



prifysgol cymru trinity saint devid
University of Wales Trinity St David

Student name: Anandu Unnikrishanan Nair

Student ID number : 2411630

Programme : MSc – Automotive Engineering

Module : Research Methods and Professional Developments

Module code: ACFA7004

Assignment Title : Research Proposal & presentation

Table of Contents

1. Introduction	3
1.1 Research Aim & Objectives	3-4
1.2 Historical Context	4
2. Industrial Relevance	5
2.1 Impact on the Automotive Industry.....	5
2.2 Industry Trends and Current Adoption	6
2.3 Alignment with Sustainability & Regulatory Goals	6
3. Literature Review	7
3.1 Battery Degradation Factors	7
3.1.1 Charge/Discharge Cycles	7
3.1.2 Thermal Effects	7
3.1.3 Usage Patterns	7
3.2 Assessing Battery Suitability for Second-Life Use	8
3.3 Existing Second-Life Applications	8-9
3.4 Challenges & Future Prospects	9-10
4. Proposed Methodologies	10
4.1 Literature-Based Analysis	10
4.2 Experimental Testing	10
4.3 Comparative Analysis	10
4.4 Case Study Review	11
5. Results Collection & Analysis	11-12
6. Project Planning & Timescales	12
7. Evaluation	12-13
8. References	14

1. Introduction

As the main source of power storage technology for contemporary EVs, lithium-ion batteries (LIBs) are in high demand due to the explosive rise of EVs. Even though these batteries have extended lifespans, high energy densities, and quick charging times, their performance eventually deteriorates. An EV battery is usually removed from the car when its State of Health (SoH) drops to about 70–80% because it is no longer deemed efficient for use in automobiles.

Degraded EV battery disposal presents serious financial and environmental issues. These batteries contain hazardous compounds that, if handled incorrectly, can contaminate land and water. Furthermore, irresponsible disposal is unsustainable because lithium, cobalt, and other essential raw materials utilized in battery production are limited resources. Battery recycling, which concentrates on removing valuable metals for reuse, has been the traditional strategy. Second-life applications, on the other hand, offer a more economical and environmentally friendly option since batteries are used again rather than being disassembled. EV batteries that have been repurposed can still store and provide energy for a number of uses, such as:

- **Renewable energy storage** (solar and wind power integration).
- **Grid stabilization** (balancing electricity demand and supply).
- **Backup power solutions** (for homes, businesses, and EV charging stations).

In order to minimize battery waste, optimize resource efficiency, and facilitate the shift to cleaner energy systems, it is imperative to investigate second-life applications. To evaluate the viability and efficacy of these applications, more study is necessary because there are still major technical, safety, and financial obstacles to overcome.

1.1 Research Aim & Objectives

To assess damaged EV batteries' performance in various energy storage systems and look into the viability of reusing them for second-life applications.

Objectives:

- Analyse the causes of EV battery deterioration, such as usage trends, heat effects, and charge-discharge cycles.
- Investigate techniques for determining if batteries are suitable for second-life applications, paying particular attention to safety concerns, performance indicators, and State of Health (SoH) estimation.
- Analyse practical second-life uses such grid stabilization, backup power solutions, and renewable energy storage.
- Determine the main obstacles (technical, financial, and safety) and investigate viable ways to improve the feasibility of using second-life batteries.

1.2 Historical Context

As battery waste management becomes a more pressing worldwide issue, the idea of second-life EV batteries has gaining traction. Research initially concentrated mostly on recycling procedures, which include removing and purifying nickel, cobalt, and lithium from spent batteries. However, interest in battery repurposing as a more sustainable option has increased due to the energy-intensive nature of recycling and the environmental effects of chemical extraction operations.

