Integrating Battery Recycling Into the Circular Economy: A Sustainable Business Model for LI-Ion Battery Waste in Romania

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Abstract

This article aims to develop a sustainable and economically viable business model for a national-scale lithium-ion (Li-ion) battery recycling facility in Romania, in response to the escalating challenges of battery waste management. In line with the European Union's targets for net-zero greenhouse gas emissions by 2050, the phase-out of combustion engines by 2035, and regulatory requirements for domestic battery waste processing, the development of structured recycling systems is imperative. Furthermore, EU Regulation 2023/1542 stipulates that, by 2031, industrial, electric vehicle, and SLI batteries incorporate a minimum of 16% recycled cobalt, 6% recycled lithium, and 6% recycled nickel, with progressively stricter thresholds through 2040. The study examines how such a facility could mitigate environmental impacts, recover critical raw materials, and advance the circular economy. The research adopts a qualitative methodology based on semi-structured interviews with the president of the National Battery Recycling System (SNRB) in Romania, complemented by extensive desk research. The findings confirm that establishing a domestic recycling facility is both technically feasible and financially viable. The proposed plant, with an investment of €1.24 million, is projected to achieve a return on investment within three to six years, depending on funding sources. It will enable efficient recovery of critical raw materials, reduce dependence on raw extraction, and mitigate environmental hazards associated with battery waste. This study offers a business framework tailored to Romania's specific market needs, aligning with EU environmental goals while addressing infrastructure gaps. It highlights the importance of regulatory frameworks and public-private partnerships in fostering sustainable recycling ecosystems. The implementation of this model can guide policymakers, investors, and industry stakeholders towards building scalable recycling infrastructure, promoting environmental responsibility, and advancing Romania's transition to a circular economy.

Keywords

Li-ion battery, battery recycling, sustainable business, circular economy, rare metals, Green Deal, repurposing.

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Introduction

There are several elements that indicate the need for a change in the way we look at the battery waste market in general and automotive waste in particular, and the actions needed to manage what is expected to be a significant influx of batteries in the future without neglecting the environmental impact and of course, the financial one:

1. EU is aiming for net-zero greenhouse gas emissions by 2050, and electric vehicles do not emit greenhouse gas emissions (European Commission, 2018).
2. All battery types must be fully collected and recycled using advanced methods to recover key materials like cobalt, lithium, nickel, and lead. High recovery rates protect the environment, support future battery innovation, and lessen reliance on raw material extraction (European Commission, 2020).
3. EU intends to end sales of combustion engines by 2035 and the significant increase in sales of electric vehicles and scooters/tricycles in recent years will create major challenges in the future regarding the recycling of Li-ion batteries (Euractiv, 2022).
4. EU Regulation 2023/1542 requires that by 2031, industrial, electric vehicle, and SLI batteries incorporate a minimum of 16% recycled cobalt, 6% recycled lithium, and 6% recycled nickel, with progressively higher targets set for 2036 and beyond.

Furthermore, the European Commission has recently proposed that Member States retain waste batteries within their country of origin, introducing a dedicated hazardous waste code for lithium batteries, particularly from separately collected municipal waste streams. While intended to enhance management oversight, this requirement may challenge states lacking adequate treatment and recycling infrastructure. The proposal aligns with Regulation (EU) 2024/1157 on waste shipments, which strengthens restrictions on the export of strategic waste streams, including batteries, beyond the European Union (European Commission, 2025).

Lithium-ion batteries outperform conventional types with higher energy density, lower self-discharge, and longer life. Their temperature resilience makes them ideal for plug-in and hybrid EVs, aligning with projected global sales of nearly 100 million units annually by 2045 (Paul et al., 2024).

Back in 2010, in Romania, Pleşea and Vişan (2010), wrote that the collection of car accumulators was done properly, according to the law, but when it came to the collection of batteries, he said that it was done from time to time, existing a very low number of traders that were really in the process of recycling these products.

