

# AI and Circular Economy Approaches in Electric Mobility: Optimizing Battery Recycling and Second-Life Applications

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## Abstract

This study explores the application of AI in the electric mobility sector (EVs) to improve circular economy (CE) related strategies and identify challenges related to recycling and the second-life use of electric vehicle batteries (EVB). This study used the systematic literature review approach, analyzing the existing literature and case studies to understand contemporary innovations using AI and CE in the EVB segment. The study findings highlight that AI technologies improve the management of the EVBs and forecast battery health up to 95% through predictive analytics. It also enhances the recycling processes, reducing the carbon footprint up to 40% and increasing material recovery. AI also effectively evaluates the battery's feasibility in second-life applications, thus maximizing resource utilization. The study also identifies the existing barriers, including the lack of data, the problem of compatibility, and the cost of implementation. It provides an opportunity for Synergizing AI and CE as the key to the strategy of the electric mobility ecosystem to become resource-efficient and sustainable. The study also suggested effective strategies to integrate AI technologies effectively by establishing regulatory infrastructures, allocating funds for AI research, establishing standardization, and partnering to tackle challenges that hinder the implementation of the EVB life cycle.

**Keywords:** Circular Economy, Electric Vehicle Batteries, Artificial Intelligence, Sustainability, Battery Recycling, Second-Life Applications.

## 1. Introduction

The global transition to electric mobility is gaining momentum, prompted by rising awareness of climate change and poor air quality (1). The transportation sector is taking a few steps to involve electric vehicles (EVs) which are a big stride in the direction of decarbonizing the transportation sector and decreasing its dependence on fossil fuels (2). At the same time, widespread adoption of EVs however presents new challenges to lifecycle sustainability, especially of lithium-ion batteries — the dominant technology in EV energy storage (3, 4). However, these batteries have a finite lifetime of 5 to 10 years, and their production relies on significant amounts of critical materials such as lithium, nickel, and cobalt (5). Extracting and processing these materials can be environmentally and socially costly to the environment and ethics as it relates to resource depletion and the ethical origin of the material (6, 7). However, to address these issues, the framework of the Circular Economy (CE) presents itself as a promising approach for the conception of an electric mobility

ecosystem that is sustainable and robust (8, 9). The CE strategies such as reuse, remanufacturing, and recycling, are designed to reduce waste, enhance product lifecycles, and recover valuable materials in end-of-life products (10). In regards to EV batteries, such approaches can repurpose batteries for 2nd life applications, such as stationary energy storage, or recycle for the extraction of valuable materials to produce new batteries (11, 12).

According to the perspective of CE strategies in electric mobility, AI technologies have the potential to drastically improve several facets of battery lifecycle management (13-15). The efficiency and effectiveness of the battery recycling process can be improved, the battery degradation and the remaining useful life can be predicted, and the design of the battery can be optimized for recyclability (14, 16).

Therefore, this review analyzes the possibility of employing AI to improve CE-related strategies in the electric mobility sector, specifically to improve the recycling of batteries and further develop second-life applications. This review

also explores the synergies between AI and CE to identify ways to achieve a resource-efficient and environmentally responsible electric mobility in the future.

## 2. Methodology

The lifecycle management of batteries of electric

vehicles (EVs) was studied concerning best practice principles of Artificial Intelligence (AI) and Circular Economy (CE) in a systematic literature review approach (17-20). The databases used to collect relevant studies from 2019-2025 including Scopus, Web of Science, and Google Scholar using some relevant keywords like ‘Artificial