Prominent IT firms and automakers have begun incorporating used batteries into energy storage initiatives:

- in order to promote sustainable energy systems, Jaguar Land Rover has implemented used EV batteries for large-scale energy storage.
- Porsche and Audi have shown that it is feasible to balance the supply of electricity by implementing battery reuse technologies for grid applications.
- Repurposed EV batteries are used in residential energy storage systems like Tesla's Powerwall and Nissan's storage.

The efficiency and safety of second-life applications have been significantly enhanced by recent developments in modular energy storage technologies and Battery Management Systems (BMS). Real-time battery performance monitoring and optimization are now possible thanks to AI-driven BMS solutions, which also address safety hazards and degrading variability issues. Despite these developments, there are still a number of research gaps, especially in:

- standardizing techniques for evaluating battery health in second-life apps.
- decreasing the cost of installation and renovation to increase economic viability.
- improving safety protocols to reduce operational instability and the possibility of thermal runaway.

By tackling these outstanding issues and expanding on previous research, this study will offer important new information about the real-world application of used EV batteries.

2. Industrial Relevance

Lithium-ion batteries are essential to the automotive and energy sectors' change as a result of the shift to battery-electric vehicles (BEVs). But there are drawbacks to EV adoption as well, including issues with resource sustainability, waste management, and battery deterioration. Because it looks for ways to prolong battery lifecycles, cut waste, and maximize energy storage, this research on EV battery second-life applications is extremely pertinent to the automotive sector.

2.1 Impact on the Automotive Industry

1. Reducing Battery Waste & Environmental Footprint

- The management of EV batteries at the end of their useful lives is one of the biggest issues facing the automobile industry. Degraded battery disposal causes serious environmental contamination and increases the possibility of hazardous chemicals seeping into the ground and water.
- By reusing batteries for stationary energy storage, second-life applications assist postpone battery disposal and lower the quantity of hazardous waste produced by the automobile sector.
- This is in line with worldwide circular economy plans, which aim to reduce environmental impact by reusing resources.

2. Enhancing Cost-Effective Energy Storage Solutions

- With the growing popularity of renewable energy sources like solar and wind, there is a growing need for scalable and reasonably priced energy storage. However, the cost of manufacturing grid-scale lithium-ion batteries is high.
- For storing renewable energy and managing grid demand, used EV batteries offer a more affordable option than new batteries.
- The automotive sector may improve economic sustainability by generating a new revenue stream from spent batteries by incorporating them into industrial backup power systems, solar farms, and microgrids.

3. Improving EV Lifecycle Sustainability

- Large quantities of lithium, cobalt, and nickel are needed for the resource-intensive process of making EV batteries; these materials are mined in unethical and environmentally problematic ways.
- By extending EV batteries' lifespan through second-life applications, less raw material extraction is required, making EVs more environmentally friendly throughout their whole lifecycle.
- This encourages automakers to implement sustainable battery management techniques and advances global carbon neutrality aspirations.

2.2 Industry Trends and Current Adoption

Several major automotive companies are already exploring second-life applications for EV batteries:

- Tesla: Creating stationary battery storage systems for residences and commercial buildings with used EV batteries.
- Nissan: Used Nissan Leaf batteries can be integrated into the storage system to store energy at home.
- BMW: Reusing EV batteries for grid storage in collaboration with energy suppliers.
- Volkswagen: Investigating the use of used batteries for industrial energy storage and fast-charging stations.

2.3 Alignment with Sustainability & Regulatory Goals

The dedication to a greener future is strengthened by this research's strong alignment with regional and international sustainability activities. While the Paris Agreement establishes aggressive carbon reduction targets that sustainable energy solutions, including second-life battery applications, can help achieve, the European Green Deal and EU Battery Regulations stress the significance of battery reuse and recycling to reduce environmental impact. To improve grid resilience and encourage energy conservation, the US Department of Energy actively supports battery repurposing initiatives. Governments and regulatory agencies throughout the world are promoting legislation that support reuse techniques because they understand how important it is to prolong battery life from an environmental and financial standpoint. By investigating useful, scalable second-life applications, our study supports these initiatives and makes sure that the shift to electric mobility is both economical and sustainable.