O'Neill (2021) argues that while scaling EV battery recycling is conceptually simple, significant commercial and technical challenges remain. Olsson et al. (2018) highlight the potential for second-life Li-ion batteries to enhance circularity across the battery value chain.

The paper finds that while stakeholders recognize the potential of second life, organizational and cognitive barriers exist, and suggests that actors in the battery value chain should form new collaborations to seize business opportunities and develop new models.

At the international level, there are a lot of studies focused on the Li-ion batteries recycling process or second life usage, proposing business models (Wrålsen et al., 2021; Popescu et al., 2022; Shahjalal et al., 2022), while, when it comes to Romania, the subject is almost untouched. Thus, the authors found a gap in the literature and came up with the present paper, which aims to demonstrate that there is a solution for a sustainable and profitable business model in Romania. Establishing national-scale battery recycling facilities could significantly reduce unusable waste streams and enhance the circularity of battery components.

The paper is structured in five chapters, starting with the introduction and continuing with a review of the scientific literature, methodology, and a business model for battery recycling. In the last chapter, the conclusions are presented.

1. Review of the scientific literature

Li-ion batteries contain a mixture of materials (black mass) that could be recovered from spent batteries through a process that generally involves three main methods: pyrometallurgy, hydrometallurgy, and direct recycling (Paul et al., 2024). But, before that, several steps are required, such a pretreatment processes (storage, diagnosis, sorting and cell discharge methods) and mechanical dismantling, through techniques like: crushing, sieving, and both sequential and automated segregation (Bhar et al., 2023). A battery consists mainly of active cathode and anode materials, which contain valuable metals and compounds, found in finite quantities in nature: lithium (Li), cobalt (Co), nickel (Ni) and manganese (Mn), serving as an "urban mine" (Ran et al., 2024). Among them, cobalt (Co) and lithium (Li) are the most important in terms of scarcity and cost (International Energy Agency, 2024).

- *Cobalt (Co):* the most valuable and rare, approximately 70% of global production is extracted from the Democratic Republic of Congo. Cobalt mining raises ethical concerns (labor exploitation, environmental impact), thus making it crucial to recycle due to its value and the difficulties of extraction.

Cobalt supply projections highlight strong dependence on global production trends and policy effectiveness. Under a business-as-usual scenario, supply meets conservative demand, while an optimistic scenario shows a slight surplus but still falls short of Net Zero needs. A pessimistic view warns of significant shortages, stressing the need for strategic policies and long-term investment to secure supply for climate goals.

- *Lithium (Li):* essential (the key element of the battery), but not extremely rare is extracted from Australia, China and Chile. The extraction process is polluting and consumes water in significant quantities.

Lithium supply projections show a consistent shortfall across all scenarios. The pessimistic case highlights risks from tech delays and limited investment, while even the optimistic scenario fails to meet Net Zero goals. This gap underscores the urgent need for policies to boost investment, advance technology, and scale recycling to support electrification and sustainable energy. (Shannak, Cochrane and Bobarykina, 2024).

Cui et al. (2024) proposed three business models referring to repurposing, recycling, and circular production for lithium-ion batteries, arguing that a circular economy for automotive battery recycling is achievable without government subsidies if all stakeholders act in the community's interest. Conversely, Lima et al. (2022) developed a recycling business model for Brazil, highlighting that economic viability depends largely on tax exemptions, regulatory incentives, and technological maturity. Lithium-ion batteries, which never fully discharge, require multi-step treatment processes at end-of-life, typically after about ten years (Yu et al., 2024).

Batteries constitute 20–30% of a vehicle's weight, with small electric cars (40–50 kWh) carrying batteries of 250–350 kg and larger vehicles up to 1.500 kg, posing a substantial environmental burden. Recycling is further complicated by storage risks due to lithium's high reactivity and flammability, necessitating strict safety measures (Shukla and Shankul, 2024). A major barrier remains the inconsistent and inadequate volume of collected batteries, compounded by the absence of public data on annual collection rates in Romania and the need for stronger legislative and public engagement.