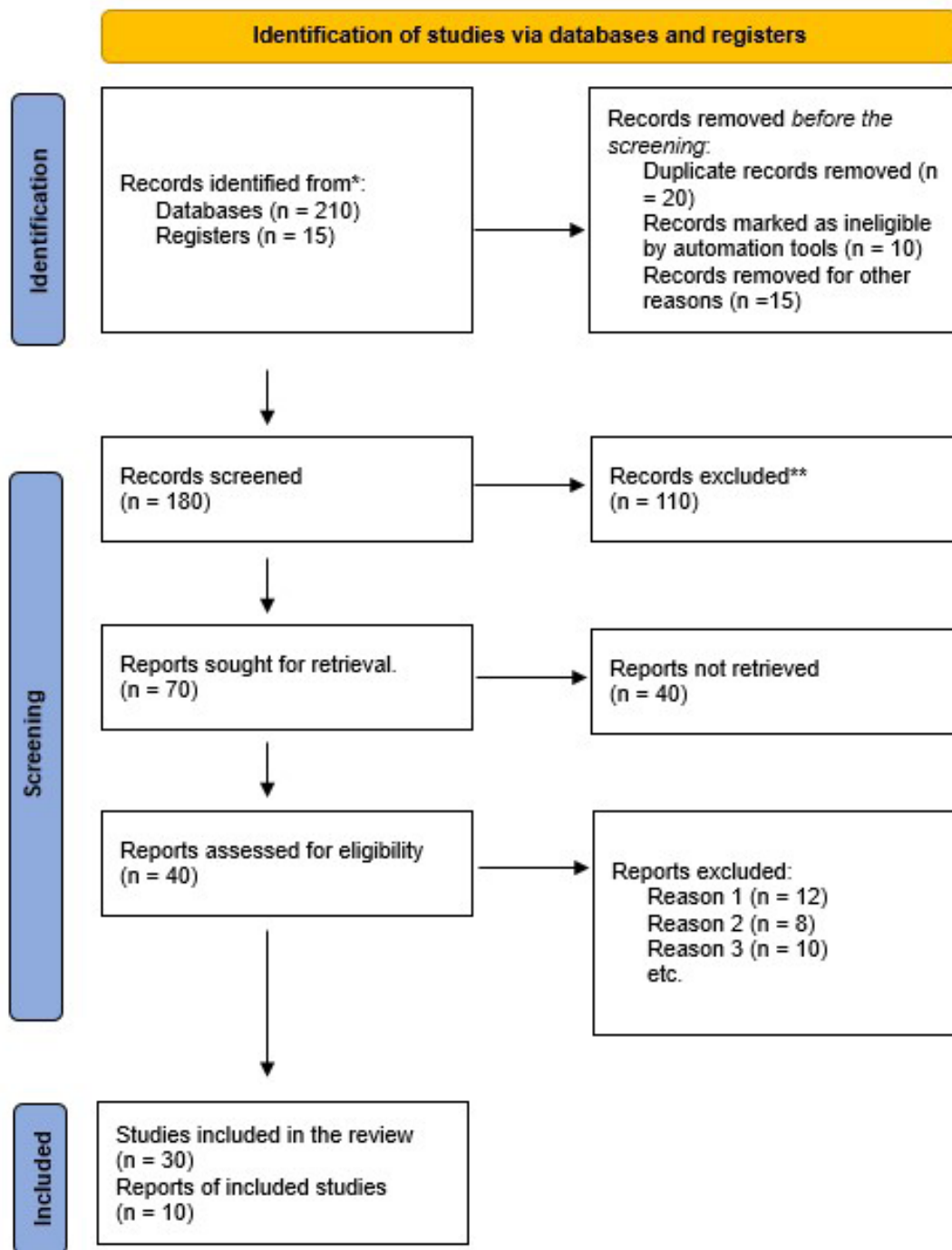


Figure 1 PRISMA Flow Diagram for AI & Circular Economy in EV Battery Lifecycle Management

Intelligence’, ‘Circular Economy’, ‘Electric Vehicle Batteries’, ‘Battery Recycling’, ‘Second Life Applications’ for the starting point. Fitting within the past five years and following the trend of relevance, and therefore timeliness, the search was conducted on peer-reviewed journals, conference proceedings, and industry reports.

According to specific inclusion and exclusion criteria, the literature was filtered (21). Only studies that discussed AI applications in EV battery lifecycle management, on the one hand, or CE strategies, on the other hand, were included. On the contrary, studies that did not take on the context of AI or CE concerning EV batteries were excluded. Therefore, the collected literature was analyzed to identify the key themes, trends, and challenges triggered by AI-driven CE strategies of EV batteries. This analysis

consisted of predictive analytics, recycling optimization as well as second-life battery applications using AI.

To give practical insights, automotive and battery manufacturers were analyzed through selected case studies. The case studies showed how these AI and CE principles were successfully integrated into real life, providing good lessons on scalability, innovation, and collaborative ecosystems. Moreover, to synthesize the findings from the literature review and case studies, this review provides a comprehensive understanding that how AI can assist in CE principles implementation in the electric mobility sector, specifically EV battery cycle management using a thematic analysis. These syntheses provided opportunities, challenges, and future directions for AI-driven CE strategies.

#	Author(s)	Year	Full Title	Main Focus Area
1	Akinola, P.	2024	Leveraging cost-effective AI and smart technologies for rapid infrastructural development in the USA	AI, CE
2	Akram, M. N. & Abdul-Kader, W.	2024	Repurposing Second-Life EV Batteries to Advance Sustainable Development: A Comprehensive Review	AI, Second Life
3	Alamerew, Y. A. & Brissaud, D.	2019	Circular economy assessment tool for end-of-life product recovery strategies	CE, Recovery Strategies
4	Alsulaimi, A. & Abdullah, T.	2020	Management of stakeholder communications in IT projects	Stakeholder Management
5	Antony Jose, S., et al.	2024	Recent Advancements in Artificial Intelligence in Battery Recycling	AI, Recycling
6	Arévalo, P., et al.	2024	A systematic review of the integration of artificial intelligence into energy management systems for electric vehicles	AI, Energy Management
7	Arshad, F., et al.	2022	Life cycle assessment of lithium-ion batteries: a critical review	CE, Lifecycle Assessment
8	Awan, U., et al.	2021	Industry 4.0 and the circular economy: A literature review and recommendations for future research	Industry 4.0, CE
9	Beales, E. J., et al.	2021	Environmental and social consequences of mineral extraction for low-carbon technologies	CE, Environmental Impacts
10	Bhupathi, H. P. & Chinta, S.	2022	Smart Charging Revolution: AI and ML Strategies for Efficient EV Battery Use	AI, Battery Usage
11	Camilleri, M. A.	2019	The circular economy's closed loop and product service systems for sustainable development: A review and appraisal	CE, Product Systems