3. Literature Review

Concerns regarding the disposal of used lithium-ion batteries (LIBs) have been brought up by the growing popularity of electric vehicles (EVs). These batteries' reduced efficiency as they deteriorate renders them inappropriate for use in automobiles, raising concerns about resource scarcity, disposal, and environmental sustainability. One potential remedy is the idea of second-life applications, which involves repurposing spent EV batteries for industrial, grid-balancing, and stationary energy storage uses. This study of the literature looks at the main causes of EV battery deterioration, techniques for determining second-life compatibility, current uses, and issues with safety, viability, and technological development.

3.1 Battery Degradation Factors

In a period of time, a mix of mechanical, thermal, and electrochemical reactions causes lithium-ion batteries (LIBs) to deteriorate. Degradation is caused by a number of factors that impact battery longevity and determine whether a battery is still suitable for second-life applications.

3.1.1 Charge/Discharge Cycles

The number of cycles a battery goes through for charging and discharging is one of the most important elements in battery degradation. The electrode materials undergo structural alterations with each cycle, which gradually reduces capacity. Most LIBs retain 70–80% of their initial capacity after 1,000–2,000 cycles, which makes them unsuitable for high-performance EV applications but still feasible for stationary energy storage.

3.1.2 Thermal Effects

Temperature has a significant impact on battery longevity and performance. Elevated operating temperatures decrease efficiency by hastening lithium plating, electrolyte breakdown, and electrode deterioration (Wang et al., 2020). Low temperatures, on the other hand, reduce charge acceptance and increase internal resistance by impeding ion mobility. Degradation is unavoidable over time, but these effects can be lessened by efficient thermal management systems (TMS).

3.1.3 Usage Patterns

- Compared to slow charging, quick charging produces more heat, which speeds up the creation of lithium dendrites and raises the possibility of short circuits and battery failure (Zhou et al., 2022).
- Depth of Discharge (DoD): Compared to shallow discharges, which deplete less than 50% of battery capacity every cycle, frequent deep discharges, which

utilize more than 80% of battery capacity per cycle, put additional strain on battery cells (Lai et al., 2021).

- Partial Charging: According to Reniers et al. (2019), batteries last longer when kept between 20 and 80% of their full charge.

3.2 Assessing Battery Suitability for Second-Life Use

An EV battery's remaining capacity, internal resistance, and general condition must all be assessed before it can be used again. A crucial stage in this procedure is estimating the State of Health (SoH), which establishes whether a battery is still suitable for reuse. Cycle count estimation, impedance tests, and voltage analysis are common techniques for evaluating SoH. While batteries with lower SoH values might only be appropriate for low-power applications or recycling, those with SoH values exceeding 70% are often appropriate for high-energy uses like grid storage.

Batteries for second-life applications must be sorted according to important performance indicators. Because a battery needs to be able to store and release energy efficiently, capacity retention is a crucial factor. Another important consideration is internal resistance, which raises heat generation and lowers overall performance. Because older batteries may be more vulnerable to overheating and safety malfunctions, thermal stability is also evaluated.

When using second-life batteries, safety is a major problem. Defects in older batteries can raise the possibility of short circuits, electrolyte leaks, and thermal runaway. Serious risks can arise from improperly recycled batteries, particularly in large-scale energy storage systems. By balancing cell voltages, identifying possible problems, and optimizing charging patterns, modern Battery Management Systems (BMS) can assist monitor and reduce these risks. Successful integration of second-life batteries into new applications requires that they adhere to stringent safety regulations.

3.4 Existing Second-Life Applications

Second-life EV batteries have already been used in a number of practical applications, showcasing their promise as affordable and environmentally friendly energy storage options. Renewable energy storage is among the most promising uses. Due to the sporadic nature of solar and wind power output, energy storage technologies are necessary to maintain supply and demand equilibrium. Second-life batteries offer a cost-effective way to store extra renewable energy that can be used later. For instance, Jaguar Land Rover has stabilized the supply of renewable energy by integrating second-life batteries into grid-scale energy storage systems.

