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Business Model Innovation of Automotive Energy Storage Systems in the Context of Energy Transition

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Abstract: In the context of global energy transition, automotive energy storage systems, as a core component of the new energy vehicle industry, play a crucial role in business model innovation for promoting sustainable industrial development. This paper conducts an in-depth analysis of the opportunities and challenges faced by automotive energy storage systems under energy transition trends, explores the characteristics and shortcomings of existing business models, and proposes a series of innovative business models based on industry development dynamics, aiming to provide reference for relevant enterprises and decision-makers and promote the healthy development of the automotive energy storage systems market.

1. Introduction

With the increasing global attention to environmental protection and sustainable development, energy transition has become an irreversible trend. In the transportation sector, new energy vehicles are gradually becoming important alternatives to traditional fuel vehicles due to their lower carbon emissions and high energy efficiency. As the "heart" of new energy vehicles, automotive energy storage systems not only determine the vehicle's driving range and performance but also play a key role in energy storage and management. Traditional business models for automotive energy storage systems can no longer meet the rapidly developing market demands, making business model innovation an inevitable choice for driving industry development.

2. Current Status of the Automotive Energy Storage Systems Industry under Energy Transition

2.1 Policy-Driven Rapid Development of New Energy Vehicle Industry

Governments worldwide have introduced encouraging policies to promote the popularization of new energy vehicles. For example, China has implemented policies such as new energy vehicle subsidies and purchase tax exemptions, greatly stimulating market demand. Europe has also promoted automakers to increase R&D and production of new energy vehicles through strict carbon emission regulations. Policy promotion has led to continuous growth in new energy vehicle sales, thereby driving rapid expansion of the automotive energy storage systems market[1].

2.2 Technological Progress Enhances Energy Storage System Performance

Lithium-ion battery technology continues to iterate, with energy density continuously improving and costs gradually decreasing. For example, CATL's Qilin battery has achieved industry-leading energy density levels, significantly improving the driving range of new energy vehicles. Additionally, new energy storage technologies such as solid-state batteries and sodium-ion batteries are actively being developed and piloted, injecting new vitality into the development of automotive energy storage systems.

2.3 Diversification of Market Demand

Consumer demand for new energy vehicles is no longer limited to basic transportation functions, with higher requirements for vehicle intelligence, connectivity, and energy storage system safety, reliability, and charging/discharging speed. Meanwhile, different application scenarios such as urban commuting, long-distance transportation, and shared mobility also present diversified characteristics in their demands for automotive energy storage systems.

3. Analysis of Existing Automotive Energy Storage System Business Models

3.1 Vehicle Sales and Battery Bundling Model

This is currently the most common business model, where vehicle manufacturers sell automotive energy storage systems together with the complete vehicle. Consumers purchase the battery along with the new energy vehicle. The advantage of this model is its simplicity and directness, with consumers owning complete vehicle property rights after purchase. However, high battery costs lead to relatively expensive vehicle prices, increasing the purchasing threshold for consumers. Meanwhile, battery lifespan and performance degradation issues also create concerns for consumers[2].

3.2 Battery Leasing Model

To reduce consumer vehicle purchase costs, some companies have introduced battery leasing models. Consumers only need to purchase the bare vehicle, while the battery is used through leasing. The leasing company is responsible for battery maintenance, replacement, and recycling. This model effectively reduces initial capital pressure for vehicle purchases, but consumers need to pay certain battery leasing fees during use, and market regulations regarding leasing terms, fee standards, and other aspects are not yet complete, which can easily lead to disputes.

3.3 Charging Service Model

Charging operators provide charging services for new energy vehicles by building charging piles, battery swapping stations, and other infrastructure. Consumers pay fees based on charging volume or duration. This model somewhat addresses the "range anxiety" problem of new energy vehicles, but charging infrastructure construction costs are high with long payback periods, and uneven distribution of charging facilities in different regions limits service scope and market expansion.

4. Innovation Directions for Automotive Energy Storage System Business Models

4.1 Vehicle-Battery Separation and Battery Asset Management Model

Under the energy transition wave, the vehicle-battery separation model is moving from theoretical concept to practical implementation. By establishing specialized battery asset management companies, a new industrial division paradigm of "vehicle manufacturing" and "battery services" can be constructed. Such companies need comprehensive full-industry-chain operational capabilities: in R&D, they collaborate with research institutions to tackle core technologies such as battery safety and fast charging; production involves flexible manufacturing systems to accommodate battery specification requirements for different vehicle models; leasing services innovate with subscription-based, mileage-based billing, and other flexible solutions to reduce consumer vehicle purchase costs[3].