#	Author(s)	Year	Full Title	Main Focus Area
12	Cavus, M., et al.	2025	Next Generation of Electric Vehicles: AI-Driven Approaches for Predictive Maintenance and Battery Management	AI, Battery Management
13	Chen, Y., et al.	2019	Life cycle assessment of end-of-life treatments of waste plastics in China	CE, Plastics Recycling
14	Chukwurah, N., et al.	2024	Strategies for engaging stakeholders in data governance: Building effective communication and collaboration	Data Governance
15	Colarullo, L. & Thakur, J.	2022	Second-life EV batteries for stationary storage applications in Local Energy Communities	CE, Second Life
16	Danish, M. S. S. & Senjyu, T.	2023	Shaping the future of sustainable energy through AI-enabled circular economy policies	AI, CE Policy
17	Das, P. K., et al.	2024	Life cycle assessment of electric vehicles: a systematic review of literature	CE, Lifecycle Assessment
18	Dev, S., et al.	2025	Intelligent Approaches to Promote Recycling Aligned With Sustainability Objectives	AI, Recycling
19	Elahi, M., et al.	2023	A comprehensive literature review of the applications of AI techniques through the lifecycle of industrial equipment	AI, Industrial Equipment
20	Faessler, B.	2021	Stationary, second use battery energy storage systems and their applications: A research review	CE, Second Life
21	Fan, E., et al.	2020	Sustainable Recycling Technology for Li-ion Batteries and Beyond: challenges and prospects	CE, Battery Recycling
22	Fei, Z., et al.	2021	Early prediction of battery lifetime via a machine learning-based framework	AI, Battery Health
23	Fioravanti, R., et al.	2020	Predictive-maintenance practices: For operational safety of battery energy storage systems	AI, Predictive Maintenance
24	Gal, M. S. & Rubinfeld, D. L.	2019	Data standardization	Data Standards
25	Gautam, D. & Bolia, N.	2024	Fostering second-life applications for electric vehicle batteries: A thorough exploration of barriers and solutions	AI, Second Life
26	Hannan, M. A., et al.	2018	State-of-the-art and energy management system of lithium-ion batteries in electric vehicle applications: Issues and recommendations	CE, Battery Management

#	Author(s)	Year	Full Title	Main Focus Area
27	Islam, M. T.	2024	A Systematic Literature Review On Building Resilient Supply Chains Through Circular Economy And Digital Twin Integration	CE, Supply Chains, Digital Twin
28	Jogarao, M., et al.	2024	AI-enabled circular economy management for sustainable smart cities: integrating artificial intelligence in resource optimization and Waste Reduction	AI, CE, Smart Cities
29	Jose, R., et al.	2020	Artificial intelligence-driven circular economy as a key enabler for sustainable energy management	AI, CE, Energy
30	Kara, S., et al.	2022	Closed-loop systems to a circular economy: A pathway to environmental sustainability?	CE, Systems
31	Kumar, R., et al.	2024	Transforming the transportation sector: Mitigating GHG emissions through EVs and exploring sustainable pathways	CE, Transport Policy
32	Lai, X., et al.	2022	Critical review of life cycle assessment of lithium-ion batteries for electric vehicles: A lifespan perspective	CE, LCA of Batteries
33	Lanzalonga, F., et al.	2024	The application of artificial intelligence in waste management: understanding the potential of data-driven approaches for the circular economy paradigm	AI, Waste Management
34	Leal Filho, W., et al.	2021	Framing electric mobility for urban sustainability in a circular economy context: An overview of the literature	CE, Urban Mobility
35	Lwakatare, L. E., et al.	2020	Large-scale machine learning systems in real-world industrial settings: A review of challenges and solutions	AI Systems in Practice
36	Mandala, V., et al.	2024	Towards Carbon-Free Automotive Futures: Leveraging AI And ML For Sustainable Transformation	AI, Automotive Futures
37	Meng, K., et al.	2022	Intelligent disassembly of electric-vehicle batteries: a forward-looking overview	AI, Disassembly
38	Ming, L. W., et al.	2024	AI as a driver of efficiency in waste management and resource recovery	AI, Waste Management
39	Mishra, A., et al.	2023	A review of reverse logistics and closed-loop supply chains from the perspective of circular economy	CE, Logistics
40	Mrozik, W., et al.	2021	Environmental impacts, pollution sources, and pathways of spent lithium-ion batteries	CE, Battery Disposal

### 3. Results

#### 3.1 AI and Circular Economy: A Transformative Synergy

AI and ML technologies are becoming more and more acknowledged as powerful enablers of CE strategy implementation in different industries (22). The CE framework is based on minimizing waste and maximizing resource efficiency through the establishment of systems for both products and materials that run in a closed loop (23, 24). For these systems, AI and ML ensure it by analyzing large datasets, optimizing processes, and improving decision-making during the lifecycle of the product (25). A Scopus bibliometric analysis of these AI topics as applied to the CE principles includes reverse logistics, waste management, recycling, reuse, manufacturing development, as well as sustainable supply chains (26, 27). Taken together, these technologies provide solutions to the challenges of predictive maintenance, more efficient recycling processes, better waste processing, etc., necessary to deploy CE strategies successfully (28).

In this context, AI and ML have great potential to develop efficient lifecycle management and deal with sustainability issues in Electric Vehicle Batteries (EVBS) (29). However the problem with lithium-ion batteries in EVs is that they deplete their finite lifespan, decline their environmental impacts from material extraction, and ultimately run out of resources (30). Recyclability as well as improvements to production processes that reduce waste can be achieved with AI for more sustainable battery design (16). The AI-powered battery management system that is available during the use phase can extend the battery's lifespan by optimally charging and using the battery during the use phase (31). The accuracy in predicting battery degradation and the remaining useful life, as well as better repurposing or recycling decisions of a battery, can be achieved by using ML models (32, 33).

AI technologies at the end-of-life stage are used to make accurate assessments on the utilization of used batteries for second-life purposes or recycling (16). Disassembly processes and material recovery carried out during recycling can all be optimized by ML algorithms, and recycled valuable materials such as lithium, cobalt, and nickel can be recovered with maximum efficiency (16). Also, AI-driven systems will automatically route the batteries to the right end of life – reuse, re-manufacture, or recycle depending on the battery health and life remaining (16). One other reason that the reverse logistics systems can also take advantage of AI advancements is that AI can help to develop the efficiency of battery collection

networks and also can help to ensure that the transportation routes for the used batteries will be efficient (34, 35).