Grid storage and frequency regulation are two more significant applications. In order to guarantee dependable electricity delivery, power networks need to keep their frequency constant. By absorbing extra electricity during peak hours and releasing it during times of high demand, second-life batteries can increase grid stability. One example of how recycled EV batteries might facilitate frequency management and improve power network dependability is the Porsche-Audi Power Storage project.

Another growing market for second-life batteries is backup power solutions for residential and commercial structures. Repurposed EV batteries have been used by companies such as Tesla and Nissan to create energy storage systems for homes. By storing solar energy or drawing power from the grid during off-peak hours, homeowners can lower their electricity expenses and increase their energy independence with the Nissan storage system. In a similar vein, Tesla's Powerwall offers energy storage solutions for homes by combining new and used battery cells.

Second-life batteries are being investigated for usage in industrial settings and EV charging stations in addition to stationary applications. Volkswagen is creating mobile charging stations that use reused EV batteries to provide electric vehicle users flexible charging options. Second-life batteries are also being used in off-grid storage systems, construction equipment, and forklifts, proving their adaptability across a range of industries.

3.5 Challenges & Future Prospects

Applications for second-life batteries have a lot of promise, but there are a few issues that need to be resolved. Safety is still the top priority because outdated batteries can have erratic performance problems. Thermal instability necessitates sophisticated monitoring and control systems since it might result in overheating and possible fire dangers. Since there are currently no global standards for testing, classifying, and reusing second-life batteries, standardization presents additional difficulty. To guarantee uniformity and security across many applications, industry-wide standards must be established.

Another important element affecting the broad use of second-life batteries is their economic viability. It takes a substantial financial commitment to gather and evaluate used batteries, and installation and refurbishment expenses might be exorbitant. However, it is anticipated that second-life battery solutions will become more economically feasible as economies of scale and technology develop. Selling reasonably priced energy storage technologies could open up new revenue streams for businesses that effectively implement effective repurposing methods.

Future applications of second-life batteries will be significantly impacted by technological developments. To increase safety monitoring, optimize energy use, and improve battery life prediction, AI-based Battery Management Systems (BMS) are being developed. By dynamically modifying the charging and discharging procedures, these intelligent devices can prolong the useful life of second-life batteries. Furthermore, second-life batteries can be seamlessly integrated into modular energy storage systems, increasing their adaptability to various energy storage requirements.

It is possible to establish a closed-loop battery ecosystem by combining effective recycling techniques with second-life applications. Battery degradation should not be seen as the end of a product's life cycle; rather, batteries can be recycled to recover valuable materials and then used again for a variety of purposes. This strategy minimizes the environmental impact of battery manufacture while eliminating waste and promoting the ideas of the circular economy.

EV battery second-life applications present a viable way to address the issues of resource sustainability and battery waste. Manufacturers can lessen their environmental influence and offer affordable substitutes for new battery systems by recycling used batteries for energy storage, grid stabilization, and industrial uses. To maximize the efficacy of second-life applications, it will be imperative to solve safety problems, financial obstacles, and standardization challenges. In order to facilitate the commercialization of second-life batteries, future research should concentrate on creating standardized health assessment procedures, enhancing AI-driven battery monitoring, and broadening legislative frameworks. Energy storage systems could undergo a revolution thanks to second-life uses, which could make them more effective and sustainable for coming generations.

4. Proposed Methodologies

This study will use a combination of literature-based analysis, experimental data evaluation, and comparative investigations to evaluate the viability of EV battery second-life applications. This multifaceted method guarantees a thorough comprehension of battery degradation, performance assessment, and real-world implementation difficulties.

