transformation
Existing research analyzes the effects of green transformation from environmental, economic, and comprehensive perspectives.

Environmental Effects
Scholars often use carbon performance as an evaluation index. Studies have designed carbon performance evaluation standards applicable to Chinese enterprises, verifying their accuracy in actual performance evaluation. Quantitative evaluations of energy consumption and pollution emissions during transformation provide a reference for reducing environmental impact. In the power battery industry, environmental effects also include indicators such as the recycling rate of waste batteries, the utilization rate of green energy, and the concentration of pollutant emissions, which are important manifestations of the environmental benefits of green transformation.

Economic Effects
There is a debate regarding economic outcomes. Some scholars argue that green product innovation significantly promotes economic performance by improving social reputation and image. Others point out that high transformation costs, such as patent and equipment purchases, may weaken profitability in the short term. However, the "technology compensation effect" suggests that negative impacts gradually weaken, eventually leading to positive enterprise value. For power battery enterprises, the economic effects of green transformation are reflected in multiple aspects such as revenue from recycled battery materials, tax incentives, and improved supply chain resilience, which are different from the economic effect evaluation of general manufacturing enterprises.

Comprehensive Effects
Recent studies evaluate effectiveness from economic value realization (market expansion) and social value (core competitiveness and reputation). In the power battery industry, the comprehensive effects of green transformation also include the improvement of ESG ratings, the acquisition of international product certifications, and the enhancement of the international competitiveness of enterprises, which are important manifestations of the comprehensive value of green transformation.

Paths of Green Transformation
Literature suggests transformation occurs primarily through green strategy and green innovation.

Green Strategy

Strategies should run through the entire product life cycle, integrating green awareness into all links. Establishing a green development system is key to successful transformation. For power battery enterprises, green strategy also needs to consider the characteristics of the industrial chain, such as the green management of upstream raw material suppliers and the recycling of downstream waste batteries, forming a whole-industry-chain green development strategy.

Green Innovation

“Green technological innovation helps reduce production and environmental protection costs. This includes product upgrading, process upgrading, and industrial diversification. Green supply chain management is also identified as a key path for ensuring sustainable development. In the power battery industry, green innovation is mainly reflected in the optimization of production processes, the research and development of recycling technologies, and the application of digital intelligent manufacturing technologies, whichare the core driving forces for green transformation. (Dai & Yang, 2022)”

Theoretical Foundations

Sustainable Development Theory

Emphasizes that development should focus on long-term goals, pursuing economic construction and social development based on protecting the ecological environment. “For power battery enterprises, sustainable development means not only achieving economic benefits but also assuming environmental and social responsibilities, and promoting the coordinated development of the industry and the environment (World Commission on Environment and Development, 1987)”.

Stakeholder Theory

Suggests that enterprises must coordinate the needs of numerous stakeholders (shareholders, employees, suppliers, government, public) to ensure stable operation. Meeting these expectations is a basic guarantee for long-term development. In the green transformation of power battery enterprises, it is necessary to balance the interests of various stakeholders, such as meeting the environmental requirements of the government, the quality requirements of customers, and the employment and development needs of employees.

Green Supply Chain Theory

Contrasts with traditional models by considering environmental impacts. It advocates for green supply chain management to enhance environmental protection images, improve operational efficiency, and enhance core competitiveness. For power battery enterprises, green supply chain management covers the entire process from the procurement of raw materials to the sales and recycling of products, and is an important part of green transformation.