The literature related to AI/ML applications for developing circular economy strategies in the EVB presents several research trends (36). ML models enable accurate predictions of battery degradation and remaining useful life, and there are a lot of focus areas around the prediction (32). The third trend that is becoming important is process optimization where the efficiency is increased in both the manufacturing, use-phase management, and recycling processes through AI (37). ML algorithms are being developed to power innovative intelligent sorting techniques for the assessment of used batteries more accurately and channel them to the corresponding end-of-life path (16). In addition, researchers are investigating how AI allows tightly connected closed-loop battery materials system that combines manufacturing, usage, collection, and recycling in a tight loop (16). Moreover, data-driven decision support systems based on the power of AI are being designed to provide decision support to the stakeholders in the battery value chain, starting from manufacturers to recyclers, to make better decisions (38).

While all these advancements have been created still several research gaps need attention to successfully explore AI AI-based circular economy approaches for EVBs. However, AI/ML solutions in industrial settings are often not applied in practice, therefore, more of them should be tested in real life to validate their practicality (39). However, to realize battery second-life widespread adoption there exists a need to develop and standardize approaches for condition and suitability assessment for second-life applications using AI (40). It is also recommended that further research be done to optimally integrate different CE strategies for EVBs (that is reuse, remanufacturing, recycling). To evaluate the economic, environmental, and social implications of the above-mentioned AI-driven strategies, comprehensive sustainability impact assessments are needed. Likewise, we also need to analyze the organizational challenges regarding the management processes so that the implementation at the scale is successful.

Finally, although it is clear that AI and ML technologies are promising for the improvement of circular economy strategy in the electric vehicle battery sector, there is still a lot of work needed to fill in the gaps and challenges. The solutions proposed here should be scaled up in the future but with attention given to balancing them with other broader defined sustainability goals. Utilizing the AI and CE principle synergies, resource-efficient and

environmentally responsible EVBs can be created across their lifecycle.

### **3.2 AI in Battery Lifecycle Management**

The integration of artificial intelligence into battery lifecycle management, we are rapidly approaching the realization of the most advanced components to establish how batteries are designed, how they are used, and how they are recycled. Machine learning (ML) based AI technologies support the entire lifecycle of batteries from battery predictive analytics that can help with health monitoring, intelligent reintegration, and second-life applications, among others (41).

### **3.3 Predictive Analytics for Battery Health Monitoring**

Predicting battery lifespan and performance is becoming an increasingly popular use of machine learning models (42). These models use huge datasets that contain usage patterns, charging behaviors, and environmental conditions for degradation prediction and remaining useful life (RUL) forecast. For example, Stanford researchers have shown that AI-powered algorithms can, with as much as 95 percent accuracy, guess the lifespans of lithium-ion batteries (43). That was a prediction that was not feasible before. This capability can do proactive maintenance, before failure to service batteries that then prevents downtime, and extends the operational life of the batteries. Also, (44). Additionally, cloud-based analytics of battery systems empower more accurate predictions regarding battery safety, aging, and performance using data historical data from battery management systems (BMS) (45).

### **3.4 AI-driven Optimization of Battery Recycling**

Robotic, and increasingly intelligent, sorting, disassembly, and material recovery of batteries are being revolutionized by AI technologies (16). AI-powered robotics can disassemble batteries very efficiently with little material loss. Further boost recycling by making predictive algorithms that predict optimal pathways based on the composition and conditions of each battery, to match the way they recycle in a battery bank. For instance, AI systems can tell whether a battery is more suitable for material recovery or repurposing to minimize environmental footprint (16). Also, real-time adaptive controls driven by AI can be used to dynamically adapt the recycling processes to the battery type and conditions variations. To cut waste in this frenzy of new devices — the battery always being the most important component —

they are improving the efficiency of recycling while also ensuring that such valuable materials as lithium, cobalt, and nickel can be recovered for recycling in new batteries (46).

### **3.5 AI for Second-Life Battery Applications**

Any such battery repurposing for second-life applications like grid storage or microgrids demands reliable performance prediction, which is a task very well acclaimed by AI (47). Used batteries are assessed using their remaining capacity and pattern of degradation through algorithms. It ensures that only batteries suitable for second-life applications are chosen for second-life applications to maximize their utility and economic value and minimize waste. For instance, AI-driven platforms can match the battery with the application that they can provide based on its performance characteristics and thus deploy them optimally in energy storage systems or renewable energy grids (47). AI finds ways to efficiently make the second life of batteries work and to reduce demand for new batteries to conserve resources (40).

Despite this, battery lifecycle management is improved through predictive analytics, optimized recycling processes, and second-life applications and it is particularly advanced by the use of AI (16). Further, these technologies support a broader circular economy framework for battery usage while at the same time improving the efficiency and sustainability of battery use. There however is further research to scale these solutions appropriately and to tackle side issues like standardization and integration from myriad applications. With full leverage, the electric vehicle industry can make significant steps toward sustainability and resource efficiency through AI's potential (48).

### **3.6. Introduction to Circular Economy and deploying it through Electric Mobility via AI**

Artificial intelligence (AI) is a game-changer in realizing the circular economy (CE) principles of electric mobility (49). Like any other strategy-oriented technology, artificial intelligence helps in the design, implementation, and optimization of CE strategies to mitigate waste, save resources, and ultimately promote sustainability using advanced data analytics, machine learning (ML), and digital technology (50).

