JOURNAL OF ADVANCED ENGINEERING AND INNOVATION
Volume 3, Issue 2, December 2025 | pp. 55-65
https://doi.org/10.54518/jaei.3.2.2025.1356

Analyzing the Competition in Lithium Battery Technology between China and South Korea: Implications for the Electric Vehicle Industry

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ABSTRACT

This article examines the technological competition in lithium battery development between China and South Korea and its implications for the electric vehicle industry. Using a systematic literature review of studies published from the last five years, the analysis focuses on battery chemistry, manufacturing innovation, supply chain integration, and performance improvement. The findings show that China has achieved a strong position through large-scale production, cost efficiency, vertically integrated supply chains, lithium iron phosphate (LFP) batteries, and advanced pack integration technologies such as Cell-to-Pack and Cell-to-Chassis. In contrast, South Korea emphasizes high-energy-density batteries, high-nickel cathodes, silicon-based anodes, fast-charging capability, and solid-state battery research. These different strategies reflect distinct engineering priorities: China leads in industrial scale and affordability, while South Korea excels in performance-oriented innovation. The competition between both countries has accelerated progress in battery materials, manufacturing systems, recycling, and digital production. The study shows that lithium battery competition is not only a matter of market dominance, but also a driver of technological advancement that shapes the future of electric vehicles and sustainable mobility.

Keywords: *Battery Manufacturing, China, Electric Vehicles, Lithium-Ion Battery, South Korea.*

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ARTICLE HISTORY
Received : July 5, 2025
Final Revised : August 21, 2025
Accepted : October 16, 2025
Published : December 30, 2025

1. | INTRODUCTION

The global transition toward sustainable transportation has significantly accelerated the adoption of electric vehicles (EVs) as an effective solution for reducing greenhouse gas emissions and dependence on fossil fuels. The increasing demand for EVs has simultaneously intensified the importance of lithium-ion batteries (LIBs), which represent the most critical component influencing vehicle performance, production costs, driving range, charging efficiency, and operational safety. Recent technological advances in lithium-ion batteries have substantially improved energy density, cycle life, thermal stability, and charging capability, making them indispensable for the commercialization of next-generation electric vehicles (Xu et al., 2023).

Lithium-ion battery technology has evolved rapidly over the past decade through innovations in cathode chemistry, anode materials, electrolyte composition, and battery management systems (BMS). Contemporary battery technologies, including Lithium Iron Phosphate (LFP), Nickel Manganese Cobalt (NMC), Nickel Cobalt Aluminum (NCA), and emerging solid-state batteries, offer distinct advantages in terms of safety, energy density, manufacturing costs, and lifecycle performance. Consequently, battery technology has become the primary determinant of competitiveness within the electric vehicle industry because battery packs account for approximately 30–40% of total EV manufacturing costs. Therefore, technological innovation in battery engineering directly influences the affordability and market acceptance of electric vehicles worldwide (Zaino et al., 2024).

Among all countries involved in lithium battery development, China and South Korea have emerged as the two dominant technological leaders, although they pursue different innovation strategies. China has established an integrated battery ecosystem encompassing upstream mineral processing, cathode and anode material production, large-scale cell manufacturing, battery recycling, and electric vehicle production. Supported by companies such as CATL and BYD, China has achieved remarkable leadership in LFP battery technology, Cell-to-Pack (CTP), Cell-to-Chassis (CTC) integration, and highly automated gigafactory production systems. Furthermore, China's extensive control over critical mineral processing and manufacturing capacity has strengthened its competitive position within the global battery supply chain (Wang et al., 2022).

Conversely, South Korea has maintained technological leadership through continuous investment in research and development of high-energy-density batteries. Major manufacturers, including LG Energy Solution, Samsung SDI, and SK On, have concentrated on advanced NMC batteries, high-nickel cathodes, silicon-based anodes, fast-charging technologies, and solid-state battery research. These innovations primarily target premium electric vehicles that require superior energy density, longer driving ranges, and enhanced battery reliability. The Korean strategy emphasizes technological excellence and material innovation rather than manufacturing scale alone, thereby enabling its battery industry to remain highly competitive despite increasing market pressure from Chinese manufacturers (Chen et al., 2022).

