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Assessment of Barriers and Drivers for the Second-Life Electric Vehicle Battery Supply Chain

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Abstract

As the adoption of electric vehicles (EVs) scales up around the world, the management of end-of-life batteries has emerged as a significant challenge - and chance - towards more sustainable use of resources. Second-life applications, which refer to the reuse of EV batteries for stationary energy storage systems or other applications, can provide both environmental and economic benefits. However, while theoretically viable, the development and deployment of second-life battery supply chains are limited due to a multiplicity of technical, regulatory, economic, and social considerations overall. This paper provides a holistic assessment of the main barriers and drivers affecting the growth of second-life EV battery supply chains. The study builds on a comprehensive literature review, and initial industry input, to present key challenges including: the lack of standard testing and evaluation protocols, uncertainty about used battery performance, regulatory frameworks unaligned with circular economy principles, and high costs of collection and repurposing. The authors identify key drivers for the adoption of second-life batteries including: increasing demand for stationary storage, developments in battery diagnostics, the growth of the circular economy agenda and supporting policies. By representing the barriers and drivers, this study presents a cohesive and comprehensive starting point for future policy and strategic decision making relating to the supply chain. The study will also provide the authors to develop priorities for action and identify next steps to encourage collaboration across the sector.

Keywords
Second-life batteries, Electric vehicle supply chain, Circular economy, Battery repurpose, Barriers and drivers

1. Introduction
The rapid expansion of electric vehicles (EVs) worldwide is resulting in significantly more lithium-ion batteries reaching their end-of-life (EOL) and the pressing need for sustainable strategies to address this new and growing waste stream is at the forefront of decision makers' minds. Even though a battery may no longer meet the demanding performance expectations associated with transportation, it can still have significant remaining capacity that allows for "slack" in performance for second-life applications, such as stationary energy storage, microgrids, and backup systems (Vu et al., 2020; Hossain et al., 2019). On the other hand, by facilitating second-life applications for EV batteries, although better for the environment if certain conditions are met, relates to principles of circular economy (Baars et al., 2021; Nurdiawati & Agrawal, 2022), since there is a reduction in the extraction and cultivation of raw materials, reduced the environmental consequences of battery waste, and contributed to transformational change to a renewable energy systems (Baars et al., 2021; Nurdiawati & Agrawal, 2022). The application, implementation, and scalability of second-life battery applications to the waste stream have many challenges in the supply chain, which include technical uncertainties (e.g., product life and quality), lack of standardization (e.g., types of batteries),

regulatory ambiguity (e.g., proper disposal and recycling regulations), and unrepaired logistical fragmentation (e.g. recycling schemes) (Prenner et al., 2024; Kampker et al., 2023).

While scholarly research around the technical and environmental viewpoints has interested much of the academic literature, there have not been meaningful, thorough and timely reviews to account for the supply chain aspects, business models and the interaction of barriers and drivers on the second-life battery ecosystem (McCrossan & Shankaravelu, 2021; Chirumalla et al., 2024). The following is an effort to contribute to the collective understanding of the factors relevant to the characterizing 2nd order battery supply chain, as it relates to and supports the adoption of a second-life battery ecosystem at scale. It is worth mentioning that learning about these important factors will also help towards developing strategies for a circular economy and informing policymakers, industry stakeholders and researchers trying to reduce the carbon footprint of the energy and transportation sector (Kostenko & Zaporozhets, 2024).

This research aims to provide a systematic and complete literature review of the second-life electric vehicle battery supply chain in order to identify and analyze key issues, opportunities, barriers, and drivers impacting its future. More specifically this research has the following objectives:

(1) to present a detailed overview of the current second-life EV battery supply chains structure;
(2) to categorize the key issues and opportunities that were observed in recent literature;
(3) to analyze the main barriers and drivers effecting the implementation of second-life battery solutions in terms of technological, economic, regulatory and logistical perspectives;
(4) to identify gaps in the literature and make recommendations for future research; and
(5) to contribute new ideas in valuable ways to the academic discourse surrounding circular economy and supply chain management for second-life batteries, aiding academics and practitioners.

2. Methodology

In order to establish credibility and transparency for this literature review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was utilized as the procedural framework. PRISMA has received widespread acceptance in research academics for providing a systematic and replicable approach to conducting a literature review, which facilitates identification, screening, and selection of high-quality studies while reducing bias (Chirumalla et al., 2024). A systematic approach is needed to ensure that the literature review provides a holistic and credible synthesis of the literature regarding second-life EV battery supply chain.

