



Research in Engineering Education Symposium (REES)
Regional Conference in Engineering Education (RCEE)
& Research in Higher Education (RHEd)
September 29 – October 3, 2025
Johor, Malaysia



An Interdisciplinary Curriculum Framework on Aged Battery Reuse for Power Grid Applications in Engineering Education

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ABSTRACT

BACKGROUND & CONTEXT

Aged traction batteries have been widely recommended by researchers globally for use in power grid energy storage systems to mitigate fluctuations caused by high renewable energy integration. However, the primary challenge in implementing this solution is that electrical engineers and power market manager in the power grid industry lack access to cutting-edge knowledge for assessing the safety of aged batteries and power market management.

PURPOSE OR GOAL

This paper presents a course framework designed for electrical engineering students aspiring to become electrical engineers or power market managers. The course equips them with advanced interdisciplinary tools to rapidly master essential methodologies for assessing the safety of aged traction batteries and effectively managing power markets that incorporate reused batteries.

APPROACH OR METHODOLOGY

During the lectures, students will be introduced to technical foundations and advanced, state-of-the-art knowledge through the use of animations and simulation tools. The laboratory-based experiments are closely aligned with the lecture content to reinforce theoretical concepts through practical application.

OUTCOMES

The proposed educational framework addresses the critical knowledge gap among power systems engineers in evaluating the safety of aged traction batteries for potential reuse as grid-scale energy storage. It also helps bridge the knowledge gap for students aspiring to become power market managers in emerging grids that increasingly rely on reused batteries.

CONCLUSIONS

This paper presents an educational framework that equips electrical engineering students with knowledge of cutting-edge technologies and management practices for reused batteries in power grids, an area often overlooked in traditional power engineering education.

KEYWORDS

curriculum framework, electrical engineering, second-life batteries, management, circular economy.

Introduction

Background and Motivation

With the surging global demand for electric vehicles (EVs), the annual volume of retired EV batteries is projected to reach 100-120 GWh by 2030 (International Energy Agency, 2020). It is estimated that over 6.8 million EV batteries will be decommissioned by 2035 (Xu et al., 2020). China holds the largest share of the global EV market, accounting for over 40% of worldwide sales (China Association of Automobile Manufacturers, 2021). With China's commitment to achieving carbon neutrality by 2060, the reuse and recycling of aged EV batteries are expected to become a key industrial sector. In fact, China generated approximately 530,000 tonnes of retired power batteries in 2022 alone (Adhikari et al., 2023). However, current technological limitations hinder large-scale reuse or recycling of these aged batteries. Challenges that are expected to be overcome within the next five to ten years. Currently, fewer than 25% of end-of-life batteries in China are processed through officially certified and regulated channels (The National Committee of the CPPCC, 2023). Consequently, nearly 75% are handled by unlicensed entities, posing significant environmental risks and resulting in the inefficient use of energy and natural resources (Baum et al., 2022).

Reuse versus Recycling Pathways

The reuse and recycling of aged batteries is crucial for advancing comprehensive sustainability goals and exemplifying the core principles of a circular economy. However, it is important to note that reuse and recycling represent distinct approaches to handling aged batteries. When an EV battery's capacity falls to approximately 70–80%, it marks the end of its primary lifecycle in electric mobility (Casals et al., 2018). At this point, the battery enters its second lifecycle, where it can be repurposed as energy storage for renewable energy systems, helping to mitigate the power fluctuations caused by their intermittent nature. It is forecasted that by 2040, reused second-life batteries will account for up to 86% of the energy storage in wind energy systems and 36% in solar energy systems in China (Volan et al., 2021). The technologies employed for second-life batteries in power grid applications are not new. The concept of second-life battery projects can be traced back to 2015, when Bosch, BMW, and Vattenfall launched their initiative (Gohla-Neudecker et al., 2015). Subsequently, Nissan advanced similar efforts in 2016 by integrating 280 decommissioned Leaf batteries into the xStorage Buildings System through The Mobility House project, which supported building-level energy storage (Martinez-Laserna et al., 2018). Since 2018, China has implemented a series of policies to regulate EV battery recycling, placing primary responsibility on automakers through the Interim Measures for the Administration of Recycling and Utilization of Power Batteries (MIIT, 2018). Battery recycling typically refers to the recovery of materials within the battery. When comparing the recycling of batteries with a state-of-health (SOH) greater than 70% to those with an SOH less than 50%, the recycling of aged batteries with lower SOH is more environmentally friendly, as the amount of materials recovered is nearly the same. In general, aged batteries with an SOH below 40% are recommended for recycling, while those with an SOH between 40% and 80% are better suited for reuse as energy storage systems (Manzetti et al., 2015).