Table no. 1. Batteries put on market in Romania

	Put on market 2022		Put on market 2023		Put on market 2024	
	tons	*number*	*tons*	*number*	*tons*	*number*
Total	**5,385.54**	**97,784,341**	**7,031.08**	**97,958,188**	**9,447.11**	**92,835,369**
of which, Li-ion batteries and related	1,200.53	164,507	2,358.20	293,009	4,040.01	976,351

Source: National Battery Recycling System (SNRB)

Table no. 2. Batteries collected in Romania by one of the largest organizations in the field

	Collected 2022		Collected 2023		Collected 2024	
	tons	*number*	*tons*	*number*	*tons*	*number*
Total	**883.35**	**2,245,488**	**1,060.62**	**2,896,261**	**1,036.65**	**2,940,539**
of which, Li-ion batteries and related	632.72	2,002,094	149.52	2,147,462	262.48	2,535,470

Source: National Battery Recycling System (SNRB)

2. Research methodology

The objective of this article is to develop a business model for a battery recycling facility, given the absence of such infrastructure in Romania. Consequently, a qualitative research approach, based on a semi-structured interview, was deemed the most appropriate method for this study.

The discussions were conducted with the president of the National Battery Recycling System (SNRB), one of the largest non-governmental organizations in Romania, and a founding member of EUCOBAT (European Compliance Organization for Batteries). SNRB's mission is to assume the responsibilities of battery and accumulator manufacturers and importers, by establishing an efficient system for the collection and recycling of waste batteries and accumulators (SNRB, 2025). The interview was guided by a structured framework consisting of targeted questions designed to keep the conversation focused on the research objectives and to ensure the collection of accurate and relevant information. The structured interview framework guided three online meetings, each lasting approximately 90 minutes.

In addition to the primary data collection, desk research was undertaken, which involved the review of various documents, press releases, public reports, and market analyses pertaining to the battery sector in Romania and across Europe, as: Grand View Research, 2025 for Battery Market Overview 2024-2028 and in Lithium-Ion Battery Market Overview 2024-2028 in Europe, as well as for Battery Market Overview 2024-2028 in Romania. The majority of the data collected through interviews and secondary sources was qualitative in nature. However, quantitative data was also incorporated, specifically from the organization's internal reports and financial records, providing a more comprehensive understanding of the topic.

3. Business model for battery recycling facility

This study proposes the development of a dedicated battery recycling facility, designed to integrate environmental stewardship with economic viability. The facility will adopt a closed-loop recycling model aimed at minimizing waste, recovering strategic materials, and supporting the circular economy in alignment with the objectives set forth in Regulation (EU) 2023/1542.

- *Location and Target Market:* The facility will be in an industrial park near a major urban center to optimize logistics, strategically located near the transportation infrastructure for easy access to collection points and distribution networks, targeting battery manufacturers, retailers, and end consumers by providing recycled materials and eco-friendly disposal solutions.
- *Investment and Financial Objectives:* The initial investment is projected at €1,240,000, with a payback period of six years. EU funding could accelerate the return on investment to approximately three years.
- *Expected Environmental and Economic Benefits:* The facility will reduce battery waste, lessen dependence on raw material extraction, and mitigate disposal risks, while fostering long-term profitability and strengthening corporate social responsibility initiatives.