The literature search was conducted across a number of academic databases: Scopus, Web of Science, IEEE Xplore, ScienceDirect, and SpringerLink, in order to access the broadest range of possible relevant studies from peer-reviewed journal articles, conference proceedings, and doctoral dissertations. The search keywords consisted of combinations of the following terms: "second-life batteries," "electric vehicle batteries," "circular economy," "supply chain," "barriers," "drivers," and "business models." Throughout the searches, all terms were optimized together according to the indexing and syntax in each database to provide maximum coverage of relevant literature.

The rationale for beginning the time frame of 2018 was developed and methodologically justified. Recently, the second-life EV battery realm has made considerable advancements with respect to technological developments and regulatory interest, more specifically since 2018, as the world appeared to have collectively garnered momentum with discussions of sustainability, the circular economy, and actions of decarbonization (Baars et al., 2021; Hossain et al., 2019). Prior to 2018, the literature was scant, fragmented, exploratory, and shallow. As a result, by adopting a time frame of 2018–2025, the review represents a contemporary review of developments related to supply chain management, policy, and technology in the second-life EV battery sector.

The PRISMA process was applied in order of identification, screening, eligibility, and inclusion. In the identification stage, a total of 327 documents were retrieved from the databases using the defined search terms. During the screening stage, 54 duplicates were removed, leaving 273 records. Titles and abstracts were then screened based on inclusion criteria: (1) second-life application of EV batteries, (2) supply chain perspective, (3) barriers, drivers, opportunities, or business models. This resulted in the exclusion of 117 records deemed irrelevant or not sufficiently aligned with the research objectives.

In the eligibility phase, the remaining 156 full-text articles were assessed for substantive contributions related to supply chain, market, and policy aspects. Articles focusing solely on electrochemical or technical laboratory studies, without broader system-level discussions, were excluded—eliminating 96 additional articles.

Finally, 60 studies were deemed suitable and included in the final data set for this literature review. These references comprise a multidisciplinary mix of high-impact journal articles, conference proceedings, doctoral dissertations, and institutional reports, providing a robust and comprehensive foundation for the review. The selection process is illustrated in the PRISMA flow diagram (Figure 1), offering a transparent visualization of the systematic procedure undertaken.

This systematic selection process ensures that the literature reviewed represents the most relevant, recent, and rigorous contributions to the second-life EV battery supply chain literature. The final set of references provides a solid foundation for identifying the main challenges, opportunities, barriers, and drivers (Toorajipour et al., 2024; Prenner et al., 2024; Kostenko & Zaporozhets, 2024), while also highlighting future research directions in this rapidly evolving field.