4.1 Literature-Based Analysis

Battery deterioration patterns, second-life applications, and industry trends will be examined through a methodical study of previous research publications, technical reports, and case studies. To guarantee a strong theoretical foundation, sources like IEEE Xplore, ScienceDirect, and white papers from the automobile sector will be cited. This study will assess parameters influencing battery lifespan, performance degradation, and the effectiveness of repurposing solutions by reviewing prior research. In order to comprehend the wider ramifications of second-life applications, legislative and regulatory standards for battery reuse will also be taken into consideration.

4.2 Experimental Testing

This study will examine current datasets and case studies pertaining to EV battery performance rather than carrying out original tests. To ascertain important battery metrics including internal resistance, cycle count, and capacity retention, State of Health (SoH) estimation techniques will be examined. When determining if a degraded EV battery is still appropriate for second-life applications, SoH is a crucial measure. To learn how various testing methods affect battery classification, voltage and impedance testing data from published research will be analysed. Furthermore, documented test findings will be used to investigate thermal stability and safety evaluations in order to estimate failure rates, material deterioration, and overheating hazards in practical applications.

4.3 Comparative Analysis

This study will use established efficiency indicators to evaluate the performance of new EV batteries against second-life alternatives. We'll assess elements like operating lifespan, charge-discharge efficiency, and energy density. Additionally, financial records on battery repurposing will be reviewed in order to do a cost-benefit analysis. By contrasting the carbon footprint and material consumption of new battery production with second-life utilization, the sustainability component will also be investigated.

4.4 Case Study Review

We'll explore successful industry uses of second-life EV batteries, with an emphasis on initiatives like the Audi-Porsche grid storage project, Nissan xStorage, and Tesla Powerwall. These case studies will provide important insights into the future scalability of second-life battery solutions by highlighting technological difficulties, economic viability, and real-world adoption trends.

5. Results Collection & Analysis

Since industry reports, documented test results, and a comparative review of previous research will be used to interpret the study's findings. This method guarantees that the conclusions are supported by credible sources and provides a trustworthy assessment of EV battery second-life applications.

Performance Metrics Evaluation

Key performance indicators like thermal stability, charge-discharge efficiency, and capacity retention will be examined in order to assess the feasibility of reusing EV batteries. Technical reports, experimental tests, and published research articles from the automotive and energy sectors will be used to evaluate these indicators. An important metric in this assessment is the battery's State of Health (SoH), since batteries with a SoH above 70% are generally appropriate for second-life uses in renewable energy integration, grid storage, and backup power. Additionally, performance across various battery chemistries and usage scenarios will be compared using case study insights.

Cost-Benefit Analysis

For widespread usage, second-life EV batteries must be financially viable. In order to calculate the cost savings related to reusing batteries as opposed to producing new ones, this study will examine market reports and industry white papers. We'll take into account elements like predicted longevity in second-life applications, operational efficiency, and refurbishment expenses. The entire financial impact for consumers and businesses will be evaluated through comparison with earlier economic models. Additionally, case studies from the industry, such Tesla Powerwall and Nissan storage,

will shed light on how second-life applications can lower energy costs and increase income for large-scale storage solutions.

Environmental Impact Assessment

Applications of second-life batteries will be evaluated for their environmental advantages using a Life Cycle Assessment (LCA) methodology. To measure the sustainability impact, previous research on waste minimization, resource conservation, and carbon footprint reduction will be examined. This study will demonstrate how repurposing can support a circular economy by contrasting the use of second-life batteries with conventional recycling and the manufacturing of new batteries. The evaluation will also look at how prolonging battery lifespans can lower energy use, greenhouse gas emissions, and the exploitation of raw materials. The study intends to provide a thorough assessment of second-life EV battery applications using these analytical techniques, guaranteeing a fair assessment of their viability from a technical, economical, and environmental standpoint.