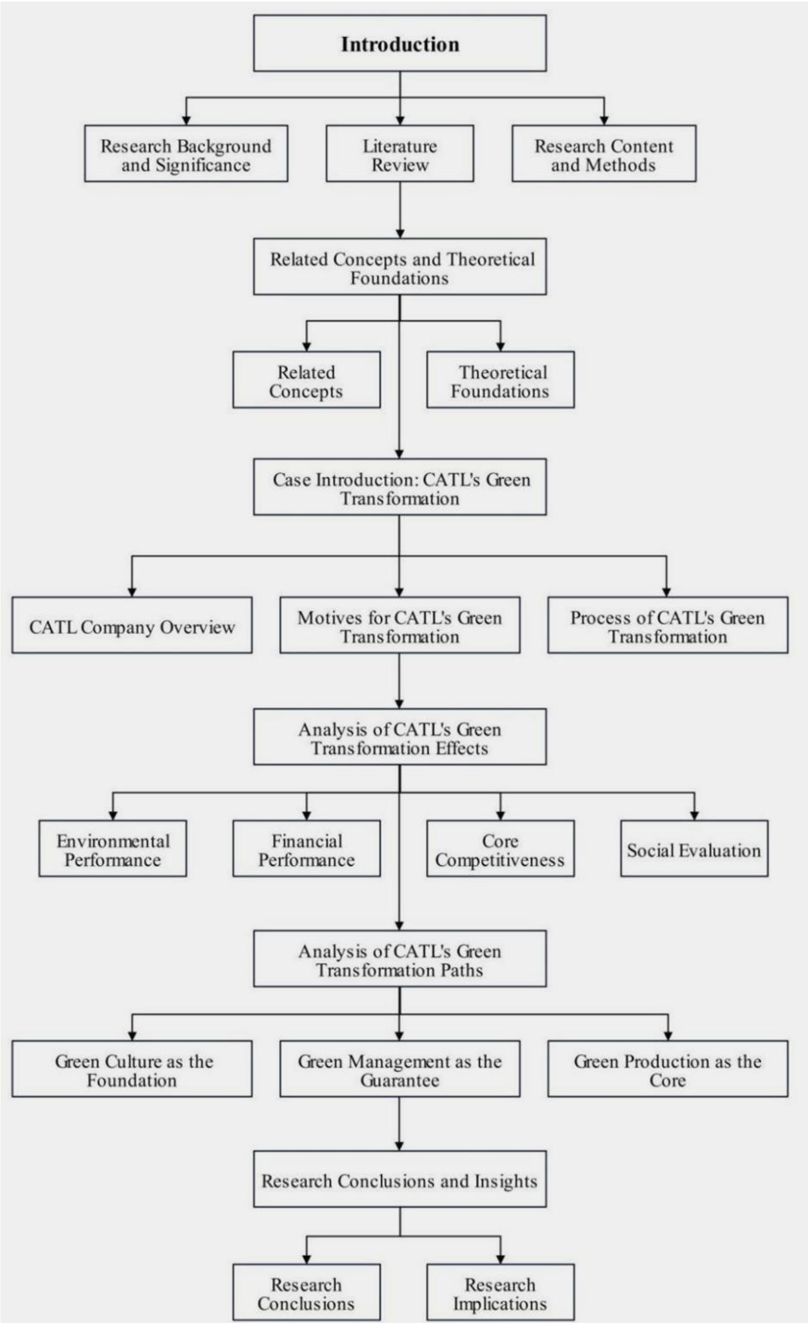
Research Gap

While research has widely examined EV development, significant gaps remain. Most domestic research on power batteries focuses on valuation rather than green transformation processes. Furthermore, existing works often examine industries at a macro level, offering few systematic case studies of leading enterprises like CATL, especially lacking in-depth analysis of the specific implementation paths and multi-dimensional effect mechanisms of green transformation. This research addresses these gaps by integrating policy analysis with a firm-level case study, and comprehensively exploring the green transformation of CATL from the perspectives of motivation, path, effect, and enlightenment.

Conceptual Framework
Based on the literature, this study adopts a framework connecting external drivers to internal strategies and final outcomes. The framework posits that government policy an industry requirements drive the firm (CATL) to adopt specific transformation paths (Green Culture, Management, Production), resulting in multi-dimensional performance improvements (environmental, economic, core competitiveness, social evaluation).

Conceptual Framework
The study framework model is depicted in Figure 1.

Figure 1. Research Framework



Research framework

Description: A flowchart showing Introduction -> Lit Review -> Case Analysis -> Effects (Env/Fin/Comp/Social) -> Paths (Culture/Mgmt/Prod) -> Conclusions.

RESEARCH METHOD

Research Design

“This paper employs a qualitative case study design. A qualitative approach is appropriate for understanding how government policies shape strategies at the firm level. The case analysis method allows for an in-depth examination of CATL's specific transformation practices, including the motivation, path, and effect of green transformation, and can fully reveal the internal logic and external manifestation of green transformation. (Hou & Chen, 2018)”

Case Selection: CATL

CATL was selected for three reasons:
Market Leadership: It has ranked first in global battery consumption for six consecutive years, with a market share exceeding 30%. In 2022, its installed capacity reached 191.6 GWh, which is higher than the sum of the installed capacities of LG Energy Solution (70.4 GWh), BYD (70.4 GWh), and Panasonic (38 GWh), showing absolute market advantages.

Strategic Pioneer: It is the first battery enterprise to launch a comprehensive carbon neutrality plan (2025 for core operations, 2035 for value chain). As early as 2019, it began to explore the accounting of product carbon footprints and carbon reduction across the entire value chain, taking the lead in the industry in formulating clear carbon neutrality goals and paths.

Transformation Maturity: CATL began exploring carbon footprint accounting early (2019) and has been selected for the S&P Global Sustainability Yearbook, indicating mature green practices. It has released 3 social responsibility reports and 2 ESG reports, and has achieved remarkable results in environmental performance, financial performance, and social evaluation, with high research value.

Data Collection

The analysis relies primarily on secondary data. Sources include:
Corporate Reports: CATL’s annual financial reports, Social Responsibility Reports (2018-2020), and ESG Reports (2021-2022). These reports provide detailed data on CATL's green transformation measures, environmental performance, financial performance, and social evaluation, which are the core data sources of this study.