Safety Concerns and Diagnostic Innovation

This raises the question: why is battery recycling more prevalent than the reuse of aged batteries? The fundamental reason lies in historical safety concerns surrounding second-life batteries. Power grids have been unable to ensure the safe integration of these batteries for grid support applications. However, recent advancements in rapid diagnostic technologies have addressed many of these issues (Yang et al., 2015). Now is the opportune time to promote and adopt these innovations. In the near future, such technologies will be in high demand among power system engineers, as second-life batteries are expected to increasingly replace traditional spinning reserves to help maintain grid stability (Dunn et al., 2011).

Closed-loop Supply Chains and Marketing Insights

Not only are cutting-edge technologies for second-life batteries essential for future electrical engineers working on power grids, but knowledge of emerging supply chains for reused batteries is also increasingly important for future power market managers. As second-life batteries are expected to play a key role in the economic dispatch of power resources, both technical and logistical expertise will be crucial in shaping the future of energy systems. Closed-loop supply chain (CLSC) focus on recovering products from consumers and creating value through reuse. Within this framework, whether and how products re-enter the supply chain depends on evaluating their residual value and the cost of reuse (Figure 1) (Guide & Van Wassenhove, 2009). Innovations in technology can act as catalysts for heightened consumer demand, prompting adaptive changes in CLSC operations across manufacturing and retail sectors (Zhang et al., 2024). Although aged EV batteries may no longer meet performance standards for vehicle propulsion, they often retain sufficient capacity for secondary use in energy storage systems (Chen et al., 2019). However, the success of such reuse initiatives depends heavily on the collection of batteries from EV owners. Consumers play a pivotal role at the start of the reverse logistics chain, as their participation determines whether batteries are properly retrieved, reused, and managed (Dong & Ge, 2022). Thus, encouraging consumer returns is not only critical for initiating the CLSC but also serves as an external catalyst for the development of more advanced and accurate battery diagnostic technologies.

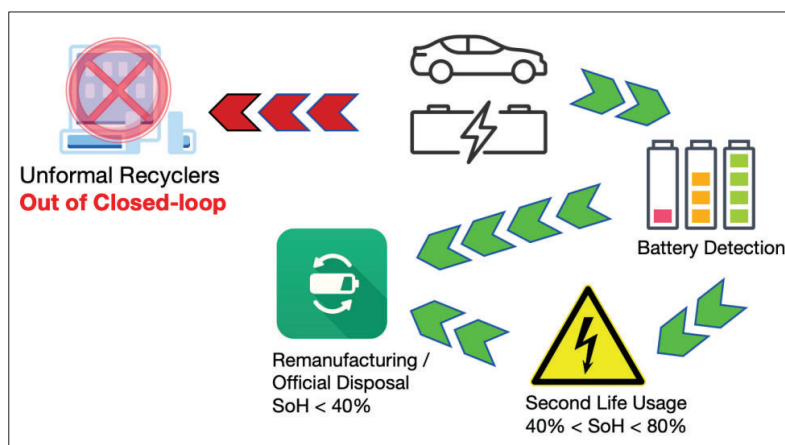


Figure 1: Aged Battery Closed-loop Supply Chain

prioritize PBC over the other factors (Dong & Ge, 2022; Tang et al., 2023). PBC is especially influential, as it captures an individual's perception of how easy or difficult a behavior is to perform. When individuals feel they have sufficient resources, knowledge, or ability, they are more likely to take action (Axsen & Kurani, 2013). Essentially, consumers evaluate the feasibility and manageability of recycling before deciding to engage. Li et al. (2023) found that perceived cost and convenience are key determinants of recycling intention in China. Similarly, Tang et al. (2023) emphasized that improving the layout of recycling facilities and access to relevant information can enhance consumers' PBC, thereby boosting their likelihood to recycle.