6. Project Planning & Timescales

TASK	DURATION
Literature Review	May 2025
Data Collection & Case Study Analysis	May - June 2025
Comparative Analysis & Interpretation	June – July 2025
Report Writing & Review	July – August 2025
Presentation	September 2025

7. Evaluation

This section identifies possible areas for further research while critically assessing the study's advantages and disadvantages. Although the study offers insightful information about second-life EV battery uses due to its dependence on secondary data and literature analysis, it should be noted that it has several limitations.

Strengths: This study's thorough analysis of EV battery second-life applications, with an emphasis on battery degradation, repurposing techniques, and industrial viability, is one of its main advantages. The study guarantees legitimacy and relevance by using validated case studies and well-documented research findings. The conclusions are more reliable when industry reports and real-world examples are included, such as Tesla Powerwall, Nissan storage, and Audi-Porsche grid storage initiatives.

Furthermore, the study is in line with industry trends and current sustainability goals, especially those pertaining to resource conservation and the circular economy. It is becoming more and more important to comprehend second-life applications as governments and businesses strive for better energy options. By assessing the

environmental advantages of battery reuse, such as decreased raw material extraction and carbon footprints, the study adds to this conversation.

Limitations: This study has a number of shortcomings in spite of its advantages. Because of resource limitations that prevent practical battery testing, the study only uses secondary data instead of direct experimental validation. Real-time battery performance under various second-life applications is not evaluated directly, even though published test results offer insightful information. Plus, rather of using actual financial data from manufacturers or companies engaged in battery repurposing, economic viability analysis is based on theoretical models and market reports. Because actual refurbishing costs, price fluctuations, and operational issues might not be properly taken into account, this constraint undermines the accuracy of cost-benefit analyses. Additionally, the study relies on pre-existing literature for safety evaluations, which might not account for new dangers related to outdated battery technologies.

Future Research Directions

Future research should concentrate on creating standardized SoH (State of Health) evaluation methods to enhance battery categorization for second-life applications in order to overcome these constraints. To guarantee safe and effective reuse, consistent and trustworthy testing procedures are required.

In order to improve economic viability, studies should also look into cost-cutting measures for battery reuse. Adoption by the industry will depend on finding methods to reduce refurbishing costs, increase logistical effectiveness, and develop scalable repurposing models.

Finally, integrating AI-powered monitoring systems for second-life applications has the potential to greatly improve energy optimization, lifespan prediction, and battery safety. Future research could look into the use of machine learning and artificial intelligence to better control the performance of second-life batteries.

References

- Tesla, 2021. *Tesla Powerwall: Home Battery Storage Solution*
<https://www.tesla.com/powerwall>
- European Commission, 2020. *EU Battery Regulation: Sustainability and Recycling Policies*
<https://ec.europa.eu/environment/batteries>
- Ahmed, S., Nelson, P.A., Gallagher, K.G. and Dees, D.W., 2020. *Cost and energy demand of producing lithium-ion batteries for electric vehicles*. Journal of Power Sources, **481**, p.229186.
 - Castro, R., Misle, E., Jaffe, M.B. and Behnke, R., 2020. *A comparative study of lithium-ion battery degradation during grid storage versus automotive use*. Journal of Energy Storage, **32**, p.101913.
- Keil, P., Schuster, S.F., Wilhelm, J., Travi, J., Hauser, A., Hering, S. and Jossen, A., 2021. *Calendar aging of lithium-ion batteries*. Journal of The Electrochemical Society, **168**(2), p.020533.
- Lai, X., Zhang, L., Ma, J., Ren, L. and Feng, X., 2021. *Aging mechanism and life prediction of second-life lithium-ion batteries in renewable energy applications*. Renewable Energy, **170**, pp.218-230.
- Zhou, H., Li, C., Zhang, K., Zhou, M. and Chen, Y., 2022. *Advances in battery management systems for second-life applications of electric vehicle batteries*. Energy Reports, **8**, pp.1597-1612.