Policy Documents: Regulations from the Chinese government (e.g., Environmental Protection Tax Law) and international bodies (e.g., EU New Battery Law). These policy documents help analyze the external motivation of CATL's green transformation.

Market Data: Statistics from SNE Research, Wind, and other industry databases regarding market share, sales, and raw material prices. These data are used to analyze the industry background and economic effects of CATL's green transformation.

Academic Literature: Relevant research results on green transformation, sustainable development, and power battery industry, which provide theoretical support and reference for this study.

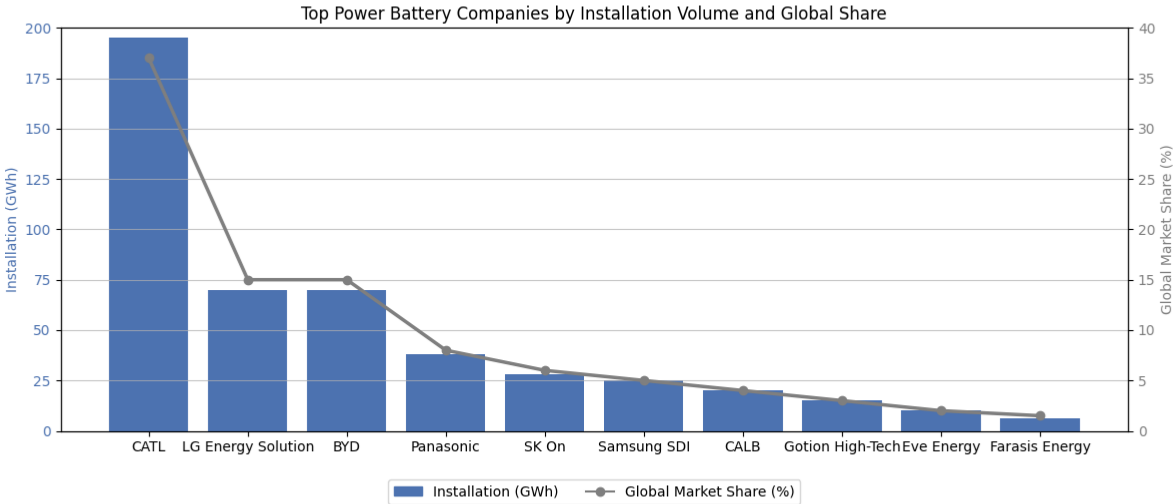
RESULTS

Industry Context and Motivations

Industry Development Status

“The global NEV market is expanding rapidly, with sales reaching 10.82 million units in 2022, a year-on-year increase of 61.6%. Correspondingly, global power battery installation reached 517.9 GWh, a year-on-year increase of 74.38%. China's power battery industry has developed rapidly, with six of the top ten global power battery enterprises being Chinese companies, accounting for over 60% of the global market share, showing strong international competitiveness. (Yan, 2019)"

Figure 2 Installed volume and share of global power battery companies in 2022



Description: A bar chart showing CATL leading with 191.6 GWh, followed by LG and BYD.

The power battery industry chain is complex, covering upstream raw material supply (lithium, nickel, cobalt, graphite, etc.), midstream battery production (positive electrodes, negative electrodes, electrolytes, separators, battery cells, modules, etc.), and downstream application (NEVs, energy storage, battery recycling, etc.). "CATL is mainly engaged in the midstream and downstream of the industrial chain, covering the R&D, production, and sales of power batteries and energy storage batteries, as well as battery recycling and utilization (Contemporary Amperex Technology Co., Limited, 2022).

Motivation for Green Transformation

Policy Drivers

Domestic Policies: The "Environmental Protection Tax Law" (2018) levies taxes on 4 categories of pollutants, including atmospheric pollutants, water pollutants, solid waste, and noise. Enterprises that exceed the standard emissions will be levied environmental protection tax at 2-3 times the rate, while enterprises that reduce pollutant concentration to below 30% or 50% of the standard can enjoy tax reductions of 75% and 50% respectively. This policy has strongly motivated CATL to carry out green transformation to reduce tax burdens. In addition, a series of policies such as the "Guiding Opinions on Accelerating the Establishment of a Sound Green, Low-Carbon and Circular Development Economic System" and the

"Implementation Plan for Science and Technology to Support Carbon Peaking and Carbon Neutrality (2022-2030)" have also provided policy guidance for the green development of the power battery industry.

International Policies: The EU's "New Battery Law" (2021) requires carbon footprint declarations ("battery passports") for batteries sold in Europe, and sets specific recycling targets for key raw materials (by 2030, at least 12% of cobalt, 85% of lead, 4% of lithium, and 4% of nickel in battery products must come from recycled materials). The US Inflation Reduction Act (2022) has put forward localization requirements and sensitive list restrictions on power batteries for NEVs that want to obtain government subsidies, increasing the market access barriers for Chinese power battery enterprises. As CATL's overseas revenue accounted for more than 30% of its total operating income in 2022, a year-on-year increase of 175.99%, complying with international green policies has become an inevitable requirement for its market expansion.