To meet consumers' rising expectations for information transparency and reliability in the battery recycling process, companies are increasingly adopting advanced diagnostic technologies (such as digital twin systems) to improve the accuracy of battery performance assessments. When consumers have access to clear and reliable information, their perceived behavioral control increases, reducing the perceived risks associated with battery recycling and enhancing their willingness to participate. Environmental knowledge related to recycling not only directly influences consumers' intent to engage in online recycling but also does so indirectly through perceptual factors (Wang et al., 2020). Thukral et al. (2022) further emphasize that consumer awareness and recycling behavior in the context of electronic waste are shaped by various interrelated factors, with information transparency and education

playing pivotal roles in promoting proactive and responsible recycling. Accordingly, establishing a direct link between consumer awareness and the logic of reuse can significantly enhance participation in second-life battery initiatives. Drawing on signal theory (Spence, 1973), firms are expected to convey credibility, professionalism, and safety in their recycling operations through clear and verifiable signals. In the context of aged EV batteries, these signals may include certified diagnostic reports, standardized evaluation procedures, or digital platforms that transparently display real-time battery condition data. This technological transition is driving greater demand for engineering professionals with specialized expertise, encouraging universities to incorporate digital twin systems and battery diagnostic technologies into electrical engineering curricula to meet evolving industry needs.

At present, curricula addressing the supply chain management of reused batteries for energy storage applications are notably absent, even within the electrical engineering departments of leading universities worldwide. As a result, electrical engineering graduates aiming to become power system managers often require supplementary training upon entering the industry, thereby increasing onboarding and training costs for power companies.

Bridging Education and Industry

This paper aims to offer insights into designing university and college curricula that integrate both the technological and supply chain management aspects of reused traction batteries. These curricula are intended for students aspiring to become electrical engineers or power system managers in the near future. The proposed programs will include both lectures and hands-on training (Figure 2). Lectures will be delivered by a combination of academic and industry experts. Academic instructors will cover state-of-the-art research and emerging technologies, while industry professionals will share practical insights and current applications. Practical training will be conducted both in university laboratories and in collaboration with power companies. Laboratory sessions will reinforce students' understanding of core technologies, whereas industry placements will emphasize real-world implementation and the operational integration of reused batteries in power markets. Power companies are expected to support this initiative, as it reduces their training costs and ensures a pipeline of well-prepared, high-quality graduates for future employment.

