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Completed Assessment for

The economic, technical, and environmental aspects of electric storage battery recycling

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INTRODUCTION

The term ‘electromobility’ refers to an alternative transportation system based on vehicles propelled by electricity. Electromobility could circumvent problems related to both oil and biofuels while meeting our mobility needs and desires. Current interest in electromobility can be justified by the megatrends in the automotive industry, including concerns for energy security, air pollution, and climate change legislation, recent technology improvements, and growing interest for electromobility in key markets. Also, the transport sector is presently responsible for 25% of energy-related CO2 emissions [1]. While global car sales figures are declining overall, sales of electric vehicles are rising. In 2019, 35 percent more electric cars and plug-in hybrids were sold in Germany. Sales rose even more strongly in Singapore (241%) and the Netherlands (120%). The global electric vehicle market size valued $118,864.5 million in 2017, and is projected to reach $567,299.8 million by 2025, growing at a CAGR at 22.3% from 2018 to 2025. [3] The electric vehicles are equipped with three major components: electric, motor, and battery. Batteries are presently the most favored energy storage device and make them the core BEV component. [1]

Significance of Battery Recycling:

The anatomy of electric vehicles utilizes a different type of batteries: Lithium-ion, Molten salt (NA-NiCl2), Nickel Metal Hydride (Ni-MH), and Lithium Sulphur (Li-S). [4] Out of all batteries currently present in the market, Lithium-ion batteries are most widely used in EVs given their high energy and power densities. [1] Globally, lithium-ion battery market was valued $30,186.8 million in 2017, and is projected to reach $100,433.7 million by 2025, growing at a CAGR of 17.1% from 2018 to 2025. [5] With this growing market, it is necessary to understand the amount of scrap produced by these batteries at the end of their lives. The mismanagement of spent batteries is the key concern due to the presence of hazardous components mercury, lead, cadmium. If not handled properly, these substances risk the environment and human health. To reduce the risk, all spent batteries undergo treatment. [6]. Additionally, recycling of LIBs can be economically beneficial as it will reduce the cost of raw materials.

The recycling of these batteries has a significant impact on the production, consumption, and cost of Lithium carbonate and other vital elements such as cobalt and nickel. Excluding USA, worldwide lithium production in 2019 decreased by 19% to 77000 tons of lithium from 95000 tons of lithium in 2018 in response to lithium production exceeding consumption and decreasing lithium prices. Moreover, Lithium carbonate prices in china decreased from approximately $11600 per ton in January 2019 to about $7300 per ton in December [7]. Lithium supply security has become a top priority for technological companies in the United States and Asia. Strategic alliances and joint ventures among technology companies and exploration companies continued to be established to ensure a reliable, diversified lithium supply for battery suppliers and vehicle manufacturers [7]. Various other factors that impact LIB recycling's benefits are discussed further in this article.

TECHNICAL ASPECTS OF BATTERY RECYCLING

To direct the spent batteries into dedicated recycling processes, they must be extracted from EOL vehicles. Following the extraction, batteries are usually disassembled down to module/cell level [8]. Recycling processes for LIB are a combination of different operations: Deactivation, pyrometallurgical, mechanical, and hydrometallurgical treatment. Deactivation can be carried out by discharge of the whole battery systems, battery modules and cells. To avoid the rise of voltage after discharge, short-circuiting of the batteries is required. Preparation of the regained battery modules, cells, or coating materials can be carried out pyrometallurgical or mechanically afterward. Utilizing pyrometallurgical treatment leads to the recovery of Ni, Co, and Cu in the molten mass [9].

The mechanical treatment combines crushing, classification, and sorting processes. The mechanical processes are used to expose high valuable coating material for further investigation of hydrometallurgical and pyrometallurgical processes [9] . In the Pyrometallurgical process, spent LIBs are fed into a furnace and smelted at high temperature (>1000°C). Decomposing plastics, electrolyte and carbonaceous components, and molten metals and alloys are collected separately [10]. The hydrometallurgical treatment is applied for the direct recovery of metals such as Co, Ni, Mn, and Li, from the mechanically separated coating powder and the extraction of Al and Li from the slag of pyrometallurgical processes to make a new cathode [9]. Direct recycling separates the different components of the black mass (active material powder from the shredding of cells) by physical processes, like gravity separation, which recover separated material without causing chemical changes with the recovery of useable cathode material [11].

The production energy can be reduced by increased use of recycled materials, enabled by recycling processes that recover materials in forms closer to direct use in new cell production [11]. From the processing point of view, the hydrometallurgical processing of the regained coating powders is the variation in its chemistry and purity. Next to the chemical deviation, different cell formats and cell housing materials influence the design of battery modules and the systems. Every cell and module manufacturer and automobile manufacturers apply their design, which complicates the automatic process of discharge and disassembly. The main challenge for mechanical preparation procedures is the separation of current collector foils and electrochemical active coating materials, as electrodes of LIBs are made of long-lasting adhesion[9].