Industry Development Needs

The power battery industry is facing challenges such as unstable supply chains, imperfect recycling systems, and fierce global competition. “The recycling channels of power batteries in China are not standardized, with only 40% of retired batteries entering formal recycling enterprises, and the remaining 60% flowing to informal channels, which not only causes environmental pollution but also wastes resources. Carrying out green transformation and strengthening battery recycling can not only reduce environmental pollution but also improve the stability and resilience of the supply chain, which is an important way for the sustainable development of the industry. (Zhu et al., 2022)”

Environmental Performance

CATL has achieved significant results in reducing its environmental footprint, mainly reflected in the following aspects:

Reduction in Carbon Emission Intensity

“While total emissions rose due to capacity expansion, the intensity per unit of production dropped sharply. In 2022, the greenhouse gas emission intensity per unit of cell product was 9.99 tons CO_2 eq/MWh, a year - on - year decrease of 38.63% (Contemporary Amperex Technology Co., Limited, 2023). ” From 2019 to 2022, CATL's carbon emission intensity showed a continuous downward trend, from 17.04 tons CO_2 eq/MWh in 2019 to 9.99 tons CO_2 eq/MWh in 2022, indicating remarkable emission reduction effects in production and manufacturing.

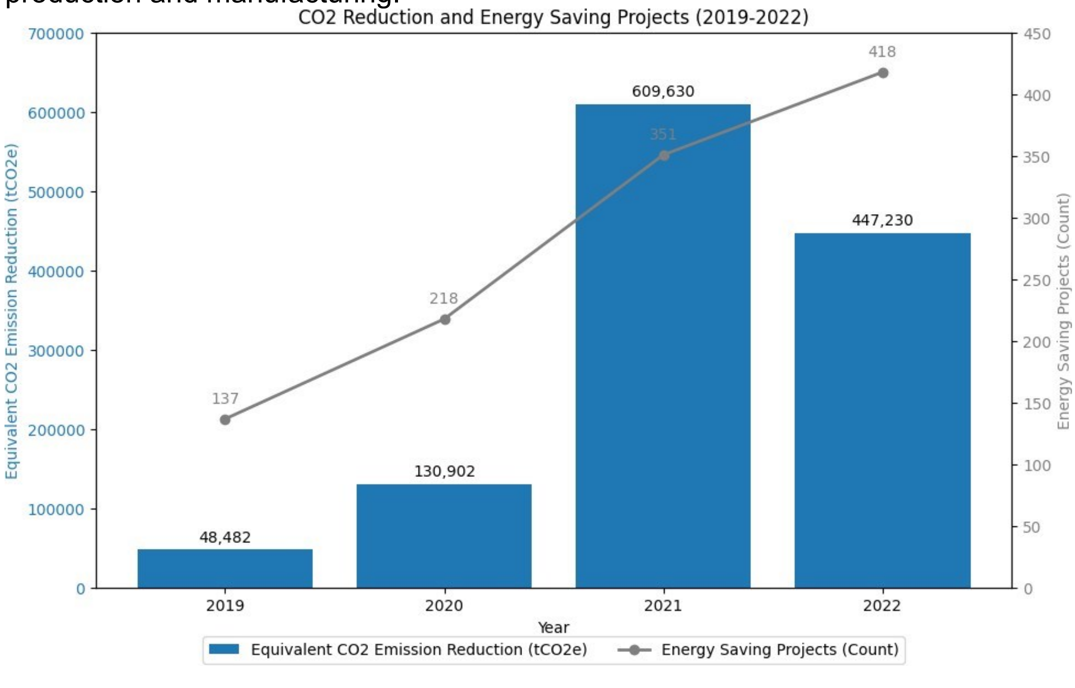


Figure 3 CATL's energy savings at the manufacturing end from 2019 to 2022
Description: A line graph showing a downward trend from 17.04 in 2019 to 9.99 in 2022.

Improvement in Energy Use Efficiency

Energy-Saving Projects: “In the context of the power battery industry, green transformation has more specific connotations. It not only requires enterprises to reduce carbon emissions and pollutant discharge in the production process but also involves the green design of products, the green management of the supply chain, and the recycling and reuse of waste batteries. Different from the green transformation of traditional manufacturing industries, the green transformation of power battery enterprises is also

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closely linked to the development of the NEV industry and the achievement of national 'dual-carbon' goals, with stronger policy relevance and industrial driving effects. (Wang et al., 2007)"

Green Electricity Utilization: The company significantly increased its use of renewable energy. Photovoltaic power generation reached 58,436 MWh in 2022, a 321% increase from 2019, equivalent to avoiding approximately 47,678 tons of carbon dioxide equivalent emissions. The proportion of green electricity usage reached 26.60% in 2022, and some factories (such as Sichuan Times) have realized 100% green electricity operation by utilizing local hydropower resources.