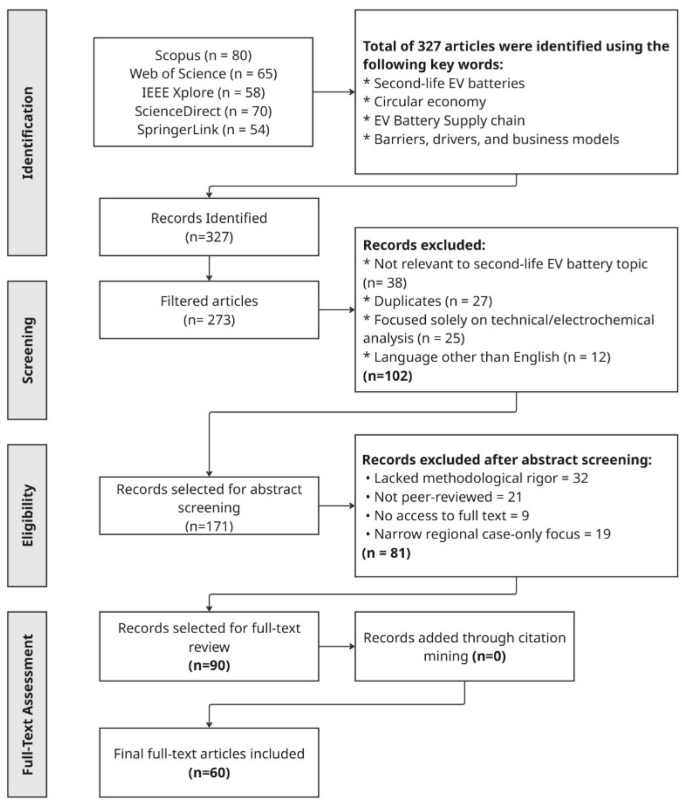

Figure 1. PRISMA Flow Diagram

3. Overview of the Second-Life EV Battery Supply Chain

The supply chain for second-life EV batteries is a partial circular (or closed-loop) supply chain that extends the usability of batteries through reuse and refurbishment before the final recycling or disposal (Rajaeifar et al., 2022). It also has a clear reverse logistics aspect, multiple stages of value recovery, and any digital monitoring (Nurdiawati & Agrawal, 2022; Chirumalla et al., 2023). The supply chain will start when a battery reaches end-of-first-life and will go through stages of collection, evaluation, repurposing, and redistribution; in which a BMS to maintain performance and safety (Hasan & Karim, 2024). Figure 2 illustrates the flow of the second-life EV battery supply chain as outlined in this section.

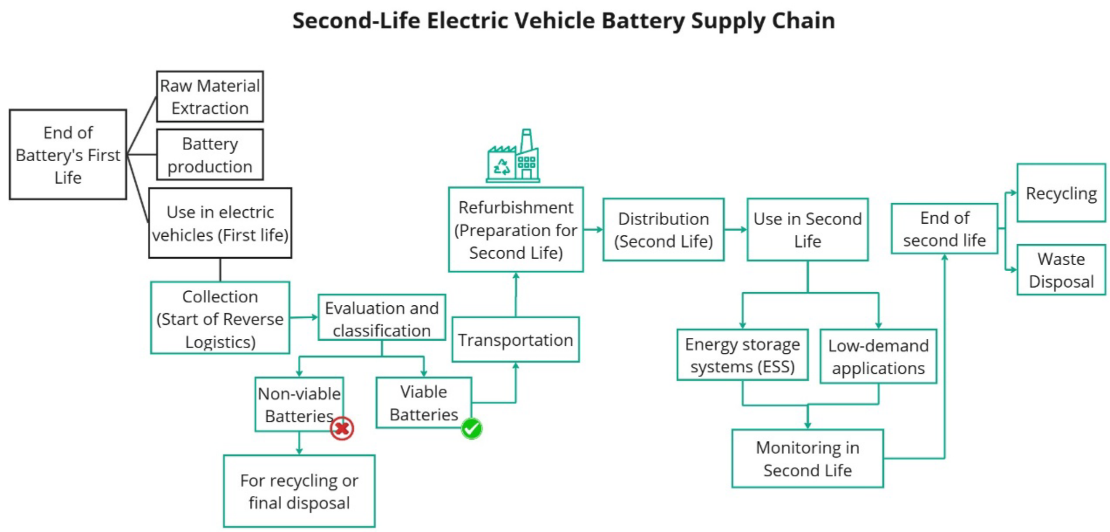

Figure 2. Lifecycle and Logistics Flowchart of Second-Life EV Battery Supply Chain

The supply chain has a number of stakeholders, whose collaboration is essential in the success and functioning of the supply chain. These stakeholders would include manufacturers and OEMs which design batteries and provide diagnostic tools, certified third-party collectors who create the compliant logistics side to the supply chain, refurbishers who evaluate and repurpose batteries, and recyclers who recover materials (Chirumalla et al., 2024; Ahmed et al., 2025). The key stakeholders across the supply chain and their roles and responsibilities are listed in Table 1.

Table 1. Key Stakeholders in the Second-Life EV Battery Supply Chain

Stakeholder Type	Examples (Generic)	Role in the Supply Chain
Manufacturers	EV producers, battery OEMs	•Design and manufacture EV batteries • Provide battery diagnostics data • Influence design for reuse/recycling
Collectors	Authorized dealerships, service centers	• Collect used EV batteries at end-of-life • Ensure compliant handling and storage • Facilitate reverse logistics
Reconditioners	Second-life integrators, ESS providers	• Evaluate battery State of Health (SoH) • Refurbish and repurpose batteries for stationary applications • Certify safety and performance
Recyclers	Battery recycling companies, material processors	• Dismantle and recover valuable materials • Dispose of non-reusable components • Support material circularity and reduce waste

4. Challenges and Opportunities in the Second-Life EV Battery Supply Chain

A strong and scalable supply chain for second-life electric vehicle (EV) batteries incurs complex challenges and large opportunities that are technological, economic, regulatory, and environmental in nature. These elements are important to understand to develop circular economy strategies and facilitate a transition to sustainability with both the energy and mobility sectors (Jegham & Sahlin Jankert, 2024).