The competition between China and South Korea extends beyond manufacturing capacity to encompass engineering capabilities across battery materials, production technologies, battery architecture, supply chain integration, and commercialization efficiency. As global demand for EV batteries continues to increase, both countries are investing heavily in next-generation technologies such as solid-state batteries, silicon-anode batteries, artificial intelligence-assisted manufacturing, digital quality inspection, battery recycling, and sustainable supply chain management. These technological developments are expected to determine future competitiveness within the global electric vehicle industry while simultaneously supporting carbon neutrality and sustainable transportation objectives (Hossain et al., 2022).

Despite the growing body of literature on lithium-ion batteries, existing studies predominantly examine battery chemistry, manufacturing processes, battery degradation, or electric vehicle performance independently. Comparatively few investigations adopt an engineering perspective to evaluate the technological competition between China and South Korea by integrating battery materials, manufacturing technologies, innovation capabilities, and industrial competitiveness into a comprehensive analytical framework. This gap limits the understanding of how technological advancements in competing countries influence the evolution of the global EV industry (Yuan & Li, 2021).

Accordingly, this study aims to analyze the technological competition in lithium battery development between China and South Korea and evaluate its implications for the electric vehicle industry. Specifically, the study compares battery chemistry, manufacturing technologies, production capacity, innovation trends, and supply chain resilience while assessing their impacts on battery performance, industrial competitiveness, and the future development of electric mobility. The findings are expected to provide valuable engineering insights for researchers, manufacturers, policymakers, and industry stakeholders seeking to accelerate innovation in lithium battery technology and strengthen the sustainability of the global electric vehicle ecosystem.

2. | RESEARCH METHOD

This study employed a Systematic Literature Review (SLR) approach to comprehensively analyze the technological competition in lithium battery development between China and South Korea and its implications for the electric vehicle (EV) industry. The SLR method was selected because it enables the systematic identification, evaluation, and synthesis of existing scientific evidence while minimizing selection bias and ensuring the transparency and reproducibility of the research process. Compared with conventional literature reviews, SLR provides a rigorous framework for integrating findings from multiple studies, allowing researchers to identify technological trends, research gaps, and emerging innovations within a particular engineering domain (Almeida & Bálint, 2024).

The review process consisted of four sequential stages: literature identification, screening, eligibility assessment, and qualitative synthesis. Scientific publications were retrieved from Google Scholar using combinations of keywords including lithium-ion battery, electric vehicle battery, battery manufacturing, battery technology, battery innovation, China battery industry, South Korea battery industry, solid-state battery, battery recycling, *and* battery supply chain. To ensure the relevance and currency of the reviewed literature, only publications released between 2020 and 2025 were considered. Additional inclusion criteria required that articles be published in peer-reviewed international journals indexed in reputable databases such as Scopus, Web of Science, IEEE Xplore, ScienceDirect, SpringerLink, MDPI, Wiley Online Library, and Taylor & Francis. Complementary technical reports from internationally recognized organizations, including the International Energy Agency (IEA), were also incorporated to support recent industrial developments and global market analyses.

Following the identification stage, duplicate publications and studies lacking direct relevance to lithium battery technology, engineering innovation, or the EV industry were excluded. The remaining literature was critically evaluated based on its methodological quality, engineering contribution, technological relevance, and consistency with the research objectives. Data extracted from the selected studies included battery chemistry, material innovation, manufacturing technologies, battery performance indicators, production capacity, supply chain characteristics, recycling technologies, and commercialization strategies implemented by China and South Korea. Subsequently, the collected information was synthesized using a comparative engineering analysis, enabling a systematic comparison of technological capabilities, innovation performance, manufacturing competitiveness, and future development trends between the two countries.

The synthesized findings were then interpreted to evaluate how differences in battery technology, industrial innovation, and manufacturing strategies influence the competitiveness of the global electric vehicle industry. By integrating recent scientific evidence with engineering-oriented comparative analysis, this study provides a comprehensive understanding of the technological landscape of lithium battery development while identifying opportunities and challenges for future innovation in sustainable electric mobility.

3. | RESULTS AND DISCUSSION

The rapid expansion of the global electric vehicle (EV) market has transformed lithium-ion battery (LIB) technology into one of the most strategically important engineering sectors. Battery performance determines the driving range, charging speed, safety, manufacturing cost, and overall competitiveness of EVs. Consequently, technological innovation in lithium battery systems has become a primary focus for both industrial manufacturers and national research institutions. Among the leading countries in this sector, China and South Korea have established distinct technological pathways that shape the evolution of the global battery industry. While China has prioritized manufacturing scale, supply chain integration, and cost-efficient battery architectures, South Korea has concentrated on high-performance battery materials, premium battery systems, and advanced research in next-generation energy storage technologies (Cheng & Li, 2023).