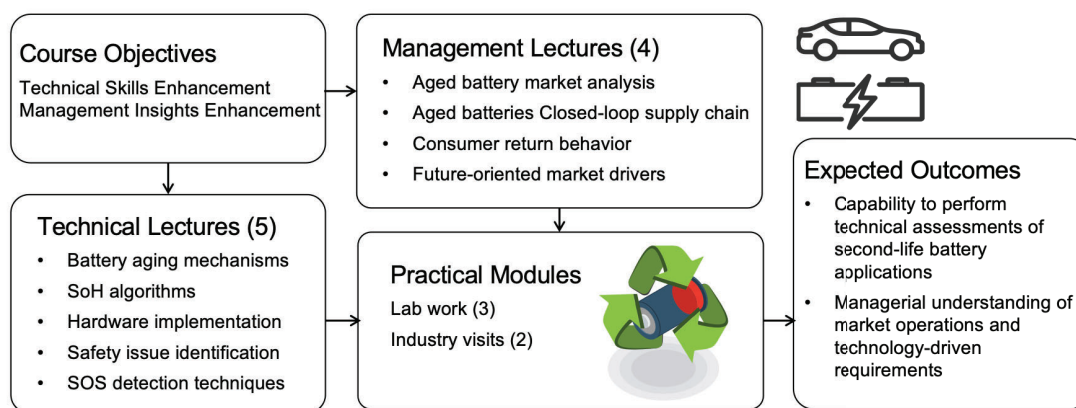


Figure 2: Curriculum Framework on Aged Battery Reuse for Power Grid

The remainder of this paper is organized as follows: Section II outlines the curriculum framework. The first subsection depicts the design for lectures on key technologies related to the integration of reused batteries into power grids. The second subsection details the curriculum for lectures focused on the marketing and supply chain aspects of reused batteries. The third subsection discusses the structure of practical training, including activities conducted in both university laboratories and partner power companies. Finally, Section III presents the conclusions and future outlook.

Curriculum Framework

Curriculum for Lectures on Key Technologies

One of the most critical technologies for electrical engineers working in power systems is the rapid and accurate detection of the SOH and state-of-safety (SOS) of aged traction batteries (Cabrera-Castillo et al., 2016). The need for fast diagnostics arises primarily from the large number of individual cells within a typical EV traction battery pack, which makes manual or slow evaluation methods impractical for large-scale reuse in power grid applications. In practice, it is challenging for robots to quickly and reliably detect the SOH and SOS of aged batteries, as the causes of potential safety hazards are highly diverse. These issues can stem from something as subtle as a missing screw or as critical as electrolyte leakage, making automated detection complex and sometimes unreliable.

Technologies for accurately detecting the SOH of aged traction batteries have been extensively studied over the past two decades (Zhang et al., 2011). Accurate SOH detection is critical not only for ensuring the safety and efficiency of battery usage in EVs, but also for determining the appropriate timing for transitioning batteries to second-life applications, such as energy storage, or for initiating material recycling for new battery production. According to common industry consensus, a traction battery is typically repurposed for energy storage when its SOH falls to around 80%. Once the SOH drops to 40%, the battery is generally recommended for recycling rather than continued use. This 40% SOH threshold also applies to aged traction batteries that have already been deployed in energy storage systems within power grids.

Therefore, incorporating diverse technologies for SOH detection is essential in the curriculum design of lecture-based courses. Assuming the course consists of nine lectures and five practical training sessions, with five of the lectures dedicated to technical content, three of these lectures will focus specifically on: (1) the fundamental aging mechanisms of Li-ion batteries, (2) algorithms for SOH estimation, and (3) hardware implementation for SOH detection. The fundamental aging mechanisms of lithium-ion batteries encompass the chemical and mechanical principles that explain battery degradation over time. The curriculum will cover equivalent physical, electrical, and thermal models, which serve as the foundation for practical implementation of fast and accurate SOH monitoring strategies. Algorithms play a critical role in SOH estimation. The course will introduce both traditional heuristic algorithms suitable for edge computing and advanced machine learning algorithms designed for cloud-based applications. Case studies using simulation tools will be presented to demonstrate algorithm implementation, and their performance will be further evaluated during practical training sessions. Hardware implementation for SOH detection will focus primarily on the circuit topologies of on-board chargers (OBCs) and battery management systems (BMSs). To maintain clarity and accessibility, the course will present simplified operational principles of the equivalent circuits, avoiding overly complex power electronics analysis.

The remaining two technology-focused lectures will cover the detection of the SOS of batteries. The first lecture will address various potential safety issues associated with traction batteries, including thermal runaway, electrolyte leakage, and short circuits. These issues and their potentially severe consequences will be illustrated through animations to enhance understanding. The second lecture will explore advanced SOS detection technologies, such as the AC current injection method, electrochemical impedance spectroscopy (EIS), and puncture testing. Among these, the AC current injection method stands out as the most cost-effective and practical for implementation in handheld devices. This lecture will also introduce the use of different diagnostic tools for rapid SOS assessment of aged traction batteries, laying the theoretical foundation for the practical training.