Relying on big data analysis platforms and IoT sensor networks, battery asset management companies can achieve digital twin management of batteries. By real-time collection of over 100 parameters including battery voltage, temperature, and charge-discharge cycle counts, health state (SOH) prediction models are constructed to dynamically adjust charge-discharge strategies. For example, for batteries in urban commuting scenarios, valley electricity slow charging strategies are adopted to extend service life; for high-frequency use batteries in ride-hailing services, intelligent warning mechanisms are set to avoid overcharging and over-discharging.

In retired battery handling, standardized cascade utilization systems need to be established. Through capacity testing and performance grading, retired power batteries are classified into different application scenarios such as energy storage power stations, low-speed electric vehicles, and communication base station backup power based on remaining capacity. For example, batteries with remaining capacity above 80% can be recombined for peak-shaving energy storage stations; batteries with 60%-80% capacity are suitable for low-speed logistics vehicles and other scenarios with lower range requirements. Combined with blockchain technology to build traceability platforms, full-process data traceability from production to recycling is achieved, ensuring cascade utilization safety and compliance. This model not only reduces the full lifecycle cost of new energy vehicles but also creates circular economy value for batteries, promoting the formation of a "R&D - Application - Regeneration" closed-loop ecosystem.

4.2 Energy Storage as a Service (ESaaS) Model

Drawing from the "Software as a Service" concept, the Energy Storage as a Service (ESaaS) model is introduced. This model focuses on full lifecycle hosting, where companies provide users with one-stop automotive energy storage solutions from demand analysis, system selection, intelligent installation, to real-time monitoring, preventive maintenance, and technology iteration. Users do not need to bear high procurement costs and long-term holding risks of energy storage equipment, only paying service fees through subscription or pay-per-use models based on driving mileage, charging duration, or energy storage capacity usage[4].

This model is particularly suitable for cost-sensitive small and medium enterprises such as new energy logistics fleets and ride-hailing platforms, as well as household energy storage users. Taking logistics enterprises as an example, after adopting the ESaaS model, enterprises can flexibly adjust energy storage capacity according to business peak and off-peak seasons, avoiding resource idleness caused by fixed investments; individual users do not need to invest in charging piles and battery packs, achieving on-demand charging through community shared energy storage terminals.

At the operational level, companies rely on Internet of Things (IoT) and big data analysis technologies to build intelligent energy storage equipment management platforms. Through real-time monitoring of battery health status and optimizing charge-discharge strategies, system utilization is improved by more than 30%; meanwhile, leveraging the bargaining advantages brought by large-scale deployment, costs are reduced in battery procurement, electricity trading, and other aspects. Additionally, the ESaaS model can derive value-added services such as carbon asset management based on energy storage equipment and peak-valley electricity price arbitrage, forming diversified profit channels. Through refined operations and continuous technology upgrades, companies can not only improve service response efficiency but also effectively extend energy storage equipment lifecycle, ultimately achieving dual improvement in economic benefits and service value.

4.3 Vehicle-to-Grid (V2G) Business Model

With the development of smart grid technology, the vehicle-to-grid business model is gradually moving from theoretical concept to practical implementation. The power battery systems equipped in new energy vehicles are essentially distributed energy storage units, with storage capacity that has significant grid regulation potential—a single passenger car battery capacity can reach 50-100kWh, and the storage scale of a ten-thousand-vehicle fleet is equivalent to a medium-sized energy storage power station. This bidirectional energy flow characteristic enables vehicles to charge at lower electricity prices during grid low-demand periods (such as nighttime) and supply power back to the grid during peak demand periods (such as weekday afternoons), forming a dynamic balance of "peak shaving and valley filling."

In actual operations, the V2G business model creates value by participating in grid auxiliary service markets. For example, in frequency regulation services, new energy vehicles can respond quickly to grid frequency fluctuations, adjusting charge-discharge power in milliseconds, with response speeds significantly superior to traditional thermal power; in peak regulation scenarios, distributed vehicle energy storage can effectively alleviate regional power supply tensions. Taking a German pilot project as an example, a single electric vehicle participating in V2G can bring approximately 300 euros in annual revenue to the car owner while helping the grid reduce peak period load pressure by 5%[5].