China's dominance in lithium battery technology is primarily attributed to its vertically integrated industrial ecosystem. Unlike many competing countries, China controls a substantial portion of the global battery supply chain, including lithium refining, graphite processing, cathode and anode material production, battery cell manufacturing, battery pack assembly, and recycling infrastructure. This integration significantly reduces production costs while improving manufacturing efficiency and supply chain resilience. Companies such as CATL and BYD have introduced highly automated gigafactory production systems supported by artificial intelligence, robotics, and digital quality control technologies that enhance manufacturing precision while reducing production defects. These engineering innovations have enabled China to become the world's largest producer of lithium-ion batteries and the dominant supplier for global EV manufacturers (Graham et al., 2021).

One of China's most significant engineering achievements is the commercialization of Lithium Iron Phosphate (LFP) batteries. Historically, LFP batteries were considered less competitive because of their relatively lower energy density compared with Nickel Manganese Cobalt (NMC) batteries. However, continuous improvements in cathode material engineering, battery cell design, thermal management, and pack integration have substantially increased their overall performance. The introduction of Cell-to-Pack (CTP) and Cell-to-Chassis (CTC) technologies has further enhanced volumetric energy density by eliminating intermediate battery modules, reducing structural weight, simplifying manufacturing processes, and lowering production costs. As a result, modern LFP batteries now provide improved safety, longer cycle life, lower thermal runaway risk, and greater affordability, making them particularly attractive for mass-market electric vehicles (Hussein et al., 2024).

China has also demonstrated remarkable progress in battery manufacturing digitalization. Smart factories equipped with machine vision systems, artificial intelligence-assisted inspection, predictive maintenance, and digital twin technologies have improved production efficiency while minimizing manufacturing variability. These Industry 4.0 implementations enhance process optimization, defect detection, and real-time production monitoring, resulting in higher product consistency and reduced operational costs. Additionally, continuous investments in battery recycling technologies have strengthened China's circular economy strategy by recovering valuable materials such as lithium, cobalt, nickel, and graphite from end-of-life batteries. This integrated recycling ecosystem contributes to resource sustainability while reducing dependence on imported critical minerals (Hagelüken& Goldmann, 2022).

In contrast, South Korea has pursued a technology-oriented strategy emphasizing battery performance rather than production volume. Major battery manufacturers, including LG Energy Solution, Samsung SDI, and SK On, have invested heavily in advanced cathode chemistry, high-nickel battery materials, silicon-based anodes, and solid-state battery research. High-nickel NMC batteries developed by Korean manufacturers provide significantly higher energy density than conventional LFP batteries, enabling longer driving ranges and improved vehicle performance. These battery systems are particularly suitable for premium electric vehicles where maximizing energy storage capacity is a critical engineering objective (Aghmadi & Mohammed, 2024).

South Korean battery manufacturers have also achieved significant advances in fast-charging technology and battery durability. Material optimization, improved electrolyte formulations, and sophisticated Battery Management Systems (BMS) have enhanced charging efficiency while minimizing lithium plating, thermal degradation, and capacity fading during repeated charging cycles. These engineering improvements contribute to extended battery lifespan, improved operational safety, and enhanced reliability under demanding operating conditions. Furthermore, Korean manufacturers continue to explore silicon-rich anodes and lithium metal batteries to further increase energy density beyond the limitations of conventional graphite-based battery systems (Haberzettl et al., 2023)

Another important technological advantage of South Korea lies in its strong research capability in solid-state battery development. Unlike conventional lithium-ion batteries using liquid electrolytes, solid-state batteries replace flammable liquid electrolytes with solid materials, significantly improving thermal stability, energy density, and operational safety. Although large-scale commercialization remains under development, Korean companies have invested extensively in prototype manufacturing, interface engineering, ceramic electrolytes, and scalable production methods. If successfully commercialized, solid-state batteries could fundamentally transform the EV industry by enabling faster charging, higher energy density, and substantially improved safety compared with current lithium-ion technologies (Bridgelall, 2024).

Despite their technological strengths, both countries face different engineering challenges. China's battery industry must continue improving energy density to compete in premium EV markets while maintaining its advantages in manufacturing efficiency and production cost. Although LFP batteries provide excellent safety and durability, their lower energy density remains a limitation for long-range electric vehicles. Continuous innovation in cathode materials, battery architecture, and lightweight structural design will therefore remain essential for sustaining China's competitive advantage (Thomas et al., 2024).