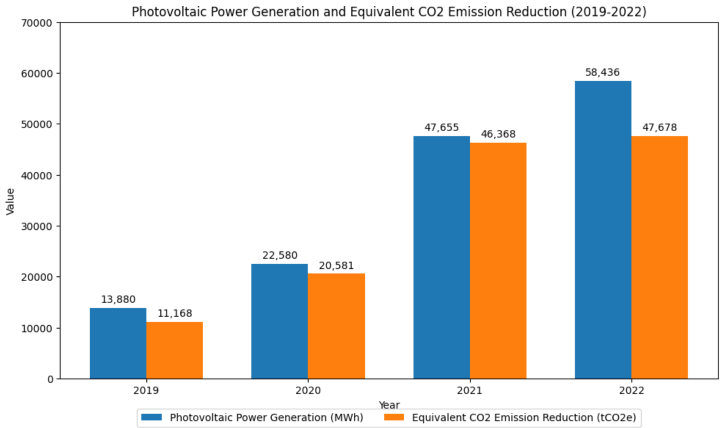


Fig. 4 CATL's photovoltaic power generation from 2019 to 2022
Description: Bar chart showing the increase in PV power generation.

Reduction in Pollutant Emission Concentration
In 2022, CATL's key pollutant discharge units (including CATL, Guangdong Bangpu, Hunan Bangpu, etc.) had actual annual emissions and emission concentrations far lower than the national standard limits, with all pollutant emission concentrations below 75% of the standard limits. For example, CATL's chemical oxygen demand (COD) emission concentration was 42 mg/L, far lower than the standard limit of 150 mg/L; ammonia nitrogen emission concentration was 1.38 mg/L, much lower than the standard limit of 30 mg/L. In addition, CATL's total recycling and reuse rate of general industrial solid waste reached 99.87%, of which 52.54% was reused for its original purpose and 34.42% was reprocessed to manufacture new materials, effectively reducing environmental pollution.

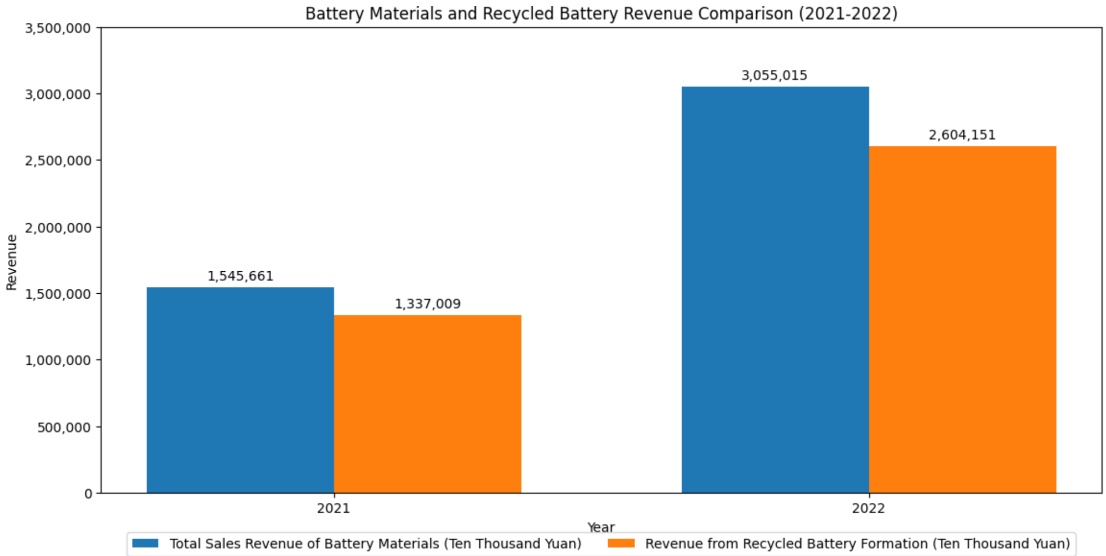
Increase in the Proportion of Recyclable Packaging
The proportion of recyclable packaging used by CATL rose from 5.0% in 2018 to 98.0% in 2022. In 2020, CATL promoted suppliers to switch from disposable packaging to recyclable packaging for incoming materials, and introduced stone paper packaging materials, which saved a large amount of forest resources and was degradable. In 2022, CATL's packaging material projects reduced annual wood usage by approximately 120,000 tons, making important contributions to ecological protection.

Financial Performance
Green transformation has proven to be economically beneficial, contradicting the view that it is purely a cost burden.