4.1 Challenges in the Second-Life EV Battery Supply Chain

A key challenge in the second-life EV battery supply chain is the fragmentation among supply chain actors, which leads to inefficiencies in coordination, communication, and data sharing between manufacturers, refurbishers, recyclers, and end-users (Chirumalla et al., 2024). The lack of standardized procedures for evaluating, classifying, and refurbishing batteries further increases complexity, as organizations often operate with siloed processes (Toorajipour et al., 2024). Logistical barriers related to transporting and storing high-voltage batteries raise significant safety concerns and costs due to hazardous materials regulations.

The absence of accepted standards and certifications undermines trust in the safety, performance, and reliability of second-life batteries, making it difficult to scale supply chain operations or encourage customer adoption (Prenner et al., 2024; Kostenko & Zaporozhets, 2024; McCrossan & Shankaravelu, 2021). Additionally, uncertainty about residual value and performance complicates business models and investment decisions (Vu et al., 2020; Fallah & Fitzpatrick, 2023). From a technological perspective, the heterogeneity of battery chemistries and designs across manufacturers complicates refurbishment and standardization efforts (Braco et al., 2021; Fallah & Fitzpatrick, 2023). Moreover, limited data availability and traceability continue to hinder accurate health assessments and suitability for second-life use (Hasan & Karim, 2024; Rufino Júnior et al., 2024).

Regulatory uncertainty across countries also creates obstacles, including differences in the waste classification, transport and liability frameworks (Rizos & Urban, 2024; Kostenko & Zaporozhets, 2024; Hossain et al., 2019). Financial constraints and disincentives further diminish the attractiveness of second life versus recycling or disposal options (Toorajipour et al., 2024). Finally, market acceptance remains limited, due to perceptions of lower quality and weaker warranties, and inhibits demand and business scaling opportunities (McCrossan & Shankaravelu, 2021; Vu et al., 2020; Casals et al., 2017).

4.2 Opportunities in the Second-Life EV Battery Supply Chain

Despite the challenges, the supply chain of second-life EV batteries presents sizable opportunities. To start, the rise in demand for inexpensive energy storage solutions to integrate renewable energy is driving market growth for repurposed batteries (Saez de Bikuña et al., 2025). Advances in diagnostics, battery management systems (BMS), and digital monitoring systems are improving feasibility, safety, and traceability of commercialization of repurposed batteries (Ajmeri & Potdar, 2025). The rise of blockchain and other digital systems have also further increased transparency and trust in these supply chains (Duan et al., 2025). Additionally, new regulatory frameworks have recently emerged, creating opportunities for new policy-based incentives aligned with circular economy principles and establishing new roles and guidelines for actors in the market (Rizos & Urban, 2024). New and collaborative business models including OEMs, energy providers, and recyclers contribute to a culture of innovation, reduce overall costs, and help develop integrated solutions for businesses and consumers along the supply chain for batteries (Ahmed et al., 2025). Finally, the continued environmental benefits associated with extending battery lifespans will all contribute to lower raw materials extraction, reduce emissions, and improve benefits towards meeting international sustainability goals (Baars et al., 2021; Aguilar Lopez et al., 2024).

5. Barriers to and Drivers of the Implementation of Second-Life EV Battery Supply Chains

The transition from conventional linear supply chains to second life electric vehicle (EV) battery systems presents a notable opportunity for improving circular economy outcomes, decarbonizing energy systems and reducing critical materials dependency. However, transitioning from traditional linear supply chains to second-life battery systems creates a range of complex, interrelated challenges that are often viewed as impediments to mainstream adoption of second-life battery supply chains. Specifically, the challenges associated with second-life battery supply chains include economic uncertainties, technical fragmentation, regulatory inconsistencies, and social hesitancy, all of which are exacerbated by the infancy of second-life markets and disparate harmonisation practices worldwide. Our understanding of the wrap-around nature of these challenges and the identification of some enabling factors are vital to alleviating current bottlenecks and developing a scalable, commercially viable second life ecosystem.

This section offers an ordered and multi-faceted viewpoint of the main barriers and drivers to the development and implementation of second-life battery supply chains. The section draws on recent peer reviewed literature, market reports, and policy analysis to provide an inclusive and fact based framework. Important elements have been categorised across economic, technical, regulatory, and social/market dimensions to build in the systemic nature of the transformation in supply chains. Table 2 below provides a comprehensive overview of the barriers and drivers, combining a comparative synopsis of the most relevant aspects of them.