ECONOMICAL ASSESSMENT OF BATTERY RECYCLING

Researchers have found various models to estimate recycling revenue, recycling cost, and battery production cost. Research-based on the EverBatt model, a China-specific database of hydrometallurgical recycling process found that 8.17% of the cost can be saved by replacing the virgin materials with recycling components, where the cost of virgin production is about $22.68 kg-1 and that for spent LIB recovering is about $20.81 kg-1 [12]. The recycling process accounts for 25.91% of the total cost, whereas cathode recycling comprises 17.41%. The recycling and cathode manufacturing cost adds up to $9.02 kg-1. In this way, the calculated cost of cathode production can be saved up to $1.29 kg-1. The reduced cost represents the benefit by recovering the Co, Ni, Mn materials, accounting for 68.86% of the total cost savings [12]. In the EverBatt model of Argonne National Lab, recovered Co/Li/Mn/Ni compounds from cathode material were considered 'good as new' by cathode powder producers and are therefore assumed to sell as their virgin counterparts [13], which makes no difference between the purchase price of recycling compounds and the raw compounds.

The cost of raw materials plays a substantial role in the total costs, accounting for 64.28%. Besides, 6.43% of the total cost is attributable to the utilities. Among the material expenses, buying spent batteries represents 87.05% of the overall expenditure due to the high price of the valuable metals in these batteries. It is estimated that recycling would be economically beneficial until the purchase price of spent LIBs reaches $2.87 kg-1 [12].

Another important advantage of recycling deals with disposal cost of spent LIBs. Typical disposal cost fall in $4,000-$5,000 per ton range. This includes shipping to site and processing within a hazardous waste landfill. Since it is classified as a hazardous waste, the cost of safe disposal would be avoided by recycling [14].

Globally, the industry's over-dependence on China has been showcased recently, with the Coronavirus outbreak leading to disruptions in the supply of components. China, a battery manufacturing powerhouse, deals with a slow down with the COVID-19 outbreak. The Chinese EV manufacturer, BYD's share, has devalued by 10% since January 2020 [15]. Moreover, Jaguar Land Rover has paused the production of it's I-pace electric SUV as is Mercedes of its EQC, due to the unavailability of critical gradients for batteries – including lithium and cobalt [16]. Battery recycling would be economically beneficial for automotive manufacturers to minimize the dependence on foreign sources of battery components. In January 2020, for example, U.S. Department of Energy announced the creation of DOE's first LIB recycling R&D Center, the ReCell Center [17].

To our contrast, Large fluctuations in the prices of raw battery materials cast uncertainty on the economy of recycling. The recent drop in cobalt's price raises questions about whether recycling of LIBs is a good business choice compared with manufacturing them with fresh raw materials. The recycled cobalt would struggle to compete with mined cobalt prices. Another long-term financial concern for LIB recycling companies is whether a different type of battery, such as Li-air, or a different propulsion system, like hydrogen-powered fuel cells, will gain a significant foothold on EV market in coming years lowering the demand for LIB recycling [17].

ENVIRONMENTAL ASPECTS OF BATTERY RECYCLING

In addition to material savings, LIB recycling has positive impacts on energy consumption and environmental protection. Li, Co, Ni, and Al production requires high energy to be extracted from the virgin resources and causes greenhouse gas emissions (CHG) from transportation and smelting processes. Other minor gradients in LIBs such as Al, Cu, and Fe, recycling can save 95%, 85%, and 74%, respectively, of the total energy required to obtain them through one extraction. In addition, most LIBs are currently disposed of in landfills unless restricted by municipal policies. Environmental hazards occur when water enters the landfill and leaches the toxic metals from LIBs. The issue is execrated because microorganisms in the landfills produce acids that can corrode the battery casing over time [10].

Various scientists have used LCA to measure the environmental impacts of LIB recycling. Life-cycle environmental impacts of each recycling processes (Pyrometallurgy, Hydrometallurgy etc.,) is generally measured by considering three major categories: global warming potential over 100 years (GWP 100), expressed in kilograms of carbon dioxide equivalent (kg CO2-eq), terrestrial ecotoxicity (TETP) and human toxicity potential (HTP). Both HTP and TETP are expressed in kilograms of dichlorobenzene equivalent (kg DCB-eq) [18]. With the assumption that the first large batch of end-of-life EVs would be treated around 2025, Chinese scientists estimated the recycling impact on energy consumption and CHG emission in 2017. According to their studies, Although LIBs share only 9% of the whole EV by weight, the study estimated that 4.1 GJ and 1.2 t CO2-eq reduce energy consumption and CHG emission by recycling, accounting for about 13% and 23% reduction when the entire EV is recycled. However, the study assumed the EV recycling situation in China in 2025 without considering other aspects such as transportation of spent LIBs from landfill to recycling location. Additionally, uncertainty exists due to unpredictable growth in techniques [19].