The *market analysis* includes the following:

- *Market Trends:* The global demand for battery recycling solutions is growing rapidly, driven by stricter environmental regulations, increasing public awareness of sustainability, and the broader transition toward a circular economy aimed at reducing dependence on virgin resources.
- *Market Segmentation:* The primary market for battery recycling comprises battery manufacturers seeking recycled materials to meet production and sustainability goals, electronics retailers responsible for collecting spent batteries from devices and EVs, and end consumers who serve as key suppliers within the recycling chain.
- *Demand:* The European battery recycling market is projected to reach $3.5 billion by 2027, driven by robust regulatory support and sustainability goals (Grand View Research, 2025a).
- *Competitors:* While established firms such as Umicore and Redwood Materials dominate internationally, Romania presents a market gap for authorized lithium-ion recyclers, offering opportunities for new entrants.
- *Regulations:* Battery recycling is regulated by EU directives like Directive 2006/66/EC and Regulation No. 1542/2023, which aim to reduce environmental impact and improve recycling rates. Com-

pliance with these regulations is essential for the facility's success (European Environment Agency, 2020-2025).

The *operational plan* includes the following:

- *Facility Requirements:* The facility will occupy 1,000 m², with distinct zones for collection, processing, and storage, designed to meet safety and environmental standards.
- *Required Equipment:* The facility will require a range of specialized equipment including collection vehicles, sorting machinery, and processing units for shredding and extracting materials like lithium, cobalt, and lead.
- *Logistics:* Partnerships with transportation providers specializing in hazardous waste handling will ensure regulatory compliance and safe transportation.
- *Operational processes:* include battery collection via retailers, safe transportation to the facility, sorting and storage, followed by processing using advanced machinery to recover valuable materials.
- *Safety Regulations:* The facility will follow comprehensive safety protocols, ensuring the proper handling and storage of hazardous materials, with staff trained in safety procedures.
- *Technologies Used:* Modern technologies will be employed to extract critical raw materials, supporting the transition to a circular economy and reducing reliance on virgin resources.

Regarding the *organizational structure*, the business will operate as a Limited Liability Company (LLC), with defined roles to ensure effective governance and operations. The General Director will oversee strategic and financial management, while the Operations Manager will supervise daily activities and safety protocols. The Sales and Marketing Manager will manage outreach and client relations, and the Environmental and Safety Specialist will ensure regulatory compliance. Production staff will be responsible for battery collection, sorting, and processing.

Regarding the *financial plan*, the initial investment and revenue projections are presented in the following tables:

Table no. 3. Initial Investment

Component	Estimated Cost (EUR)	Details
Facility Construction	700.000	Main building, offices, storage, processing areas
Equipment & Machinery	470.000	Battery shredder: 150.000 EUR; Sorting system: 100.000 EUR; Metal recovery system: 200.000 EUR; Safety equipment: 20.000 EUR
Licenses & Permits	50.000	Environmental and regulatory fees
Marketing and launch costs	20.000	
Total Initial Costs	**1.240.000**	

Table no. 4. Revenue Forecast

Revenue Source	Quantity / Year	Unit Price (EUR)	Total Revenue (EUR)
Recycled Battery Sales	250 tons	2.000	500.000
Partner Contracts*	-	-	50.000
Total Annual Revenue			**550.000**

** Agreements for the collection and recycling of used batteries from manufacturers and retailers.*

Revenue estimation is based on the average selling price for recovered metals and potential contracts with partners. Sales projections may fluctuate in response to changes in secondary raw material market prices. The European Union has set a target for 15% of the materials used in new batteries to be sourced from recycling by 2030.

Revenues are projected to grow by 10% annually, while expenses are expected to increase by 5% per year.