Industrial collaboration is key to large-scale V2G development. Automakers need to reserve bidirectional charging interfaces during vehicle design and optimize battery charge-discharge management systems; energy companies are responsible for building smart charging pile networks to achieve real-time monitoring and scheduling of massive vehicles; grid companies need to open parts of auxiliary service markets and establish standardized trading rules. The three parties build V2G operation platforms by integrating multi-source data such as vehicle location, battery status, and grid demand, using blockchain technology to construct transparent and trustworthy revenue distribution mechanisms. For example, revenue can be distributed according to ratios of "50% grid service fees, 30% platform operators, 20% car owners," with automatic settlement through smart contracts to protect all parties' interests.

To break through technical and market bottlenecks, some countries have initiated institutional innovations. California requires electric vehicles sold after 2025 to have V2G functionality, while the EU incentivizes enterprise participation in vehicle-grid interaction through the carbon emission trading system. With the maturation of technologies such as 5G communication and edge computing, the V2G business model is expected to transition from scattered individual participation to large-scale fleet operations, becoming an important flexible resource solution in the energy transition process.

4.4 Cross-Industry Integration Business Model

By building multi-dimensional cross-industry cooperation ecosystems, automotive energy storage systems can break through traditional application boundaries and create new value growth points. In real estate integration, partnerships with leading property developers can create "new energy community" demonstration projects: installing energy storage charging piles with peak-shaving and valley-filling functions in underground parking garages, charging during valley electricity periods during the day and meeting residents' charging needs at night; deploying distributed photovoltaic systems on rooftops combined with energy storage systems to achieve "self-generation, self-use, and surplus power to grid." Taking a commercial complex in a second-tier city as an example, through integrated solar-storage-charging transformation, annual electricity cost savings exceeded 2 million yuan with carbon emission reductions reaching 1,500 tons.

Cooperation with internet companies can build smart energy ecosystems. Relying on vehicle networking and IoT technologies, vehicle energy storage systems are linked with household smart meters, air conditioners, water heaters, and other equipment to develop "vehicle-residence" energy sharing platforms. During non-travel periods, car owners can use vehicle batteries as household backup power; during peak electricity periods, they can supply power back through V2H (Vehicle-to-Home) technology to obtain electricity price differential benefits. Meanwhile, by combining big data analysis of user electricity consumption habits, energy scheduling is intelligently optimized to improve overall energy efficiency[6].

In financial innovation, partnerships with banks and leasing companies introduce customized financing solutions. For operating enterprises, "energy storage equipment + charging services" comprehensive financing leasing is provided to reduce upfront investment thresholds; for individual users, green consumer credit products are developed to support purchases of new energy vehicles with energy storage functions. Additionally, exploration of combining carbon asset trading with energy storage systems, converting emission reductions generated through energy storage equipment grid load regulation into tradeable carbon credits, opens new profit channels for enterprises.

5. Challenges and Response Strategies for Business Model Innovation

5.1 Technical Standards and Safety Issues

Automotive energy storage systems span multiple technical fields including electrochemistry, thermal management, and intelligent control, with current industry technical standards showing fragmented characteristics. At the international level, standards systems such as IEC and UL have parameter definition differences; domestically, although GB/T series standards have been introduced, unified detailed rules are still lacking in key areas such as charge-discharge cycle life testing methods and low-temperature performance evaluation indicators. This lack of unified standards leads to incompatible battery management system (BMS) protocols between different companies, making cross-brand adaptation difficult for battery swapping equipment and energy storage modules, seriously constraining industry chain collaborative development.

Safety issues have become core bottlenecks constraining industry development. In recent years, new energy vehicle spontaneous combustion incidents have occurred frequently, with over 300 publicly reported battery thermal runaway accidents globally in 2023, 68% of which occurred during charging or stationary states. Besides inherent defects in battery material systems, design flaws such as temperature control system failures and overcharge protection mechanism deficiencies, as well as safety performance degradation in cascade utilization batteries, have all exacerbated accident risks. Notably, safety redundancy design for energy storage systems under extreme environments (such as high temperature, severe cold, high altitude) still has technical gaps.