Table 2. Systemic Barriers and Strategic Drivers Shaping the Second-Life EV Battery Ecosystem

Dimension	Barriers	Drivers
Economic	* Capital-intensive diagnostic and refurbishment infrastructure due to lack of modularity and scale (Haram et al., 2023) * Marginal financial return from second-life applications in regions with low energy arbitrage opportunities (Zhang & Long, 2021) * Volatile market conditions and limited long-term price signals inhibit investment in second-life programs (Pham, 2021) * Absence of integrated cost-benefit modeling tools to evaluate total ownership cost over lifecycle.	* Emergence of value stacking models combining peak shaving, frequency regulation, and resilience services (Iqbal et al., 2023) * Financing frameworks leveraging ESG funds, green bonds, and sustainable procurement mandates (Saez de BikuÃ et al., 2025) * Integration into community energy programs and microgrid design to reduce dependency on fossil-based peaking capacity * Potential to defer distribution grid upgrades through localized storage applications
Technological	* Fragmented knowledge on aging mechanisms across chemistries leads to inaccurate state-of-health (SoH) projections (Fallah & Fitzpatrick, 2023) * Heterogeneous form factors, voltage ranges, and thermal management systems challenge standard reuse frameworks (Braco et al., 2021) * Data silos between OEMs, refurbishers, and utilities hinder interoperability and data-driven circularity (Rufino JÃºnior et al., 2024) * Limited AI validation datasets for second-life batteries constrains predictive diagnostics development	* Acceleration in real-time SoH monitoring using embedded sensors and BMS integration with digital twins (Hasan & Karim, 2024) * Blockchain-enabled provenance tracking systems securing supply chain transparency (Duan et al., 2025) * Open data initiatives from academic-industry consortia enhancing test protocol standardization (Chirumalla et al., 2023) * Maturation of AI-enabled fault detection improving predictive maintenance accuracy
Regulatory	* Conflicting national waste and transport laws hinder international trade of used battery systems (Josefson & Fransson, 2020) * Lack of harmonized reuse certifications and performance benchmarks across jurisdictions (Reinhardt et al., 2020) * Extended producer responsibility (EPR) mechanisms rarely include second-life provisions (Rizos & Urban, 2024) * Legal ambiguity in ownership and liability transitions during the post-OEM value chain	* Strengthening of circular policy regimes through mandates on minimum reuse quotas (Kostenko & Zaporozhets, 2024) * Development of regional battery registries and conformity assessment protocols (Hegenbart & Rosmark, 2023) * Strategic alignment of national clean tech subsidies with second-life pilot project scalability *Introduction of international labelling and certification platforms facilitating product traceability
Social/Market	* Persistent consumer risk aversion due to historical incidents of battery failure (Vu et al., 2020) * Absence of resale warranties and trust-building mechanisms in the second-life ecosystem (Church & Wuennenberg, 2019) * Knowledge asymmetries between urban and rural markets reduce adoption consistency * Regional stigmatization of pre-used energy assets impedes social normalization (Casals et al., 2017)	* Integration of reuse within corporate ESG roadmaps and life-cycle accounting disclosures (Aguilar Lopez et al., 2024) * Awareness programs enhancing public perception of safety and value in repurposed systems (Ahmed et al., 2025) * Cross-sectoral coalitions developing best practices for second-life battery deployment (Meyer et al., 2024) * Public-private partnerships promoting equitable energy access through affordable repurposed assets

This review enhances the current literature by contributing a comprehensive and comparative synthesis of barriers and drivers identified from perspectives that cross economic, technological, regulatory, and social boundaries. Instead of prioritizing technical elements or environmental considerations, as in previous studies, this study engages and integrates systemic elements and potential trade-offs into the analysis of the second-life EV battery supply chain. Furthermore, using a structured analysis based on PRISMA and drawing on the perspectives highlighted in each paper, the review proposes a new framework that contributes to resolving the complexity of second-life adoption and supports informed decision making by policy makers, industry actors, and researchers. Through this comprehensive systematized review, this review establishes itself as an important contribution to the emerging discussion on sustainable supply chain management and circular economy initiatives for energy storage systems.