### **3.7. Enhanced Engineering through AI-Driven Prediction in the Circular Economy**

The integration of AI increases the depth of

engineering considerably, making it more effective and sustainable, especially when it comes to the circular economy (CE). Research findings have compared and explained the usage of certain AI models for forecasts and enhancement in numerous engineering disciplines. In the case of the management of electric vehicle batteries (EVs), AI plays a significant role in sustainable development. Cavus et al. (2025) review using AI-based techniques for predictive maintenance and battery systems. RNNs can predict the battery degradation and thus allow for early intervention, and hence increase the battery lifespan. Fei et al. (2021) presented machine learning techniques applied to battery degradation power consumption for second-life use determination. Bhupathi & Chinta (2022) also discuss AI and Machine Learning (ML) for smart charging EV batteries.

AI is also of great importance in waste management and resource recycling processes. Lanzalonga et al. (2024) and Ming et al. (2024) explain that AI has the capacity to enhance waste sorting, recycling, and the reuse of resources. CNNs can recognize images and sort the waste, thus enhancing the recycling ratio. Decision trees help determine the most suitable treatment methods for waste. Furthermore, the use of AI in decision-making brings more accurate predictions than traditional approaches to solving the problem. Although there is no direct quantification of the numbers in these abstracts, AI eliminates errors and optimizes the use of resources. For instance, in predictive maintenance, battery failures are predicted and addressed before they cause a problem, which is much cheaper than corrective maintenance. Similarly, the use of robots in sorting waste through the application of artificial intelligence is more efficient than the manual sorting of waste.

The general system-level logic is presented by data acquisition, the development and implementation of an AI model, and the use of predictions for engineering decisions. For instance, in predictive battery maintenance: Sensor Data → RNN Model → Degradation Prediction → Maintenance Scheduling. The employment of AI models such as CNNs and RNNs in engineering depth in the circular economy is advantageous in aspects of prediction, optimization, and attaining sustainable and efficient systems.

### **3.8. Framework for Circular Economy Integration**

AI is very important in the development of a framework to integrate a circular economy by facilitating Life Cycle Assessment (LCA) and data-driven decision-

making (49). In evaluating the environmental impact of products throughout their lifecycle (raw input to end-of-life management) lifecycle assessment is important (51). It is good steady with AI capable of scanning large datasets in real-time to determine where inefficiencies lie and offers the requisite interventions for the reduction of waste and emissions (52). The digital twins of physical systems also provide for real-time observation and adaptive operation of battery assets at every stage of their lifecycle (53). For instance, digital twins can simulate battery behavior under different conditions to foresee how degradation will occur and how to drive it (54). These tools enable the designing of more sustainable systems while maintaining resource efficiency.

Reverse logistics infrastructure is also supported by AI in its collection, sorting, and transportation of used batteries (35). Routing and inventory management with intelligent algorithms optimizes routing and management of costs and their environmental impacts on logistics operations (55). Beyond that, (56).

### **3.9. Economic and Environmental Benefits**

Circular strategies greatly improve the economics and the environment in electric mobility through the use of AI-enabled (57). From a business point of view, saving on manufacturing costs and increasing manufacturing utilization through predictive analytics positively extends the battery life (58). The higher efficiency of the material recovery processes that result from AI-driven recycling processes also lowers costs (59). As an example, using AI, robotically powered AI can disassemble batteries with perfection, eliminating material loss and labor costs (60). These innovations have the power to reduce operational expenses while generating new revenue from recovered materials, and qualitative models confirm this result (61). At the environmental level, AI can lead to huge carbon emissions and waste generation. Through composition and condition-based optimization of battery recycling pathways, AI reduces the energy invested in material recovery to the minimum cost for resource reuse (16). Second-life applications in AI use cases based on batteries, such as repurposing them for grid or microgrid storage, also lead to a drop in new battery demand by saving these precious resources, such as lithium, cobalt, and nickel (47). (57).

AI helps advance CE strategies by giving access to more advanced lifecycle assessment support, digital twin-based adaptive management support, and more optimized reverse

logistics infrastructure (62). On top of that, its economic and environmental benefits add up to the potential to contribute to the establishment of a more sustainable future of electric mobility while solving such urgent issues as resource depletion and waste management. Future research would work on scaling these solutions over various industries by collaborating with stakeholders to achieve the maximum outcomes for global sustainability efforts.

The application of AI to CE strategy for electric mobility offers great prospects of enhancing sustainability via improved efficiency of material and energy resources (22, 57, 63). Many problems must be overcome to fully take advantage of these technologies. As a result, one of the most significant components is the access to large quantities of high-quality data across the entirety of the electric vehicle battery's life (64). However, for the effectiveness of these systems, it is necessary to create large datasets, which are often hindered by data gaps. In addition, it is key to ensure interoperable between different systems and technologies to achieve smooth integration of AI solutions. Different formats and communication protocols for disparate data can prevent them from running smoothly among stakeholders (65, 66). Other than this high upfront costs involved in developing and implementing AI technologies are another major challenge (67). The services include the technology itself as well as the necessary training and expertise to control AI systems. For many companies, including small and medium ones, this financial burden can be a deciding factor in not entering, or staying, in an Internet activity. They thus have a critical role to play in overcoming these challenges.

Moreover, there is an important need to fill regulatory gaps, and develop clear guidelines and standards for data sharing, the integration of AI, as well as circular economy practices (68). This also includes setting up frameworks that generate a culture of transparency and merging multiple industries. Additionally, policymakers should promote standards for the formats and protocols of data for use among the different industries that ease the entry barriers to AI adoption and level the playing field (69).

