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A STUDY OF REGULATORY AND TECHNOLOGICAL CONSIDERATIONS OF WASTE MANAGEMENT OF ELECTRIC VEHICLE BATTERIES.

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Abstract*:* To prevent a waste issue in the future, it is necessary to find multidisciplinary solutions to deal with lithium-ion batteries that have reached the end of their useful lives and are utilized in electric vehicles. Using both legal and scientific viewpoints, this article criticizes battery waste management rules and regulations that ignore technological progress, particularly in terms of developing a market for EV batteries that are subject to electrochemical performance, durability, and safety standards as well as recycling lithium-ion battery. The new Batteries Regulation is also discussed, which is crucial for the direction of the policy going forward, Also discussed renewable sources of energy like solar rooftops will help slow and continuous charging may be an added advantage to enhance the life of the battery.

Keywords: Waste Management; Electric Vehicle; Batteries; Transportation, Solar, Photovoltaic

Introduction*:* Since EVs emit fewer greenhouse gases throughout their life cycles than conventional vehicles, they have the potential to help decarbonize the transportation industry and slow down global warming. Global recognition of this potential has led to predictions that millions of EVs may be on the road by 2030. [1] with the sale of EVs expected to reach about 4.85 billion USD of lithium-ion batteries by 2027in India. [2] Even while this would be an excellent way to reduce carbon emissions in the transportation sector, a recent study indicated that recycling methods for lithium-ion batteries that are nearing the end of their useful lives are trailing behind the rapid uptake of EVs, which will eventually cause a significant waste problem. By 2030, it is anticipated that more than 10 million tonnes of used lithium-ion batteries would be disposed of globally. Battery refers to any battery used in any sort of EV or created specifically for industrial or professional applications. Due to the expanding market for electric road vehicles, road vehicles' traction batteries fall under a separate category from other electric vehicle batteries.[6] Only 5% of the lithium in industrial batteries was recovered by 2013; this indicates improper collection and recycling practices. [7]Additionally, improper recycling results in the loss of important resources. Concerns about raw materials, particularly cobalt, nickel, and manganese, which, along with lithium, are crucial components of lithium-ion batteries, are on the rise. Recycling can provide a crucial remedy for unstable raw material prices and supply. Manufacturers can protect themselves from supply shortages and generate additional cash by recovering crucial raw ingredients from lithium-ion batteries. [8]For instance, it is anticipated that by 2040, the global lithium-ion battery recycling business will generate $31 billion in annual revenue [9] because used EV batteries may either be recycled to acquire the basic ingredients or put to use again in new applications.[10]Additionally, this would enhance the environmental performance of all parties involved in the battery lifecycle, including makers, distributors, and end users, as well as those specifically engaged in the recycling of used lithium-ion batteries. [4] Since recycling and reusing will