5.1 Barriers to the Implementation of Second-Life EV Battery Supply Chains

1. Economic Barriers: High operation costs from batteries diagnostics, logistics, refurbishment, and repackaging could account for 90% of total project costs (Haram et al., 2023). Market fragmentation and small batch volumes also contributed to per unit costs increasing more than they would in the absence of standards. Difficulties in measuring the state of health and lack of acceptable secondary markets were factors of investment discouragement due to certainty in residual value and the ability to resell in an aftermarket (Zhang & Long, 2021). Lastly, lack of tax credits and direct subsidies results in low financial appeal (Pham, 2021).
2. Technological Barriers: Existing chemistries (NMC, LFP), designs, and embedded software are diverse, which presents challenges to building automated testing procedures at scale (Braco et al., 2021). Battery state of health (SoH) assessment protocols vary widely and refurbishers are often unable to access BMS data as proprietary manufacturer's information limits their ability to recognize performance potential (Fallah & Fitzpatrick, 2023). Interoperable platforms and digital passports for batteries are limited, which creates inefficiencies in follow-on traceability workflows and repurposing (Rufino Júnior et al., 2024).
3. Regulatory Barriers: Differences across jurisdictions regarding the classification of used batteries as waste, hazardous goods, or reusable parts results in confusion for those operating across borders (Rizos & Urban, 2024). Liability ambiguities, for example in residential applications or when the battery management system is embedded in a third-party application will limit second-life battery adoption (Josefson & Fransson, 2020). Insurance and certification programs are also lacking, limiting the market's confidence in the reliability of second-life battery systems (Reinhardt et al., 2020).
4. Social and Market Barriers: End-users may be unwilling to consider second-life batteries due to perceived uncertainty associated with redesigns in second-hand systems, with regards to warranties, as well as fears compared to safety and cycles of use reminders (Vu et al., 2020). There appears to be a lack of public awareness and even limited training for technicians, system integrators and technicians performing maintenance on the batteries. In this part of the market, second-hand technology may carry community embarrassment in some cultures reducing customer acceptability (Casals et al., 2017). Furthermore, utilities might be hesitant to adopt second-use batteries simply because batteries are not adaptable. The second-use battery community may believe the use and risks are mitigated compared to vastly uncertainties.

5.2 Drivers to the Implementation of Second-Life EV Battery Supply Chains

1. Market Demand: Second-life batteries fill critical affordability gaps in developing economies and offer affordable pathways for community energy systems, backup power, and storage for solar PV (Iqbal et al., 2023). While grid modernization is ongoing, distributed energy storage systems - especially in behind-the-meter and microgrid applications - are likely to see considerable growth (Saez de Bikuña et al., 2025).
2. Technological Innovation: Innovations in AI-informed BMS, real-time health checks, and predictive modelling of failures are advancing safety, increasing transparency of performance metrics, and improving decision-making capabilities (Hasan & Karim, 2024). Blockchain-based traceability systems and IoT monitoring platforms affording secure transactions and accurate transfer of ownership during the reuse phase (Duan et al., 2025).
3. Policy Support: Well-defined regulatory frameworks like the EU Battery Regulation and Canada's Clean Energy Standard have defined reuse, targets for recycling, and tracking digitally (Rizos & Urban, 2024; Kostenko & Zaporozhets, 2024). Policies like innovation grants and public procurement preferences for reused batteries bolstering industrial engagement.
4. Collaborative Ecosystems: Strategic alliances between manufacturers, research institutions, recyclers, and grid operators are streamlining logistics, standardizing certification practices, and building shared infrastructure

(Ahmed et al., 2025; Meyer et al., 2024). Knowledge-sharing platforms and joint ventures reduce learning curves and operational costs.

5. Environmental and ESG Pressures: Second-life batteries can reduce carbon emissions by delaying recycling energy inputs and conserving virgin materials (Aguilar Lopez et al., 2024). This contributes to circular economy goals and helps manufacturers and service providers meet sustainability targets under ESG frameworks and life-cycle reporting metrics (Baars et al., 2021). Multidimensional Barriers and Drivers Affecting Second-Life EV Battery Supply Chains.

6. Research Gaps and Future Research Directions

While second-life EV battery supply chains have gain academic and industrial interest, there are still research gaps to be addressed for the effective implementation or optimization of these systems. One gap in the literature is the lacking intersection with supply chain finance opportunities that could potentially facilitate the economic viability of second-life business models, especially as it pertains to end-of-life battery management. Existing literature only touches lightly on the potential of financial mechanisms (e.g., green financing, or insurance models) to alleviate economic uncertainties and enhance stakeholder engagement along the value chain (Zhang & Long, 2021).