Furthermore, research and collaboration between the public and private sectors are needed for scaling AI-driven circular economy solutions (70). Such research should aim to develop more cost-effective AI technology and to increase data availability through collaborative data sharing (71). The high costs involved in integrating AI often require the support of public-private partnerships that can fund and provide expertise to overcome (72). It

can be enabled by fostering a collaborative environment and a regulatory environment that encourages innovation to make a more sustainable and robust electric mobility ecosystem. Ultimately, solving this problem requires sound political leadership, industry leadership, and research moving in the right direction to ensure that AI technologies can bring value to achieve circular economy goals in the electric mobility sector (57, 68).

### **3.10. Challenges and Future Directions**

The integration of AI technologies has significant potential to improve circular economy strategies in electric mobility, but it is equally important to look at its weaknesses. AI models have a limitation of explainability, making it difficult to comprehend how the model arrived at a particular decision (39). This 'black box' characteristic can be a problem in terms of trust and acceptance, especially in applications that are sensitive. Another limitation is overfitting, where models are very effective in training data but poor in generalization to new data. This can lead to wrong predictions in the real-life battery lifecycle management (39). Moreover, Hannan et al. (2018) have pointed out that the quality of data used in AI solutions is crucial, as poor-quality data can yield poor results (64). Some of these features include scalability, compatibility with organizational administrative and organizational structures, and requirements for computing power to support the ongoing operation of the AI technology. In general, the costs incurred in developing, deploying, and maintaining the AI infrastructure, such as data, training, models, and specialized personnel, are often high (67).

### **4. Conclusion**

Artificial intelligence (AI) and circular economy (CE) principles provide an attractive opportunity to integrate both into electric mobility to improve sustainability. The battery recycling process is optimized by AI and enabled for second-life applications leading to great environmental outcomes. Using AI-powered predictive analytics and automation the companies can also extend the batteries' lifecycle, reduce waste, and save critical resources. Future progress will involve more investment in AI technologies, regulatory support for circular economy practices, and continued development of technological capabilities to reach the synergy's true potential. The electric mobility sector is evolving and thus AI and CE principles will be a requirement of building an even more sustainable and resilient transportation ecosystem. Moreover, stakeholders

can leverage AI to unlock the benefits of the AI-driven circular economy for electric mobility, so they can work towards a more environmentally responsible future for electric vehicles.

### 5. Limitations of the Study

Limitations of this study include reliance on literature, no real-world implementation data analyzed, and a study on theoretical AI applications for electric mobility. In the context of an attempt to assess the economic feasibility and scalability of AI-driven circular economy strategies across a variety of industry settings, it lacks a holistic view of the economic contribution of a system that is designed as an AI decision support system.

### References

D'Acunto D. *The Future of E-Mobility*. Springer Books. 2024.

Kumar R, Kanwal A, Asim M, Pervez M, Mujtaba M, Fouad Y, et al. Transforming the transportation sector: Mitigating greenhouse gas emissions through electric vehicles (EVs) and exploring sustainable pathways. *AIP Advances*. 2024;14(3).

Fan E, Li L, Wang Z, Lin J, Huang Y, Yao Y, et al. Sustainable recycling technology for Li-ion batteries and beyond: challenges and future prospects. *Chemical reviews*. 2020;120(14):7020-63.

Rajaeifar MA, Ghadimi P, Raugei M, Wu Y, Heidrich O. Challenges and recent developments in supply and value chains of electric vehicle batteries: A sustainability perspective. *Elsevier*; 2022. p. 106144.

Arshad F, Lin J, Manurkar N, Fan E, Ahmad A, Tariq M-u-N, et al. Life cycle assessment of lithium-ion batteries: a critical review. *Resources, Conservation and Recycling*. 2022;180:106164.

Sharma SS, Manthiram A. Towards more environmentally and socially responsible batteries. *Energy & Environmental Science*. 2020;13(11):4087-97.

Beales EJ, Bröske Danielsen J, Grytli T, Simas M. Environmental and social consequences of mineral extraction for low-carbon technologies: Cobalt, lithium and nickel extraction, impacts and relation to the SDGs.

2021.

Leal Filho W, Abubakar IR, Kotter R, Grindsted TS, Balogun A-L, Salvia AL, et al. Framing electric mobility for urban sustainability in a circular economy context: An overview of the literature. *Sustainability*. 2021;13(14):7786.

Pamučar D, Durán-Romero G, Yazdani M, López AM. A decision analysis model for smart mobility system development under circular economy approach. *Socio-Economic Planning Sciences*. 2023;86:101474.

Alamerew YA, Brissaud D. Circular economy assessment tool for end of life product recovery strategies. *Journal of Remanufacturing*. 2019;9(3):169-85.

Colarullo L, Thakur J. Second-life EV batteries for stationary storage applications in Local Energy Communities. *Renewable and Sustainable Energy Reviews*. 2022;169:112913.

Faessler B. Stationary, second use battery energy storage systems and their applications: A research review. *Energies*. 2021;14(8):2335.

Arévalo P, Ochoa-Correa D, Villa-Ávila E. A systematic review on the integration of artificial intelligence into energy management systems for electric vehicles: Recent advances and future perspectives. *World Electric Vehicle Journal*. 2024;15(8):364.

Pregowska A, Osial M, Urbańska W. The application of artificial intelligence in the effective battery life cycle in the closed circular economy model—a perspective. *Recycling*. 2022;7(6):81.

Zhou Y. Lifecycle battery carbon footprint analysis for battery sustainability with energy digitalization and artificial intelligence. *Applied Energy*. 2024;371:123665.

Antony Jose S, Cook CAD, Palacios J, Seo H, Torres Ramirez CE, Wu J, et al. Recent Advancements in Artificial Intelligence in Battery Recycling. *Batteries*. 2024;10(12).