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prevent the usage of virgin materials, lithium-ion batteries themselves—which are the biggest contributors to effects like climate change, primary energy demand, and metal depletion—will be less affected by environmental impacts throughout their life cycles than items that rely on them, such as electric vehicles. This is especially true for those who are involved in the extraction of raw materials, such as mining and manufacturing, as well as Lithium-ion battery manufacture. [9,10] Since it is anticipated that over a million tonnes of used lithium-ion batteries will be dumped by 2030, this is extremely crucial.[2], which corresponds to 50 million units in total. Each battery has 8 to 15 kilograms of lithium. [13] Recycling would produce 40.000 tonnes of lithium, preventing the need for new lithium mines. The extraction of lithium from brines requires roughly 1,800,000 liters of water per tonne of lithium and is primarily done in water-scarce regions of the world at a few big mines, notably in South And Central America or Australia (rock mining). [14]Because of this, mining negatively affects local populations' declining health (due to, for example, air, soil, and water pollution) and growing inequalities caused by wealth disparity and heavy demands on infrastructure, housing, and services, among other things. [15] Although there are many obstacles in the way of achieving a sustainable economy, it is critical to recognize them as early as possible. Numerous scientific research has highlighted the significance of environmentally responsible lithium-ion battery waste management. [3], Showing how heat management techniques can be used to increase the performance and efficiency of batteries. [16,17] Research has also been done to determine how battery design affects the ability to recycle and recover vital materials from LIBs, assuring secure and profitable procedures. [18]There haven't, however, been any extensive studies conducted from an interdisciplinary approach that encompass both legal and technical components of the circular economic landscape. There is an urgent need to revise the Batteries Directive. [5] Other elements of battery production and use, such as electrochemical performance and durability or ethical sourcing, are not yet covered by any laws. [19]One of the eight technical goals set by the Faraday Institute is to be able to recycle 95% of an electric vehicle battery pack by the year 2035. Faraday Institute is actively pushing the recycling and reuse of battery components. [20]The change requires regulatory frameworks. As a result, this paper will examine the most recent changes in laws governing the management of battery trash. The legal frameworks must, however, keep up with the rate of technical advancement, particularly when it comes to the formation of a market for the recycling of lithium-ion batteries and the reuse of electric car batteries, both of which will be covered in this paper. This study is divided into sections, **Section 2** of which will discuss the background of legal frameworks and policies in place for the handling of lithium-ion battery waste and illustrate numerous technical challenges connected to the development of a market. While **Section 3** about the reusable battery and **Section 4** will provide a discussion and summary of the debate and **Section 5** will wrap up the paper under the heading of conclusion.

Section 2: Background: Lithium-ion battery recycling regulations were passed in China [21]

2017	Vehicle Power Battery Recycling and Dismantling Code	outlines the precautions to take, the steps to take, and how to store and manage vehicle batteries.
2017	Energy Detection Battery Recycling Battery Utilization in Vehicles	describes how to determine the voltage, charge and discharge current, and remaining energy in batteries as well as the polarity and look of the batteries.
2017	Rules for Coding Automotive Power Batteries	requires specific labeling for batteries
2017	Power Battery Dimensions and Specifications for Electric Vehicles	standardizes requirements for power modules, battery packs, and other components to promote recycling
2018	Notice Regarding the Pilot Project of New Energy Vehicle Power Battery Recycling	establishes an experimental program for recycling batteries
2020	Solid waste pollution prevention and control law of the People's Republic of China	establishes a "credit record" system for handling solid waste, including batteries that include lithium ion

Recycling-related Lithium-ion battery policies Written in China [21]

2018	Pilot Project for the Reuse and Use of Power Batteries in Electric Vehicles	defines battery recycling pilot projects and businesses.
2019	Construction and operation guidelines for new energy vehicle power battery recycling outlets	defines battery recycling facilities more narrowly, excluding lead acid batteries

In addition to enforcing laws requiring recycled content in specific materials or components and enhancing recycling effectiveness, this initiative also seeks to enhance the sustainability and transparency standards for batteries, while also taking into account the carbon footprint of battery production, the security of raw material supplies, the sourcing of materials with integrity, and the promotion of reuse, repurposing, and recycling. However, with an average recycling rate of 45%, there hasn't been enough progress made to solve EV battery recycling and reuse so far. [22]While lithium still depletes with a 12% global recovery rate [23]It focuses on the entire battery life cycle, from design and marketing to collecting, disposal, and recycling of used batteries. There are three main categories covered: Battery types include: 1. portable; 2. automobile; and 3. industrial. The latter group includes EV batteries. The fundamental goal of the Directive must be to lessen the adverse effects of batteries and battery waste on the environment to prevent the existence of hazardous elements, and all used batteries that are collected must go through treatment and recycling. [19]The Producer Responsibility Principle, which holds producers accountable for managing the end of the life of the batteries they sell, is incorporated into the Directive. Producers are required to pay for the costs associated with gathering, handling, and recycling all used batteries. For example, companies cannot refuse to accept used industrial batteries from customers when it comes to batteries for industrial use. The Directive does not, however, set goals for the collection of used automobile or industrial batteries. This meant that over 50,000 tonnes, or almost 10% of all industrial batteries sold, were lost each year. [24]The existing Batteries Directive has come under fire for not addressing the dangers and environmental effects associated with the various stages of a battery's life cycle. [24] Favorable environmental externalities, such as those caused by significant raw material extraction or recycling operations use a lot of energy and water. For instance, the pyrometallurgical processing of LIBs results in significant GHG emissions. The energy-intensive process of refining copper, cobalt, and nickel results in significant GHG emissions, ranging from around 3.5 kilograms of CO2 per kg of copper to approximately 12.5 kg of CO2 per kg of cobalt.