Therefore, there is an urgent need to establish a "government-guided + industry-led + enterprise-participated" standard formulation mechanism. It is recommended that the Ministry of Industry and Information Technology lead the establishment of cross-field standards committees, uniting leading enterprises such as CATL and Ningde Times with university research institutions to focus on breakthroughs in battery interface standardization and data interaction protocol unification; simultaneously establishing dynamic updated safety standard systems, incorporating indicators such as thermal runaway warning response time and battery pack protection levels into mandatory national standards. Meanwhile, encourage enterprises to increase R&D investment, optimize thermal management systems through AI algorithms, and develop intelligent battery modules with selfdiagnosis and self-repair functions to build safety defenses from technical sources.

5.2 Cost Control and Profitability Challenges

Business model innovation in the energy field faces significant capital pressure, with technology R&D requiring breakthroughs in core challenges such as battery management system optimization and bidirectional charge-discharge technology iteration, infrastructure construction involving heavy asset investments such as charging pile network layout and energy storage station transformation, while market promotion requires long-term user education and brand building. According to industry data, initial construction costs for single city-level automotive energy storage service platforms typically exceed 500 million yuan, with investment payback periods generally exceeding 8 years. How to achieve cost control and profit balance while ensuring service quality has become a key proposition for enterprise survival.

In cost management, enterprises can build cost reduction systems from multiple dimensions: through large-scale production, utilizing standardized battery design and modular assembly to reduce unit production costs by 15%-20%; optimizing supply chain management by signing long-term agreements with lithium mining companies to lock in raw material prices while introducing digital procurement platforms to achieve dynamic supplier evaluation and intelligent replenishment, reducing inventory backlog; operationally, leveraging AI prediction models to optimize energy storage equipment scheduling, improving equipment utilization to above 90%, and reducing data transmission costs through edge computing technology[7].

For profit model innovation, enterprises need to break through traditional charge-discharge service frameworks. In value-added services, subscription-based services such as battery health assessment and intelligent charging planning can be developed, with customized energy storage solutions provided for commercial vehicle fleets; in electricity market trading, participation in peak regulation and frequency regulation auxiliary services through peak-valley electricity price arbitrage, demand response services, and virtual power plant aggregation. For example, a leading enterprise achieved over 20 million yuan in quarterly electricity trading revenue by aggregating distributed energy storage resources for grid scheduling, proving the feasibility of diversified profit paths. Additionally, exploring carbon trading market revenues and joint battery bank construction with automakers also opens new profit growth points for enterprises.

5.3 Policy Support and Regulatory Coordination

Business model innovation cannot be separated from policy support and regulatory coordination. At the top-level design level, governments need to build full-cycle policy support systems: on one hand, through R&D subsidies, tax incentives, and other means, guide enterprises to increase technology R&D investment in automotive energy storage systems, such as providing special subsidies for cutting-edge technologies like solid-state batteries and intelligent management systems; on the other hand, in industrial implementation, costs can be reduced through land transfer incentives and infrastructure support to accelerate large-scale industrial development.

In regulation, the key is to resolve contradictions between policy lag and technology iteration speed mismatch. It is recommended to establish dynamic adjustment regulatory mechanisms: first, improve safety standards and quality certification systems for energy storage systems, clarifying responsibility divisions for battery recycling, cascade utilization, and other processes; second, innovate data regulatory models, using blockchain technology to achieve full lifecycle data traceability for energy storage systems, protecting user rights; third, promote cross-departmental collaborative regulation, breaking down data barriers between energy, transportation, and industrial information departments, establishing unified market entry and exit mechanisms. Through dual empowerment of policy and regulation, both enterprise innovation vitality can be stimulated and market order can be standardized, building a solid institutional foundation for sustainable development of automotive energy storage system business models.

6. Conclusion

In the context of energy transition, business model innovation for automotive energy storage systems is key to promoting sustainable development of the new energy vehicle industry. Through analyzing characteristics and shortcomings of existing business models and combining industry development trends, innovative business models including vehicle-battery separation and battery asset management, energy storage as a service, vehicle-to-grid interaction, and cross-industry integration have been proposed. However, these innovative models face numerous challenges in implementation including technical standards and safety, cost control and profitability, and policy support and regulatory coordination. Joint efforts from government, enterprises, and all sectors of society are needed to strengthen technology R&D, improve policies and regulations, optimize market environments, and continuously achieve new breakthroughs in automotive energy storage system business model innovation, laying a solid foundation for achieving low-carbon transformation and sustainable development in the transportation sector.

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