Curriculum for Lectures on Management

Currently, most electrical engineering programs focus heavily on technical training while overlooking the importance of understanding the market dynamics behind battery technologies, particularly how aged battery markets operate and how consumer behavior drives the value chain. This gap is especially critical for students who will become electrical projects managers or energy storage system designers. To address this deficiency, this course adopts a “Market-Driven–Technical Response” framework, integrating the principles of Closed-Loop Supply Chain (CLSC) management and consumer behavior theory. It aims to enhance students’ understanding of: (1) the market demands and operational logic behind the R&D of aged battery detection technologies; and (2) the ability to align technological innovation with market trends which an essential competency for engineering management roles.

This course will have four lectures dedicated to management content by integrating CLSC management with consumer behavior theory to emphasize their intertwined roles in the life cycle management of EV batteries. In this context, the interplay between technological innovation and market demand shapes the development of battery diagnostics, end-of-life routing, and recycling strategies. Within the CLSC framework involving multiple stakeholders in aged EV battery management, secondary battery users play a critical role in identifying units that satisfy predefined high-power capacity thresholds (Saeedi et al., 2024). Core technical modules such as life cycle cost (LCC) assessment and residual value estimation for aged batteries are introduced to equip students with tools to evaluate battery health status and determine appropriate second-life applications (e.g., grid storage) or end-of-life treatment (e.g., raw material recycling). These analytical techniques enable future engineers and industry managers to support more data-driven, economically viable supply chain decisions. At the same time, battery life cycle management is not purely reactive to technology but actively co-evolves with it. As technological capabilities expand, they stimulate market expectations, which in turn require firms to reconfigure their CLSC strategies accordingly. Building on this foundation, the course systematically introduces theoretical models from operations and behavioral sciences to develop students’ ability to link market dynamics with technical system design. Specifically, CLSC management theory is employed to frame how technological constraints and consumer-side uncertainties can be balanced in the strategic design of take-back programs, refurbishment workflows, and battery routing decisions.

The growing consumer sensitivity to technological advancements compels aged EV battery manufacturers to intensify their innovation efforts in order to meet rising market demands (Zhang et al., 2024). In parallel, consumer behavior theories including the Theory of Planned Behavior (TPB) are incorporated to explain the psychological and normative factors influencing consumers’ intentions to return or exchange aged batteries. Students will analyze how behavioral incentives such as green credit systems, technical data transparency, and social norm reinforcement can be deployed as strategic levers to enhance reverse logistics efficiency. These behavioral insights will also serve as inputs into scenario-based modeling exercises aimed at aligning policy design with real-world consumer responses.

The curriculum emphasizes the bidirectional relationship between technology and management in battery recovery systems. On one hand, advancements in battery diagnostics and monitoring technologies provide a technical basis for optimizing CLSC architectures. On the other hand, empirical feedback from consumer behavior and supply chain performance can serve as stimuli for further technological R&D. Thus, students will explore how strategic insights derived from market and user behavior can guide the evolution of SOH estimation tools, modular reuse technologies, or smart disassembly protocols. The inclusion of management models alongside engineering methodologies empowers students to co-design technologies with greater systemic sensitivity, ensuring alignment with economic and behavioral realities in the field of battery second life management.

Curriculum for Practical Training

Practical training is essential for electrical engineering students aspiring to become engineers or power market managers, as it provides foundational hands-on experience and a deeper understanding of market operations. We propose allocating five out of fourteen sessions to practical training in the course on reused traction batteries. Of these, three sessions will focus on laboratory-based experiments, while the remaining two will involve site visits to EV manufacturers and power grid companies.

The three lab-based experiments are closely aligned with the content covered in the lectures. The first experiment focuses on battery temperature estimation using an electro-thermal model, aimed at familiarizing students with the fundamental electro-thermal characteristics of batteries. The second experiment centers on the rapid and accurate detection of the state of health (SOH) of aged traction batteries, allowing students to observe the real-world performance of circuit topologies and control algorithms discussed in class. The third experiment involves the fast and precise detection of the state of safety (SOS) of aged traction batteries. Ideally, this experiment should be conducted in collaboration with a battery or EV manufacturing company, subject to feasibility. These lab sessions are particularly valuable for students aspiring to become electrical engineers, as they focus exclusively on state-of-the-art and widely adopted technologies, ensuring that students gain practical, industry-relevant skills within a limited timeframe.