UK Policies and Regulations:

All of the aforementioned directives were implemented into UK law because the implementation deadlines passed before the UK's status as an EU Member State. Particularly, the UK Regulations adopted the EU Batteries Directive. [6], They are intended to enhance the environmental performance of batteries and set rules for waste battery collection, treatment, recycling, and disposal of all types of batteries and have an impact on manufacturers, batteries, waste battery collectors, distributors, recyclers, and exporters. In line with the Directive, it also addresses the three different types of batteries, including industrial batteries, the disposal of which is prohibited in landfills. Industrial batteries include LIBs, and there isn't currently any legislation in the UK that specifically addresses LIBs. According to Section 35(2) of the Regulations, makers of industrial batteries are required to redeem waste industrial batteries from an end user of industrial batteries free of charge and within a reasonable amount of time. These call for lowering the quantity of garbage produced when EVLs are discarded to decrease the environmental impact of their disposal. Manufacturers and importers of automobiles are obligated to set up collection networks so that their vehicles can be taken back for free at the end of their useful lives. Additionally, they mandate that automobiles be depolluted to a specific degree at authorized treatment facilities, which includes early battery removal before further treatment. The UK government has taken action, but this hasn't impacted its commitment to working toward its world-leading environmental goals and ambitions by preserving resources for as long as feasible, maximizing their value, minimizing waste, and encouraging resource efficiency. [25]As a result, the UK will recognize the significance of LIBs revival. Because of this, legal and policy frameworks must incorporate. Repurposing and reusing applications can be economically advantageous or even profitable, depending on the benefits of using batteries, the expense of disassembly and remanufacturing, and the cost differences with the creation of new, equally-effective batteries. When taking into account battery evolution, recycling companies' profits will drop over time owing to cobalt constraints since batteries will utilize less cobalt, but they will still be profitable. They also emphasized the problems with battery collection, which can be more harmful than advancements in recycling technologies. Due to a decrease in the dependency on imports, increased resource efficiency also lowers the danger of an interruption of the supply chain. [26]Recycling has several benefits. First, recycling lessens resource depletion and instability, especially when resources are scarce or imported from possibly unethical sources. Raw material extraction imposes significant environmental costs. Therefore, substituting primary/virgin metal production, such as that of cobalt and nickel, completely or partially would significantly lessen such effects. Second, because LIBs contain valuable materials, recovering them through the dismantling process can have further economic and environmental benefits. Examples of such valuable materials include high-grade iron and other precious metals like nickel, cobalt, and manganese. Typically, a battery composition consists of cables, a battery management unit, and an aluminum (AI) case. A battery system's battery cells, which include the electrolytes, separator, cell container, and electrodes, typically make up about 52 weight percent of it. However, from a technological perspective, recycling LIBs is far from straightforward because of their very variable formulation (i.e., high material mixing and small dimensions that complicate separation) and engineering design. This means that to recover some of the materials used in LIB, a series of highly energy-intensive procedures are needed. These processes are detailed below, along with their steps and methodologies. (explained Fig. 1).