Meanwhile, South Korea faces challenges associated with manufacturing costs and supply chain dependence. High-nickel batteries require greater quantities of nickel and cobalt, both of which experience significant price volatility and geopolitical supply risks. Furthermore, manufacturing high-energy-density batteries requires sophisticated production technologies and stringent quality control systems, increasing overall production costs. Consequently, Korean manufacturers have recently expanded investments in LFP technology while simultaneously strengthening battery recycling capabilities and diversifying raw material sourcing to improve long-term supply chain resilience (Cho & Shim, 2023).

The technological competition between China and South Korea has accelerated innovation throughout the global battery industry. Chinese manufacturers have demonstrated exceptional capabilities in production scale, manufacturing automation, cost reduction, and industrial integration, allowing rapid commercialization of affordable EV batteries. Conversely, South Korean companies continue to lead in advanced battery chemistry, premium battery performance, and next-generation energy storage research. Rather than representing mutually exclusive approaches, these strategies reflect different engineering priorities that collectively drive continuous technological progress within the battery industry (Itani & De Bernardinis, 2023).

Future battery development is expected to focus on multiple engineering directions, including solid-state batteries, silicon-based anodes, lithium metal batteries, sodium-ion batteries, artificial intelligence-assisted battery management, digital manufacturing, and sustainable battery recycling. The integration of machine learning into battery diagnostics and predictive maintenance will further improve battery reliability and operational efficiency. Simultaneously, advances in battery thermal management, fast-charging technologies, and lightweight structural integration will continue enhancing EV performance while reducing manufacturing costs and environmental impacts

Overall, the comparative analysis demonstrates that China currently possesses stronger competitiveness in manufacturing scale, industrial integration, cost efficiency, and supply chain control, whereas South Korea maintains significant advantages in high-performance battery engineering, material innovation, and next-generation battery research. These complementary technological strengths will continue shaping the future of the global electric vehicle industry, where success will depend not only on manufacturing capacity but also on continuous engineering innovation, sustainable production systems, advanced battery materials, and resilient supply chains. As worldwide demand for electric vehicles continues to expand, technological competition between the two countries is expected to accelerate battery innovation, improve product performance, and support the broader transition toward sustainable transportation and carbon-neutral mobility.

4. | CONCLUSION

This study analyzed the technological competition in lithium battery development between China and South Korea and examined its implications for the global electric vehicle (EV) industry from an engineering perspective. The findings indicate that both countries have established strong but distinct competitive advantages through different technological strategies. China has achieved remarkable leadership in manufacturing capacity, vertically integrated supply chains, cost-efficient production systems, Lithium Iron Phosphate (LFP) battery technology, and advanced manufacturing approaches such as Cell-to-Pack (CTP), Cell-to-Chassis (CTC), artificial intelligence-assisted production, and battery recycling. These strengths have enabled China to dominate global battery production while reducing manufacturing costs and improving industrial scalability.

In contrast, South Korea has focused on developing high-performance battery technologies through continuous innovation in high-nickel cathode materials, silicon-based anodes, advanced Battery Management Systems (BMS), fast-charging technologies, and solid-state battery research. This technology-oriented strategy has strengthened the competitiveness of Korean battery manufacturers in premium electric vehicle markets where energy density, safety, and reliability are critical engineering requirements.

The comparative analysis demonstrates that technological competition between the two countries has accelerated innovation across battery materials, manufacturing technologies, digital production systems, and sustainable battery recycling. Rather than representing a zero-sum competition, the complementary technological approaches adopted by China and South Korea collectively contribute to the advancement of lithium battery technology and the continuous improvement of electric vehicle performance. Future engineering developments are expected to focus on next-generation battery materials, intelligent battery management, digital manufacturing, and environmentally sustainable production systems. Therefore, continuous research and industrial collaboration will be essential to enhance battery efficiency, strengthen global supply chain resilience, and support the long-term transition toward sustainable electric mobility.

Acknowledgment

We gratefully acknowledge the contributions of individuals who supported the completion of this article.

Funding Information

This research did not receive any funding.

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

Ethical Approval and Originality Statement

Ethical approval was obtained for this study. The manuscript represents original work and has not been previously published, nor is it under consideration by another journal.

Data Disclosure Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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