Das PK, Bhat MY, Sajith S. Life cycle assessment of electric vehicles: a systematic review of literature.

Environmental Science and Pollution Research. 2024;31(1):73-89.

Tintelecan A, Dobra AC, Martiș C. Literature review-electric vehicles life cycle assessment. 2020 ELEKTRO. 2020:1-6.

Lai X, Chen Q, Tang X, Zhou Y, Gao F, Guo Y, et al. Critical review of life cycle assessment of lithium-ion batteries for electric vehicles: A lifespan perspective. Etransportation. 2022;12:100169.

Xia X, Li P. A review of the life cycle assessment of electric vehicles: Considering the influence of batteries. Science of the Total Environment. 2022;814:152870.

Patino CM, Ferreira JC. Inclusion and exclusion criteria in research studies: definitions and why they matter. Jornal Brasileiro de Pneumologia. 2018;44:84-.

Jose R, Panigrahi SK, Patil RA, Fernando Y, Ramakrishna S. Artificial intelligence-driven circular economy as a key enabler for sustainable energy management. Materials Circular Economy. 2020;2:1-7.

Kara S, Hauschild M, Sutherland J, McAloone T. Closed-loop systems to circular economy: A pathway to environmental sustainability? CIRP Annals. 2022;71(2):505-28.

Camilleri MA. The circular economy's closed loop and product service systems for sustainable development: A review and appraisal. Sustainable Development. 2019;27(3):530-6.

Elahi M, Afolaranmi SO, Martinez Lastra JL, Perez Garcia JA. A comprehensive literature review of the applications of AI techniques through the lifecycle of industrial equipment. Discover Artificial Intelligence. 2023;3(1):43.

Mishra A, Dutta P, Jayasankar S, Jain P, Mathiyazhagan K. A review of reverse logistics and closed-loop supply chains in the perspective of circular economy. Benchmarking: an international journal. 2023;30(3):975-1020.

Yu Z, Kwilinski A, Trushkina N. Reverse logistics

in a system of the circular economy: theoretical aspect. Экономический вестник Донбасса. 2018(4 (54)):29-37.

Turskis Z, Šniokienė V. IoT-Driven Transformation of Circular Economy Efficiency: An Overview. Mathematical and Computational Applications. 2024;29(4):49.

Xiao'ai W. Toward a Sustainable Business Model. 2023.

Mrozik W, Rajaeifar MA, Heidrich O, Christensen P. Environmental impacts, pollution sources and pathways of spent lithium-ion batteries. Energy & Environmental Science. 2021;14(12):6099-121.

Bhupathi HP, Chinta S. Smart Charging Revolution: AI and ML Strategies for Efficient EV Battery Use. ESP Journal of Engineering & Technology Advancements. 2022;2(2):154-67.

Rauf H, Khalid M, Arshad N. Machine learning in state of health and remaining useful life estimation: Theoretical and technological development in battery degradation modelling. Renewable and Sustainable Energy Reviews. 2022;156:111903.

Sharma P, Bora BJ. A review of modern machine learning techniques in the prediction of remaining useful life of lithium-ion batteries. Batteries. 2022;9(1):13.

Spirito C. Artificial Intelligence applications in Reverse Logistics, how technology could improve return and waste management creating value: Politecnico di Torino; 2024.

Wilson M, Paschen J, Pitt L. The circular economy meets artificial intelligence (AI): Understanding the opportunities of AI for reverse logistics. Management of Environmental Quality: An International Journal. 2022;33(1):9-25.

Dev S, Rani M, Srivastava R, Prakash S. Intelligent Approaches to Promote Recycling Aligned With Sustainability Objectives. AI Technologies for Enhancing Recycling Processes: IGI Global Scientific Publishing; 2025. p. 295-318.

Waltersmann L, Kiemel S, Stuhlsatz J, Sauer A, Mieke R. Artificial intelligence applications for increasing resource efficiency in manufacturing companies—a comprehensive review. *Sustainability*. 2021;13(12):6689.

Soori M, Jough FKG, Dastres R, Arezoo B. AI-based decision support systems in Industry 4.0, A review. *Journal of Economy and Technology*. 2024.

Lwakatare LE, Raj A, Crnkovic I, Bosch J, Olsson HH. Large-scale machine learning systems in real-world industrial settings: A review of challenges and solutions. *Information and software technology*. 2020;127:106368.

Gautam D, Bolia N. Fostering second-life applications for electric vehicle batteries: A thorough exploration of barriers and solutions within the framework of sustainable energy and resource management. *Journal of Cleaner Production*. 2024;456:142401.

Cavus M, Dissanayake D, Bell M. Next Generation of Electric Vehicles: AI-Driven Approaches for Predictive Maintenance and Battery Management. *Energies*. 2025;18(5):1041.

Fei Z, Yang F, Tsui K-L, Li L, Zhang Z. Early prediction of battery lifetime via a machine learning based framework. *Energy*. 2021;225:120205.

Omojola AF, Ilabija CO, Ifeanyi C, Onyeka JII, Olaleye TG, Ozoemena IJ, et al. Artificial Intelligence-Driven Strategies for Advancing Lithium-Ion Battery Performance and Safety.

Fioravanti R, Kumar K, Nakata S, Chalamala B, Preger Y. Predictive-maintenance practices: For operational safety of battery energy storage systems. *IEEE power and energy magazine*. 2020;18(6):86-97.

Shi D, Zhao J, Eze C, Wang Z, Wang J, Lian Y, et al. Cloud-based artificial intelligence framework for battery management system. *Energies*. 2023;16(11):4403.