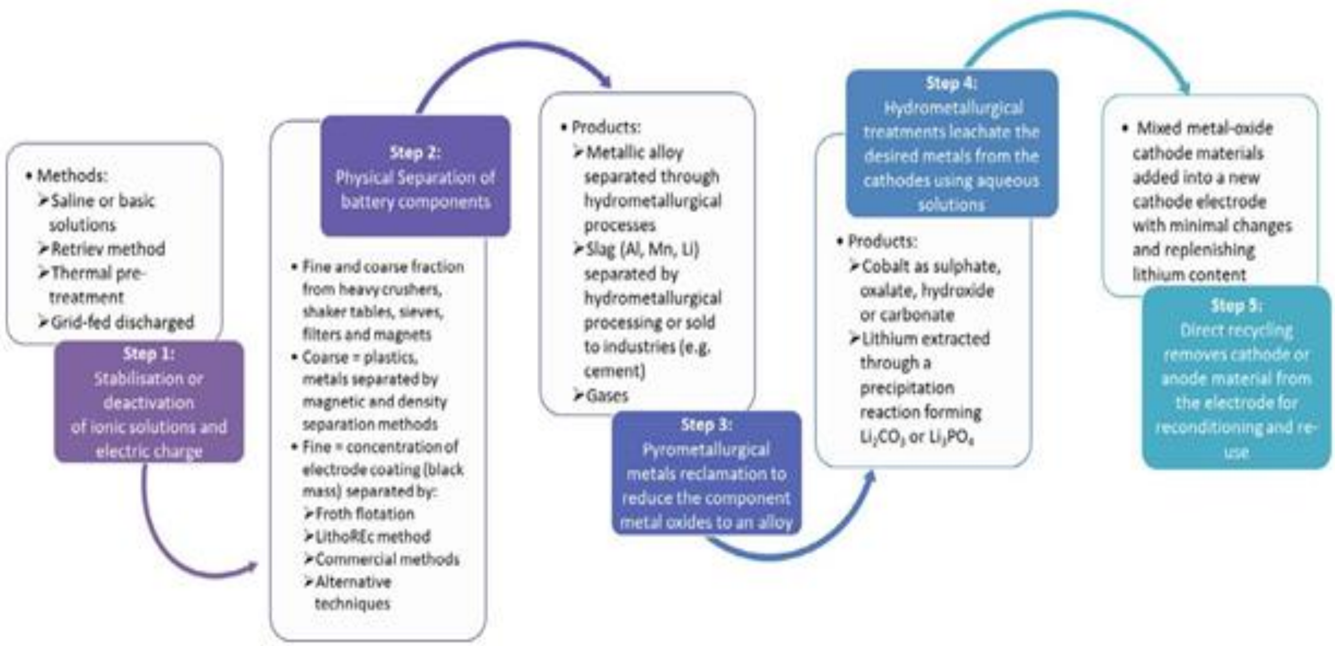

Fig. 1: Schematic of the phases and important procedures for recycling battery parts [3]

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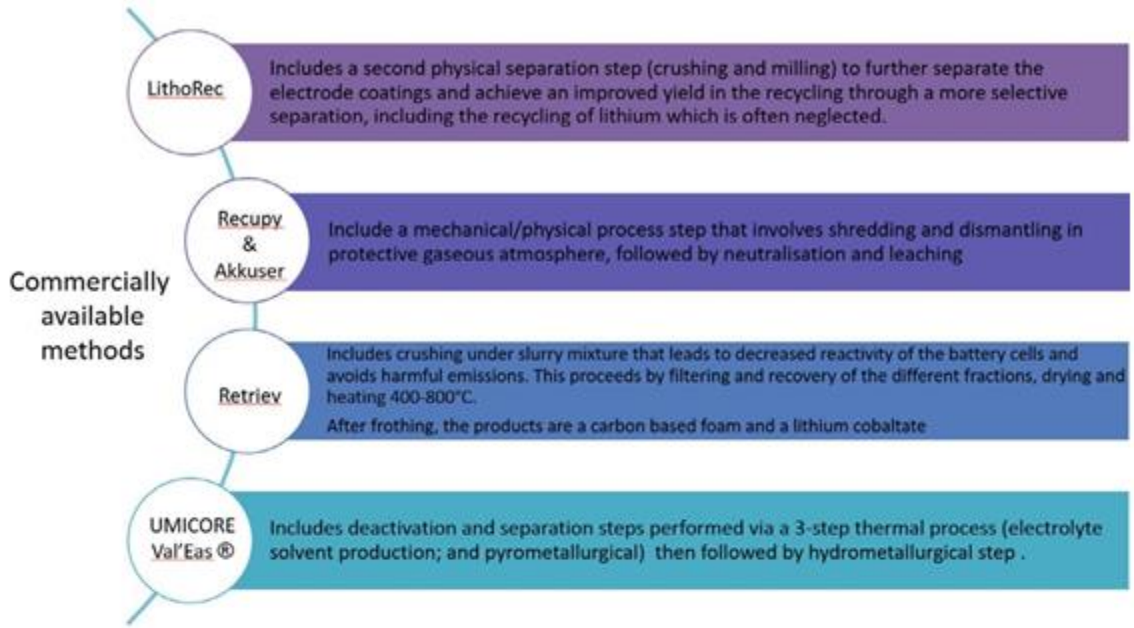