Another gap exists in the lack of empirical research into performance, profitability, and risk of circular business models implemented for second-life batteries (Jiao, 2019; Meyer et al., 2024; Josefson & Fransson, 2020). While numerous conceptual frameworks exist, more evidence is needed to show how these models operate within practical supply chains in different regions and regulatory environments (Kristiningrum et al., 2025). Further, social acceptance of second-life batteries and how consumer behavior influences acceptance can be a valuable area for research; looking at this especially in emerging markets where issues of quality and safety perception are meaningful barriers (Church & Wuennenberg, 2019).

Technological issues also need to be investigated in greater depth. Despite some advances in diagnostics and battery management systems, standardized methods for performance evaluation, certification, and traceability in second-life applications are still not available (Salek et al., 2024). Future work could focus on the integration of digital solutions (i.e., utilizing blockchain and artificial intelligence [AI]) to strengthen data management and transparency along the supply chain.

Policy-related gaps remain, particularly as they relate to harmonizing international regulations on battery reuse, liability, and environmental compliance (Hegenbart & Rosmark, 2023; Kendall & Parés Olguín, 2024). Comparative research divided by regions (i.e., EU, North America) could yield meaningful insights that help promote cross-border harmonization of regulations for a more effective cross-border supply chain (Prates et al., 2023; Canals Casals & Amante García, 2016; Cicero, 2025). Finally, it is still unclear how second-life batteries tie into larger sustainability agendas (e.g., UN Sustainability Development Goals [SDGs]), which remains widely studied yet unclear (Akram & Abdul-Kader, 2025; Alshahapy et al., 2025).

There is also research need in understanding the role of second-life batteries to support decentralized energy systems and their implications for grid resilience in developing and remote areas (Dean & Kockelman, 2022). There is a limited literature on circularity strategies in the Global South and this is worth pursuing (Prates et al., 2023; Meegoda et al., 2024; Furtado et al., 2024; Diouf, 2025).

Finally, life-cycle assessment (LCA) models need to be adapted in a way that can account for the environmental impacts of second-life applications versus recycling and disposal options (Dong et al., 2023; Faruque & Mohammad, n.d.). The effects of market dynamics on the value of second-life batteries also represents a blank slate for future research (Sun et al., 2018; Olguín et al., 2023). Moreover, sustainable supplier selection processes in EV battery chains remain underexplored, especially when integrating environmental and social factors into second-life contexts (Singh & Pandey, 2024).

7. Conclusions

This scientific paper provides a thorough examination of the barriers and drivers affecting the implementation of second-life EV battery supply chains. Based on a synthesis of current academic and industry literature, the paper identifies the key economic, technological, regulatory and societal factors that require consideration to achieve the full value of battery reuse. Despite the potential environmental and economic benefits that could be obtained from second-life EV batteries, social, economic, policy and technological barriers such as the high cost of refurbishment, heterogeneity of battery types, fragmented regulation, and low social acceptance remain unresolved at this stage. Specifically, the findings of this paper suggest that second-life supply chains appear to be in their infancy, and require coordination, convergence of technology, and confluence of policy development before second-life supply chains can mature. Priority drivers include rising energy storage needs, advances into digital diagnosis and traceability,and supportive regulatory conditions. Collaborative business ecosystems and drivers for environmentally sustainable practices are also important enablers of second-life strategy adoption.

The study has limitations. It relies upon secondary data from the literature and it does not add practical empirical validation from real-world cases or stakeholder interviews. Secondly, most of the sources are situated in North America and Europe which limits the global generalizability. In the future, continued research should include longitudinal studies on second-life battery performance, consumer behavior studies in different regions, and financial modelling on the feasibility of a second-life business. Comparative policy analyses and life-cycle assessments (LCA) could assist with efforts to develop coherence across countries interested in these solutions for second-life batteries and estimate some form of environmental impact. Finally, research on second-life batteries within decentralized and off-grid systems, particularly for developing regions, would potentially expand the relevance of this circular solution to some underserved markets.

To summarise, second-life EV battery supply chains represent a potentially effective but multifaceted pathway to electrification and optimization of resource use. To grow this solution, it will be essential to remove barriers and exploit the drivers offered in the present review, and to continue to contribute to the energy transition and circular economy.

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