However, there are environmental effects associated with the transportation of recycled LIBs. The study conducted in Australia showed that if the batteries are recycled in Australia and shipped to Europe would cause a 45% increase in GWP 100 impacts of pyrometallurgical processes and a 550% increase in impacts to HTP for hydrometallurgical processes. This study also depicted that for GWP 100, landfill showed a lower impact than the recycling processes. This result is explained by the number of processes required for recycling, many of which involve CO2 emission [18]. Having acquired environmental benefits from LIB recycling, hydrometallurgical processes are essential as they require low energy, produce fewer toxic emissions, and ideally recover all valuable metals at high purity. [10].

CONCLUSION

Electrifying transport is one of the biggest keys to solving the looming climate crisis. As the world trends towards electrification, rapidly growing LIB production demands will strain resources for valuable metals and environmental concerns from the waste generated, all of which can be addressed through LIB recycling. This essay summarizes various recycling techniques and their challenges. The hydrometallurgical process can meet the ideal recycling criteria and potentially recover Li, Ni, Mn, and Co at high efficiency and purity [10]. The most fruitful research area seems to be material separation technology on several scales. Design for recycling is another significant advance that could improve the prognosis for recycling [11].

Current commercial recycling facilities are largely focused on recovering precious and high-value cobalt. However, LIB Cathode chemistry market share is shifting rapidly towards cobalt-deficient and mixed-metal composition. Recycling facilities must adapt to handle mixed-type cathodes and comingled LIB scrap comprising diverse chemistries. Recycling incentives should consider the energy savings and environmental benefits from reducing landfilling, toxic emission, and reliance on raw material extraction. Taken together, the widespread realization of LIB recycling will require legislation and political pressure, likely in the form of economic incentives, public education, landfill disposal regulations, and defined responsibilities on the collection and disposal of spent LIBs for consumers, retailers, and EV and battery manufacturers [10].

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BIBLIOGRAPHY

[1] B. Sandén, Systems Perspectives on electromobility, Goteborg: Chalmers University of Technology, 2014.

[2] C. Russo, "The Roland Berger Newsroom," October 2019. [Online]. Available: https://rolandberger-com.mynewsdesk.com/pressreleases/growth-in-the-e-mobility-market-climate-goals-give-electric-cars-and-plug-in-hybrids-a-significant-boost-2929986.

[3] R. Kumar, "Global Electric Market overview," January 2019. [Online]. Available: https://www.alliedmarketresearch.com/electric-vehicle-market.

[4] C. Iclodean, "Comparison of Different Battery Types for Electric Vehicles," in *Insitutute of Physics (IOP)*, Romania, 2017.

[5] A. Yenduri, "Allied Market research," October 2018. [Online]. Available: https://www.alliedmarketresearch.com/lithium-ion-battery-market.

[6] E. Commission, "Evaluation of the Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC," *Commission Staff Working document,* 9 April 2019.

[7] U. S. G. Survey, "Mineral Commodity Summaries," *Mineral Commodity Summaries,* pp. 97-100, 31 January 2020.

[8] T. Elwert, "Recycling of Batteries from Electric Vehicles," *Green Energy and Technology,* pp. 289 - 321, 2018.

[9] J. Diekmann, "Ecological Recycling of Lithium-Ion Batteries from Electric Vehicles with focus on Mechanical Processes," *Journal of The Electrochemical Society,* pp. A6184 - A6191, 2017.

[10] T. Or, "Recycling of mixed cathode lithium-ion batteries for electric vehicles: Current status and future outlook," *Carbon Energy,* p. January, 2020.

[11] L. Gaines, "Lithium-ion battery recyclig processes: Research towards a sustainable course," *Sustainable Materials and Technologies,* 2018.

[12] S. Xiong, "Environmental and Economic evaluation of remanufacturing lithium-ion batteries from electric vehicles," *Waste Management,* pp. 579-586, 2019.

[13] Q. Dai, "EverBatt: A closed-loop Battery Recycling Cost and Environmental Impacts Model," Argonne National Laboratory, Chicago, 2019.

[14] I. Buchmann, "Battery Recycling as a Business," 21 June 2019. [Online]. Available: https://batteryuniversity.com/learn/article/battery_recycling_as_a_business.

[15] G. Energy, "The Coronavirus outbreak to impact China's battery storage production," 27 March 2020. [Online]. Available: https://www.power-technology.com/comment/battery-production-china-coronavirus/.

[16] A. Cohen, "Manufacturers are struggling to supply Electric Vehicles with Batteries," 25 March 2020. [Online]. Available: https://www.forbes.com/sites/arielcohen/2020/03/25/manufacturers-are-struggling-to-supply-electric-vehicles-with-batteries/#5ed046d51ff3.

[17] M. Jacoby, "It's time to get serious about recycling lithium-ion batteries," 14 July 2019. [Online]. Available: https://cen.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/i28.

[18] A. Boyden, "The environmental impacts of recycling portable lithium-ion batteries.," in *23rd CIRP Conference on Life Cycle Engineering*, Canberra, 2016.

[19] H. Hao, "Impact of recycling on energy consumption and greenhouse gas emission from electric vehicle production: The China 2025 Case," *Resources, Conversation and Recycling,* pp. 114 - 125, 2017.