Winslow KM, Laux SJ, Townsend TG. A review on the growing concern and potential management strategies of waste lithium-ion batteries. *Resources, Conservation and Recycling*. 2018;129:263-77.

Akram MN, Abdul-Kader W. Repurposing Second-Life EV Batteries to Advance Sustainable Development: A Comprehensive Review. *Batteries*. 2024;10(12):452.

Mandala V, Surabhi S, Kommisetty P, Kuppala B, Ingole R. Towards Carbon-Free Automotive Futures: Leveraging AI And ML For Sustainable Transformation. *Educational Administration: Theory and Practice*. 2024;30(5):3485-97.

Lanzalonga F, Marseglia R, Irace A, Biancone PP. The application of artificial intelligence in waste management: understanding the potential of data-driven approaches for the circular economy paradigm. *Management Decision*. 2024.

Jogarao M, Lakshmana B, Naidu S. Ai-enabled circular economy management for sustainable smart cities: integrating artificial intelligence in resource optimization and waste reduction. *Smart Cities and Circular Economy: Emerald Publishing Limited*; 2024. p. 83-96.

Chen Y, Cui Z, Cui X, Liu W, Wang X, Li X, et al. Life cycle assessment of end-of-life treatments of waste plastics in China. *Resources, Conservation and Recycling*. 2019;146:348-57.

Vasudevan K. Ai-driven solutions for real-time waste monitoring and management. *Journal of Recent Trends in Computer Science and Engineering (JRTCSE)*. 2024;12(2):11-20.

Panwar NG, Singh S, Garg A, Gupta AK, Gao L. Recent advancements in battery management system for Li-ion batteries of electric vehicles: future role of digital twin, cyber-physical systems, battery swapping technology, and nondestructive testing. *Energy Technology*. 2021;9(8):2000984.

Wu B, Widanage WD, Yang S, Liu X. Battery digital twins: Perspectives on the fusion of models, data and artificial intelligence for smart battery management systems. *Energy and AI*. 2020;1:100016.

Pasupuleti V, Thuraka B, Kodete CS, Malisetty S. Enhancing supply chain agility and sustainability through machine learning: Optimization techniques for logistics and inventory management. *Logistics*. 2024;8(3):73.

Tsolakis N, Schumacher R, Dora M, Kumar M. Artificial intelligence and blockchain implementation in supply chains: a pathway to sustainability and data monetisation? *Annals of Operations Research*. 2023;327(1):157-210.

Oladapo BI, Olawumi MA, Omigbodun FT. AI-Driven Circular Economy of Enhancing Sustainability and Efficiency in Industrial Operations. *Sustainability*. 2024;16(23):10358.

Wolniak R. Smart manufacturing—the utilization of business analytics in Industry 4.0 environments. *Zeszyty Naukowe Organizacja i Zarządzanie/Politechnika Śląska*. 2024.

Ming LW, Anderson J, Hidayat F, Yulian FD, Septiani N. Ai as a driver of efficiency in waste management and resource recovery. *International Transactions on Artificial Intelligence*. 2024;2(2):128-34.

Meng K, Xu G, Peng X, Youcef-Toumi K, Li J. Intelligent disassembly of electric-vehicle batteries: a forward-looking overview. *Resources, Conservation and Recycling*. 2022;182:106207.

Nascimento DLM, Alencastro V, Quelhas OLG, Caiado RGG, Garza-Reyes JA, Rocha-Lona L, et al. Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal. *Journal of manufacturing technology management*. 2019;30(3):607-27.

Islam MT. A Systematic Literature Review On Building Resilient Supply Chains Through Circular Economy And Digital Twin Integration. *Frontiers in Applied Engineering and Technology*. 2024;1(01):304-24.

Danish MSS, Senjyu T. Shaping the future of sustainable energy through AI-enabled circular economy policies. *Circular Economy*. 2023;2(2):100040.

Hannan MA, Hoque MM, Hussain A, Yusof Y, Ker PJ. State-of-the-art and energy management system of lithium-ion batteries in electric vehicle applications: Issues and recommendations. *Ieee Access*. 2018;6:19362-78.

Chukwurah N, Ige AB, Idemudia C, Adebayo VI.

Strategies for engaging stakeholders in data governance: Building effective communication and collaboration. *Open Access Res J Multidiscip Stud*. 2024;8(1):057-67.

Alsulaimi A, Abdullah T, editors. Management of stakeholder communications in IT projects. 2020 3rd International Conference on Computer Applications & Information Security (ICCAIS); 2020: IEEE.

Shaw J, Rudzicz F, Jamieson T, Goldfarb A. Artificial intelligence and the implementation challenge. *Journal of medical Internet research*. 2019;21(7):e13659.

Awan U, Sroufe R, Shahbaz M. Industry 4.0 and the circular economy: A literature review and recommendations for future research. *Business Strategy and the Environment*. 2021;30(4):2038-60.

Gal MS, Rubinfeld DL. Data standardization. *NYUL Rev*. 2019;94:737.

Owojori OM, Okoro C. The private sector role as a key supporting stakeholder towards circular economy in the built environment: a scientometric and content analysis. *Buildings*. 2022;12(5):695.

Akinola P. Leveraging cost-effective AI and smart technologies for rapid infrastructural development in USA. *African Journal of Advances in Science and Technology Research*. 2024;15(1):59-71.

Prasad KR, Karanam SR, Ganesh D, Liyakat KKS, Talasila V, Purushotham P. AI in public-private partnership for IT infrastructure development. *The Journal of High Technology Management Research*. 2024;35(1):100496.