Fig. 2. An overview of the current commercial battery recycling techniques [27]

Section 3: Reuse of batteries:

Advanced batteries' second lives are currently not adequately handled, and the Regulation does not support reuse strategies, especially concerning industrial batteries. [24]With use, new Lithium-ion batteries typically lose some of their performance. For instance, when an electric vehicle battery's performance falls by roughly 75% of its initial value, it cannot perform as intended. However, this does not imply that the battery is worthless. If certain requirements are met, a second life for batteries used for energy storage could assist reduce their environmental impact while ensuring a longer and more resource-efficient use of resources. [28, 29]Technically speaking, the reuse or second life of LIBs is still not a common practice. The main cause of this low adoption rate is that the majority of LIB remains in use worldwide in many of their existing applications (such as vehicles and buses). For instance, second-life LIBs have only recently attained an operational capacity of ten MWh in the USA, whereas the reusing of LIBs has yet to reach 100 MWh in Europe. [30]Because LIBs were only widely installed in electric buses starting in 2015, countries like China have only just begun to reuse them. [30] reuse of LIBs has primarily been utilized in modest, stand-alone operations, such as domestic stationary energy storage, backup storage solutions in telecom installations, or other ancillary uses for massive off-grid implementations in rural and remote places. [30] Infrastructure and clearly defined procedures are needed to encourage and establish the usage of LIBs after their original purpose has been fulfilled. For instance, telecom infrastructure businesses in China are beginning to replace the backup lead-acid battery in base stations with second-life LIBs from EVs. Manufacturers of automobiles and batteries must make sure that the designs and finished goods they produce have the qualities needed for a well-managed end-of-life and second-life application. To define procedures, logistics, laws, etc., end users of second-life batteries, such as telecom carriers, must participate in the framework development process. To enable the adoption of products' secondary lives, several strategic partnerships must be formed. To increase the lifespan of LIBs, users would strengthen the market. Renewable sources of energy like solar may be an added advantage to improve the life of the battery and can charge parallel together. [31] Also if a solar rooftop is incorporated into electric vehicles it may improve the life of the battery as well as increase the distance coverage range of the electric vehicles. [32]

Section 4: Discussions:

With new battery chemistries becoming on the market, new battery technologies being developed, and an increasing amount of battery waste, the battery landscape is constantly changing. The effectiveness of CE techniques for managing battery waste depends on a variety of elements, including technical and legal considerations. According to the study, the current regulatory frameworks—including the UK Regulations and the EU Batteries Directive—are unable to deal with the anticipated increase in EVs. The lack of precise restrictions on the handling, recycling, and "reuse" of LIBs leaves makers and consumers uncertain about the end-of-life circumstances for these batteries, suggesting that recycling or reusable LIBs is not worthwhile. Due to the recently proposed EU Batteries Regulation, which is covered in this article, this is set to change.

Section 5:

Conclusions:

Overall, there must be a close connection between technical and legal factors to adopt battery waste management that increases recycling. Therefore, both a lax regulatory environment and complex multi-material battery designs, which restrict recycling since material separation is frequently too arduous and the final product too impure to be reused, are to blame for the challenges encountered to date and discussed in this study. To remove the current obstacles, new technologies that encourage metal separations, standardized designs, geometries, and regulations that promote legal obligations for battery reuse are required to mitigate the environmental impact of batteries.

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