Revenue from Recycled Battery Materials
Through its subsidiary Bangpu Recycling, CATL extracts nickel, cobalt, lithium and other metal materials from waste batteries to produce battery materials such as ternary precursors and lithium carbonate, which are either recycled into battery production or

sold externally. With the continuous increase in the recycling volume of power batteries and the rising prices of upstream metal resources (such as lithium carbonate), the revenue from recycled battery materials of CATL has grown steadily, reaching 26.04 billion RMB in 2022. The proportion of lithium battery material sales revenue in CATL's main business revenue increased from 6.81% in 2019 to 11.86% in 2021, becoming an important source of income for the enterprise.

Fig. 5 CATL's sales revenue of battery materials from 2021 to 2022



Description: Bar chart comparing total sales revenue vs. revenue from recycled battery formation.

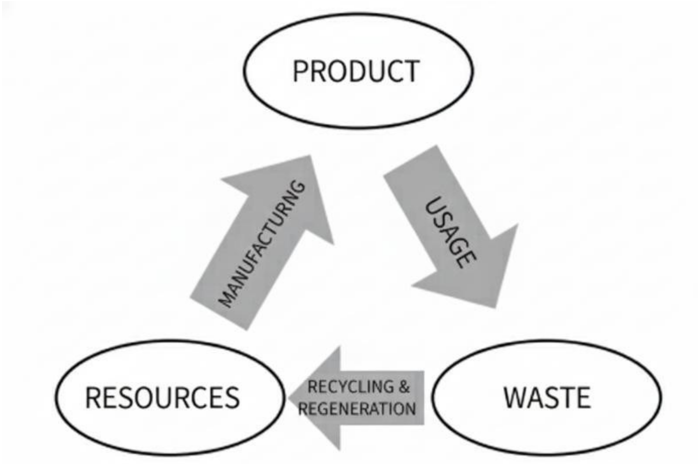
Acquisition of Tax Incentives

Due to comprehensive resource utilization, subsidiaries like Hunan Bangpu qualify for significant tax breaks. According to the "Catalogue of Preferential Enterprise Income Tax for Comprehensive Utilization of Resources" and the "Catalogue of Preferential VAT for Comprehensive Utilization of Resources and Services", 90% of Hunan Bangpu's income from selling resource comprehensive utilization products and providing related services can be included in the total income, and it also enjoys a VAT refund policy of 50% of the tax paid, which effectively reduces the enterprise's tax burden and improves capital utilization efficiency.

Core Competitiveness: Supply Chain Resilience

CATL has enhanced its competitiveness by establishing a "directional cycle model". By acquiring Bangpu Recycling in 2015, CATL created a closed-loop system where waste batteries are recycled into raw materials and returned to production. This model enables CATL to obtain waste batteries directly from end-users through Bangpu Recycling's nationwide recycling outlets, and quickly disassemble and regenerate them into usable battery materials, reducing dependence on raw ore mining and imports, and strengthening supply chain resilience.

Figure 6 Directional cycle model



Description: A diagram showing the cycle between Resources -> Manufacturing -> Product -> Usage -> Waste -> Recycling -> Resources.
In addition, CATL has expanded its business scope by providing zero-carbon ecological construction solutions for local governments. Based on its technological advantages in the clean energy field and carbon reduction experience, it has signed strategic cooperation agreements with cities such as Beijing, Shenzhen, and Ordos to promote the green and low-carbon transformation of various fields, opening up new business growth points and enhancing its green competitive advantage.

Social Evaluation
CATL's efforts have garnered international recognition. In 2022, CATL achieved excellent results in mainstream ESG ratings at home and abroad, including MSCI ESG Grade A (top 9% in the global industry), CSA 51 points (top 7% in the global industry), SynTao Green Finance Grade AAA (1/36 in China's electrical equipment category), and Wind ESG Grade AA (2/319 in China's electrical equipment category). It was also selected into the first edition of the Sustainability Yearbook (China Edition) 2023 released by S&P Global, standing out from 1,590 Chinese enterprises.

In terms of product certification, CATL's energy storage 280Ah lithium iron phosphate cell product obtained EPD certification compliant with the relevant standards of the EPD ITALY platform in 2022, becoming the world's first product in the power battery industry to obtain this certification, which helps the enterprise expand the European market. In terms of factory construction, Sichuan Times (a subsidiary of CATL) obtained carbon neutrality certification in March 2022, becoming the world's first "zero-carbon factory" in the battery industry. By December 2023, four of CATL's factories had obtained carbon neutrality certification, accelerating the implementation of its zero-carbon strategy.

DISCUSSION

This section analyzes how CATL achieved the results described above. The analysis identifies three core paths: Green Culture, Green Management, and Green Production.

Green Culture as the Foundation
The foundation of CATL's transformation lies in its corporate culture, which is reflected in the construction of a sustainable governance structure and employee engagement.