Furthermore, to strengthen students' engineering insight and managerial judgment, the course incorporates two practical training sessions to visit leading EV manufacturers, battery recycling enterprises, and energy storage and dispatching units within the power grid sector. These visits are designed to provide students with firsthand exposure to the battery traceability systems, pricing mechanisms for recycling, and the post-retirement pathways for secondary utilization. Additionally, students will observe decommissioned battery energy storage projects currently operated by power grid enterprises, with particular attention to their operational strategies and regulatory challenges in load balancing and ancillary services. By engaging in field-based research and analysing real-world technical and managerial challenges, students aspiring to become power market managers will develop a deeper understanding of current limitations in market operations and enhance their ability to align electrical engineering practices with evolving industry demands.

For instance, Haoersai Technology Group, as a representative actor in the battery swapping industry and cooperated with several universities such as Tsinghua University and Beijing Institute of Technology in China, has established a dual integration mechanism that connects scientific research with industrial application. Its postdoctoral research station plays a central role in advancing technological research and development. Within the context of its heavy-duty truck battery swapping initiative, aged batteries are systematically collected and transferred to a centralized battery repository for standardized testing and evaluation. Based on diagnostic outcomes, suitable batteries are repurposed for secondary applications, thereby extending their functional lifespan. Data from each stage of the process is continuously monitored and analyzed via an AI-enabled platform, facilitating dynamic adjustments to the aged battery value chain in response to real-time performance metrics. Such enterprises provide valuable case contexts for curriculum development, offering students exposure to integrated technological systems and enhancing their understanding of market-oriented battery lifecycle management.

Conclusions and Future Work

This paper proposes a new curriculum framework for electrical engineering students to better prepare them for careers as electrical engineers or power market managers in emerging power grids that integrate reused aged traction batteries. The curriculum includes nine lectures and five practical training sessions, with the practical components closely aligned with the lecture content. The lectures cover both foundational knowledge in battery technologies and industry management, as well as critical, cutting-edge technologies and up-to-date industry insights on

the supply chain of aged traction batteries. Given the limited study time, the course focuses on the most widely adopted technologies and practices to ensure students can quickly transition into practical roles after graduation. Future iterations of the curriculum will incorporate digital twin and AI-based technologies to further enhance its relevance and impact.

To systematically evaluate the instructional effectiveness of the course, an anonymous student survey will be administered across multiple Chinese universities following institutional ethics approval. The questionnaire will employ a five-point Likert scale and cover learning engagement, knowledge mastery, interdisciplinary integration, understanding of SOH and SOS diagnostics, practical self-efficacy, and course satisfaction. Background variables will include year of study, specialization, and relevant internship experience. Data will undergo reliability and validity testing and will be analysed using multivariate regression and structural equation modeling to assess attainment of course objectives and to identify key determinants. In the first phase, the survey will be piloted in two engineering universities within electrical engineering programs using cluster sampling at the end of the term, with a minimum target of 200 valid responses. Subsequent waves will extend to institutions across different regions and tiers, and findings will inform refinement of the syllabus, the depth of laboratory exercises, and the industry-practice components, thereby building a transferable evidence base.