Table no. 5. Financial Projections

Year	Revenues (EUR)	Expenses (EUR)	Net Profit (EUR)
1	550.000	429.000	121.000
2	605.000	450.450	154.550
3	665.500	472.973	192.527

Table no. 6. Breakeven Point Calculation

Cost Type	Annual Cost (EUR)
Fixed Costs	264.000
Variable Costs	165.000
Total Annual Costs	429.000
Indicator	**Value**
Contribution Margin (EUR/ton)	1.340
Breakeven Point (tons)	197

- *Determining Fixed and Variable Cost:* Fixed costs, essential for facility operation, total €264.000 annually. These include employee salaries (€150.000), equipment maintenance (€10.000), depreciation of equipment and construction (€64.000), marketing (€20.000), and other administrative expenses (€20.000). Variable costs, which fluctuate with production volume, total €165.000. These include processing costs (€100.000), utilities (€15.000), and logistics (€50.000).
- *Revenue Calculation:* Revenue is generated by selling recycled materials at €2.000 per ton.
- *Contribution Margin:* The contribution margin per ton is calculated as the selling price minus the variable cost per ton.
- *Break-even Point:* The break-even point is reached when total revenues equal total costs. It is calculated as: Total Fixed Costs / Contribution Margin

The facility must process and sell approximately 197 tons annually to cover both fixed and variable costs, with any additional volume contributing to profitability.

- *Funding Sources:* Funding strategies include traditional bank financing to support initial capital and operational costs; European Union funding, notably through the LIFE Programme, to align with environmental policy objectives; venture capital investment targeting green technologies; public-private partnerships with municipalities to secure financial support and long-term contracts; and crowdfunding to engage environmentally conscious individuals while enhancing public visibility and support.

The *primary marketing objective* is to raise public awareness of the environmental importance of lithium-ion battery recycling, aiming to increase collection rates and support the facility's sustainable operation.

- *Marketing Strategies* - A multi-faceted marketing strategy will include educational campaigns targeting local communities and stakeholders, a comprehensive digital presence leveraging social media and SEO, and strategic partnerships with electronics retailers and automotive service centers to expand collection networks.
- *Sales Channels* - Sales efforts will focus on securing long-term contracts with companies in the electronics, automotive, and renewable energy sectors, offering tailored recycling service packages to ensure a consistent supply of recyclable materials.

Regarding *environmental impact*, it is important to mention the ecological benefits and regulatory compliance.

- *Ecological Benefits* - The facility will reduce hazardous waste by diverting end-of-life batteries from landfills and recovering valuable raw materials, thus strengthening sustainable waste management. It will contribute to natural resource conservation by reclaiming critical elements like lithium, cobalt, and nickel, supporting circular economy principles and reducing the environmental impacts of mining. Proper recycling practices will prevent the release of toxic substances, safeguarding soil, groundwater, and air quality.
- *Regulatory Compliance* - Operations will fully comply with local, national, and international environmental regulations, including Directive 2006/66/EC of the European Parliament on waste batteries and accumulators, as well as Regulation (EU) 2023/1542, which governs the sustainable management of batteries and associated waste streams. Compliance with these legal frameworks ensures not only environmental protection but also the alignment of the facility's operations with broader EU sustainability and climate policy objectives.

Conclusions

An updated regulatory framework, aligned with the current challenges of the lithium-ion battery sector, is essential for establishing a functional recycling system. Such a framework would directly influence public policy by creating favorable conditions for market development through the establishment of standardized pricing and quality benchmarks for battery recycling. These measures would enhance transparency and efficiency, supporting both private and public sector efforts to achieve environmental objectives.

Beyond regulatory measures, investment in human capital and the promotion of innovation through applied research are critical for advancing sustainable technologies. Partnerships with universities can foster technological improvements in recycling processes, leading to more efficient and environmentally friendly solutions and reinforcing circular economy principles (Chigbu, 2024).

A regulatory environment that supports research and innovation can significantly shape public policy, encouraging both private and public investments in sustainable recycling technologies. In this context, public policy plays a vital role in enabling the transition toward a circular economy, enhancing environmental protection, and reducing reliance on finite resources.

This business plan, underpinned by a robust legislative framework, comprehensive market analysis, a clear operational model, and a viable financial strategy, provides a strong foundation for establishing a lithium-ion battery recycling facility. The project has the potential to drive both profitability and sustainable development, while contributing meaningfully to the expansion of the circular economy.

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