Construction of Sustainable Governance Structure
In 2018, CATL established a Sustainable Development Management Committee chaired by the Board Secretary, with company executives as members, responsible for making

decisions and supervising the planning and implementation of sustainable development work. In 2022, the committee further established an Enterprise Sustainable Development Management Council, with backbones from core business departments as members, and set up various base working groups and group working groups under it, forming a complete sustainable governance system. The committee identifies and evaluates material issues (such as climate governance) every year, and reports to the Board of Directors, ensuring that sustainable development is integrated into the company's strategic decision-making.

Employee Engagement in Green Development
CATL has formulated energy-saving regulations for office areas, encouraging employees to save energy in daily work. It popularizes sustainable development knowledge through emails, corporate newsletters, and posters, and regularly conducts sustainable development training for employees. In 2022, it carried out 3 sustainable development courses and 5 company-level training sessions on product life cycle assessment and carbon footprint. The company designates September as "Sustainable Development Activity Month" every year, carrying out activities such as public welfare forest watering, Plogging, and environmental protection themed activities. By 2022, the CATL Volunteer Service Team had 24 branches, with more than 14,700 employees participating, embedding green development concepts into employees' daily work and life.

Green Management as the Guarantee
Effective management systems ensure the execution of green strategies, including the construction of an environmental management system and supply chain empowerment.

Construction of Environmental Management System
CATL established an environmental management system certified by ISO 14001, formulated a series of system documents such as the Environmental Management Manual and Waste Gas Emission Control Management Procedure, and realized the whole-process control of pollution sources in product development, production, sales, use, disposal, and recycling.
Product Development: Incorporate factors such as production energy consumption, carbon emissions, and material recyclability into the R&D process, conductpredictive Life Cycle Assessment (LCA) for new technologies, and carry out predictive analysis of product environmental impact in the testing phase.

Production Process: Formulate the Product Environmental Management Procedure, select raw materials with low environmental footprints, conduct risk management of prohibited substances for suppliers, and build an energy management system with reference to ISO 50001 to reduce energy and water consumption.

Sales and Recycling: Focus on the R&D and management of green packaging, incorporate packaging-related indicators into departmental performance appraisal, and formulate internal management systems for waste disposal to ensure the compliant disposal of solid waste and the up-to-standard discharge of wastewater and waste gas.

Supply Chain Empowerment
CATL has formulated the Supplier Management Procedure, clarifying the requirements for supplier classification, evaluation, and management, and taking the carbon footprint of raw materials as an important evaluation indicator. In 2022, it launched the "CREDIT" Value Chain Sustainability Transparency Audit Program, the first audit tool for the lithium battery supply chain in the industry, which includes 5 modules (sustainable development management mechanism, business ethics standards, environmental protection, labor practices, and responsible procurement), covering 24 secondary evaluation indicators and 135 tertiary evaluation indicators. In 2022, CATL invited a third-party organization to

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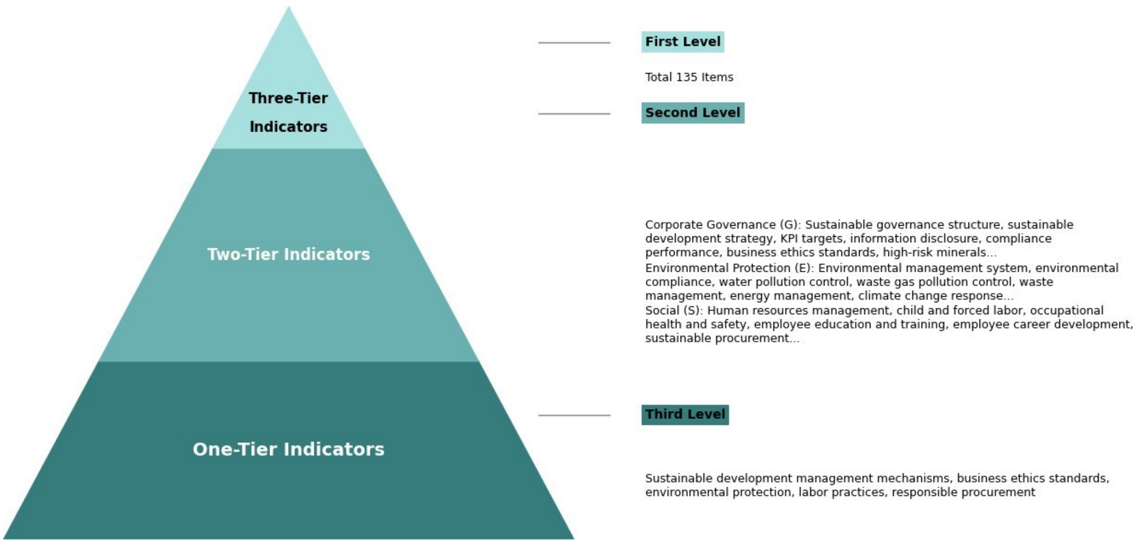
conduct on-site audits on 35 core raw material suppliers based on this program, helping suppliers improve their sustainable development capabilities and greening the entire supply chain.