References

- Adhikari, B., Chowdhury, N.A., Diaz, L.A., Jin, H., Saha, A.K., Shi, M., Klaehn, J.R., Lister, T.E. (2023). Electrochemical leaching of critical materials from lithium-ion batteries: a comparative life cycle assessment. *Resour. Conserv. Recycl.* 193, 106973. <https://doi.org/10.1016/j.resconrec.2023.106973>
- Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Dec.* 50, 179–211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Axsen, J., Kurani, K.S. (2013). Hybrid, plug-in hybrid, or electric—What do car buyers want? *Energy Policy* 61, 532–543. <https://doi.org/10.1016/j.enpol.2013.05.122>
- Baum, Z. J., Bird, R. E., Yu, X., & Ma, J. (2022). Lithium-Ion Battery Recycling—Overview of Techniques and Trends. *ACS Energy Letters*, 7(2), 712–719. <https://doi.org/10.1021/acsenenergylett.1c02602>
- Cabrera-Castillo, E., Niedermeier, F., & Jossen, A. (2016). Calculation of the state of safety (SOS) for lithium ion batteries. *Journal of Power Sources*, 324, 509–520. <https://doi.org/10.1016/j.jpowsour.2016.05.068>
- Casals, L. C., García, B. A., & Canal, C. (2018). Second life batteries lifespan: Rest of useful life and environmental analysis. *Journal of Environmental Management*, 232, 354–363. <https://doi.org/10.1016/j.jenvman.2018.11.046>
- Chen, M., Ma, X., Chen, B., Arsenault, R., Karlson, P., Simon, N., & Wang, Y. (2019). Recycling End-of-Life electric vehicle Lithium-Ion batteries. *Joule*, 3(11), 2622–2646. <https://doi.org/10.1016/j.joule.2019.09.014>
- China Association of Automobile Manufacturers. Economic operation of China's automobile industry. Accessed at http://www.caam.org.cn/chn/4/cate_154/con_5235337.html on 12 January 2022.
- Dunn, B., Kamath, H., & Tarascon, J. (2011). Electrical energy storage for the grid: a battery of choices. *Science*, 334(6058), 928–935. <https://doi.org/10.1126/science.1212741>
- Gohla-Neudecker, B., Bowler, M., & Mohr, S. (2015). Battery 2nd life: Leveraging the sustainability potential of EVs and renewable energy grid integration. In *Proceedings of the 2015 International Conference on Clean Electrical Power (ICCEP)* (pp. 311–318). Taormina, Italy. <https://doi.org/10.1109/ICCEP.2015.7177641>
- Guide, V. D. R., & Van Wassenhove, L. N. (2009). OR FORUM—The Evolution of Closed-Loop Supply Chain Research. *Operations Research*, 57(1), 10–18. <https://doi.org/10.1287/opre.1080.0628>
- International Energy Agency, 2020. *Global EV Outlook 2020*. Accessed at <https://www.iea.org/reports/global-ev-outlook-2020> in June 2020.
- Li, J., Xu, Y., Jiao, J., Yang, R., & Zha, J. (2023). Do recycling channels affect young consumers' choices for formal power battery recycling? *Journal of Cleaner Production*, 425, 138766. <https://doi.org/10.1016/j.jclepro.2023.138766>
- Manzetti, S., & Mariasiu, F. (2015). Electric vehicle battery technologies: From present state to future systems. *Renewable and Sustainable Energy Reviews*, 51, 1004–1012. <https://doi.org/10.1016/j.rser.2015.07.010>
- Martinez-Laserna, E., Gandiaga, I., Sarasketa-Zabala, E., Badeda, J., Stroe, D.-I., Swierczynski, M., & Goikoetxea, A. (2018). Battery second life: Hype, hope or reality? A critical review of the state of the art. *Renewable and Sustainable Energy Reviews*, 93, 701–718. <https://doi.org/10.1016/j.rser.2018.04.035>
- Ministry of Industry and Information Technology of the People's Republic of China. (2018, February 26). *Interim Measures for the Administration of Recycling and Utilization of Power Batteries for New Energy Vehicles*. Accessed at https://www.gov.cn/xinwen/2018-02/26/content_5268875.htm on 26 February 2018.
- Ramzan, S., Liu, C., Xu, Y., Munir, H., & Gupta, B. (2020). The adoption of online e-waste collection platform to improve environmental sustainability: an empirical study of Chinese millennials. *Management of Environmental Quality an International Journal*, 32(2), 193–209. <https://doi.org/10.1108/meq-02-2020-0028>
- Sabbir, M. M., Khan, T. T., Das, A., Akter, S., & Hossain, M. A. (2022). Understanding the determinants of consumers' reverse exchange intention as an approach to e-waste recycling: a developing country perspective. *Asia-Pacific Journal of Business Administration*, 15(3), 411–439. <https://doi.org/10.1108/apjba-11-2021-0565>
- Saeedi, M., Parhazeh, S., Tavakkoli-Moghaddam, R., & Khalili-Fard, A. (2024). Designing a two-stage model for a sustainable closed-loop electric vehicle battery supply chain network: A scenario-based stochastic programming approach. *Computers & Industrial Engineering*, 190, 110036. <https://doi.org/10.1016/j.cie.2024.110036>
- Spence, M. (1973). Job market signaling. *The Quarterly Journal of Economics*, 87(3), 355–374. <https://doi.org/10.2307/1882010>