Figure 7 "CREDIT" Value Chain Sustainability Transparency Audit Program



Description: A pyramid diagram showing the three tiers of indicators for supplier auditing.

Green Production as the Core

Green production is the engine of CATL's environmental performance, including optimization of resource utilization, digital intelligent manufacturing, and closed-loop recycling of production waste.

Optimization of Resource Utilization

R&D of Energy Management System: The independently developed CFMS (CATL Facility Management System) smart management system integrates Building Automation (BA), Energy Management System (EMS), and Facility Management (FM) modules, realizing real-time monitoring, early warning, and trend analysis of energy consumption, ensuring the safe, efficient, and low-carbon operation of factories.

Replacement of Renewable Energy: According to local resource endowments, purchase hydropower, nuclear power, wind power and other green electricity, and develop distributed photovoltaic power generation through subsidiaries. Promote the electrification of internal logistics and employee commuting to reduce carbon emissions from transportation.

Optimization of Water Resource Utilization: Implement targeted water-saving measures in the production process, such as the reuse of concentrated water from DI and EDI water, pipeline modification of EDI concentrated water, and introduction of flash steam recovery devices for steam boilers, effectively improving water resource utilization efficiency.

Energy Conservation and Efficiency Improvement at the Manufacturing End: Carry out equipment performance optimization and system transformation, such as optimizing the standby storage in the battery formation capacity process, improving the operating efficiency of coating machines, and reconstructing the boiler system, reducing energy consumption per unit product.

Digital Intelligent Manufacturing

CATL extensively applies cutting-edge intelligent manufacturing technologies such as big data, cloud computing, digital twin, edge computing, radio frequency technology, and 5G to build an intelligent and information-based integration system. Big data analysis realizes precise monitoring and prediction of the production process; cloud computing provides strong computing power and data storage capacity; digital twin technology builds a virtual factory to simulate and optimize the production process; edge computing improves data processing efficiency; radio frequency technology and 5G enhance the communication speed and stability between devices. These technologies improve product consistency, realize predictive maintenance of equipment, and strengthen knowledge management, improving production efficiency and resource utilization rate.

Closed-Loop Recycling of Production Waste

CATL's subsidiary Guangdong Bangpu has developed unique directional recycling technology, with the total recovery rate of nickel, cobalt, and manganese metal materials reaching more than 99.3%. By establishing a systematic recycling system and advanced treatment technology, it extracts reusable materials from waste batteries and reapplies them to the production of new batteries, forming a closed-loop recycling system of the battery industry chain, promoting the efficient use of resources and reducing environmental pollution.

CONCLUSION

Research Conclusions

This study has systematically analyzed the strategies and effects of CATL’s green transformation under the "dual-carbon" target, and drawn the following conclusions:
Proactive Responsibility: As a leading enterprise in the power battery industry, CATL has taken the initiative to shoulder social responsibilities, formulated carbon neutrality plans ahead of the national timeline, and integrated green development concepts into corporate culture and governance structure, setting an example for the industry. Strategic Focus: The company succeeds by focusing on key links with high emission reduction potential—specifically green production and supply chain management. By optimizing resource utilization, promoting digital intelligent manufacturing, and building a closed-loop recycling system, it has achieved remarkable environmental and economic benefits. Comprehensive Ecosystem: CATL does not operate in isolation; it leverages its capital and technological advantages to link upstream and downstream partners, builds a collaborative green ecosystem through supply chain empowerment, and promotes thegreen development of the entire power battery industry chain.

Managerial Implications

Based on CATL's experience, this study offers three enlightenments for the power battery industry: Build Consensus: Enterprises must prioritize social responsibility and build a consensus on eco-conservation. By establishing a green corporate culture and a sustainable governance structure, they can embed green development concepts into all aspects of operation and management, and gather internal and external forces to promote green transformation. Focus on Resource Endowments: Companies should analyze their specific resource conditions (such as local renewable energy resources, industrial chain supporting capabilities, etc.) and focus on key nodes such as energy conservation and emission reduction in production, battery recycling, and supply chain greening to maximize the effect of green transformation. Collaborate for a New Pattern: Individual transformation is insufficient. Enterprises should activate overall advantages by cooperating with the industrial chain— integrating upstream suppliers and downstream recyclers, jointly building a green supply chain and recycling system, and promoting the high-quality and sustainable development of the entire power battery industry.

ACKNOWLEDGMENT

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DECLARATION OF CONFLICTING INTERESTS

The authors have declared no potential conflicts of interest concerning the study, authorship, and/or publication of this article.

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