- Tang, Y., Zhang, Q., Liu, B., Li, Y., Ni, R., & Wang, Y. (2023). What influences residents' intention to participate in the electric vehicle battery recycling? Evidence from China. *Energy*, 276, 127563. <https://doi.org/10.1016/j.energy.2023.127563>
- The National Committee of the Chinese People's Political Consultative Conference (CPPCC). Proposal to enhance the standardization of power battery recycling systems. Accessed at <http://www.cppcc.gov.cn/zxww/2023/11/15/ART11700016160966320.shtml> on 15 November 2023.
- Thukral, S., Shree, D., & Singhal, S. (2022). Consumer behaviour towards storage, disposal and recycling of e-waste: systematic review and future research prospects. *Benchmarking an International Journal*, 30(3), 1021–1072. <https://doi.org/10.1108/bij-12-2021-0774>
- Volan, T., Vaz, C. R., & Uriona-Maldonado, M. (2021). Scenarios for end-of-life (EOL) electric vehicle batteries in China. *Revista De Gestão*, 28(4), 335–357. <https://doi.org/10.1108/rege-12-2020-0143>
- Wang, C., Zhu, T., Yao, H., & Sun, Q. (2020). The impact of green information on the participation intention of consumers in online recycling: an experimental study. *Sustainability*, 12(6), 2498. <https://doi.org/10.3390/su12062498>
- Xu, Z., Wang, J., Lund, P. D., Fan, Q., Dong, T., Liang, Y., & Hong, J. (2020). A novel clustering algorithm for grouping and cascade utilization of retired Li-ion batteries. *Journal of Energy Storage*, 29, 101303. <https://doi.org/10.1016/j.est.2020.101303>
- Yang, H., Hong, J., Liang, F., & Xu, X. (2023). Machine learning-based state of health prediction for battery systems in real-world electric vehicles. *Journal of Energy Storage*, 66, 107426. <https://doi.org/10.1016/j.est.2023.107426>
- Zhang, J., & Lee, J. (2011). A review on prognostics and health monitoring of Li-ion battery. *Journal of Power Sources*, 196(15), 6007–6014. <https://doi.org/10.1016/j.jpowsour.2011.03.101>
- Zhang, W., Zhu, L., Liu, X., Wang, W., & Song, H. (2024). Optimal strategies in electric vehicle battery closed-loop supply chain considering government subsidies and echelon utilization. *Journal of Energy Storage*, 99, 113341. <https://doi.org/10.1016/j.est.2024.113341>
- Zhang, Y., Wu, S., & Rasheed, M. I. (2019). Conscientiousness and smartphone recycling intention: The moderating effect of risk perception. *Waste Management*, 101, 116–125. <https://doi.org/10.1016/j.wasman.2019.09.040>

Acknowledgements

The authors acknowledge the Fundamental Research Grants Scheme (FRGS), grant number FRGS/1/2024/SS01/UTM/02/4 - R.J130000.7829.5F725 funded by the Ministry of Higher Education (MOHE) Malaysia, and part of this research is supported by UTMFR, grant number 23H26, Universiti Teknologi Malaysia.

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