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RECYCLING OF USED BATTERIES FROM ELECTRIC VEHICLES

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Abstract: The increase in the number of electric vehicles in the coming years is a challenge in the management of used batteries. At the same time, recycling used batteries is an opportunity for both waste processors and battery manufacturers. Used Li–ion batteries are a secondary source of very valuable materials. Recycling results in a number of deficient and expensive elements such as cobalt and lithium. Automating battery disassembly reduces costs leading to economically viable recycling and influences the efficiency of the separation processes and the purity of the resulting elements. The utilization of useful elements produces technological, economic and ecological effects.
Keywords: research project, batteries, waste, recycling, cobalt

1. INTRODUCTION

A battery is an electrochemical medium consisting of an assembly of two or more galvanic cells capable of converting chemical energy into electrical energy. Electric vehicle batteries pose a challenge for the future given that this is the most expensive element in the electric vehicle [1]. Worldwide, automakers [2] have forecast investments of more than 500 billion in electrification of model ranges by 2035, and some companies [3] have set out to focus production on electric vehicles only since 2030. An important problem in this case is the battery, which has a high price and the materials used in manufacturing (cobalt, lithium, nickel) are deficient and expensive, especially in the current global context.

Battery technologies and types have evolved over time, and their autonomy has now increased considerably. The battery capacity, expressed in kWh, is extremely important and the higher the value, the greater the vehicle can travel between charges. For example: Dacia Spring has a battery capacity of 25 kWh, the Smart EQ Fortwo Coupe has a battery of 16 kWh, the BMW IX xDrive50 has a battery of 105.2 kWh capacity, and the Mercedes EQS AMG 53 4MATIC+ has a battery of 107.8 kWh [3–8]. Also, with the increase of capacity increases its size and/or weight and the production costs are higher. The weight of the battery varies as follows: At Dacia Spring it is less than 300 kg, at medium class 450–550 km, and at Tesla Model S 540 kg. The battery weighs about 23 to 29% of the total weight of the car.

Considering the average weight of a 300kg battery and considering the number of electric vehicles that will come out of use, it is estimated that 250,000–300,000 tons of used batteries will be used. In addition to the increasing quantities of these wastes, an important problem is fire safety in case of their storage.

The elements and materials contained in electric vehicle batteries are not available in many countries, and access to resources is crucial to ensuring a stable supply chain [7, 9]. In the future, electric cars become a secondary resource valuable for critical materials such as cobalt and lithium. At the same time, the rapid growth of the electric vehicle market is imperative in order to meet the global targets to reduce greenhouse gas emissions to improve air quality in major cities. Thus, an increasing number of electric vehicles is a challenge in waste management for recyclers at the end of their life cycle life. Used batteries are an opportunity because manufacturers need elements and materials to manufacture them.

Basically, a battery in electric vehicles has prices ranging from $ 4,000 to $ 20,000, which is generally the production cost, and at the end customer, the battery, as a total part of the car price, ends up costing much more. The costs are so high due to the components of the battery, especially the cathode, because of the metals used, such as cobalt, lithium or nickel.

The world–wide deposits of these elements are mostly in Australia, RD Congo, Chile and China, and about 80% of processing and refining operations are in China. The demand for lithium–ion batteries will be six times higher than today in a decade, and to cover it, nearly 400 lithium, graphite, nickel and cobalt mining sites would need to be opened worldwide.

In 2011, 30% of the lithium consumption was for ceramics and glass, followed by batteries and greases/castings In 30 years, the demand for lithium will be approximately 63 million tons, which will be 40 million tons more than the remaining reserves (Figure 1) [9]. Sources, quantity and collection of discarded lithium–ion batteries are presented in Figure 2 [7].

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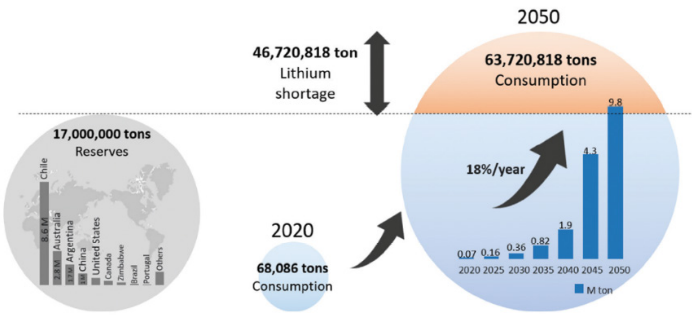

Figure 1. Global lithium reserves and lithium depletion scenario after 30 years [9]

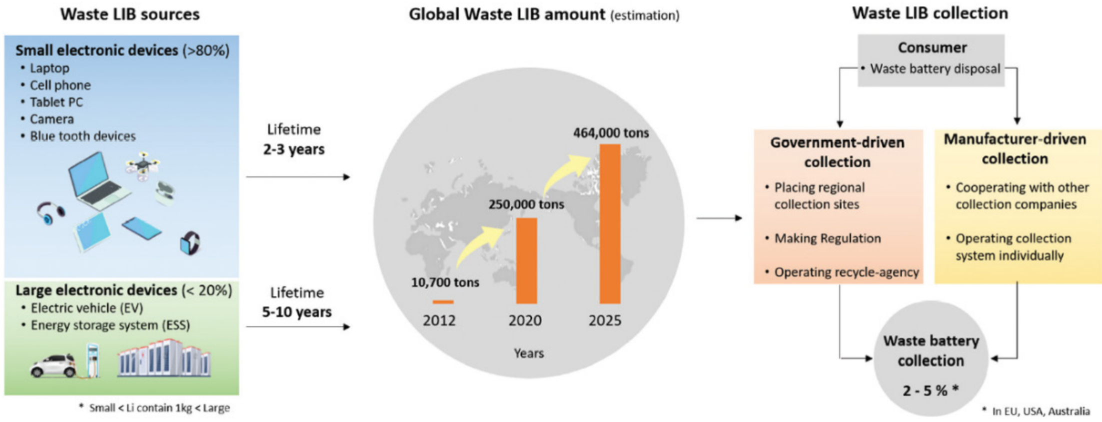

Figure 2. Sources, quantity and collection of discarded lithium–ion batteries [9]

Currently, the recycling of Li–ion batteries is being investigated with interest, but most research is focused on the recovery of cobalt, which is the most expensive material in the battery. It is also of interest to recover lithium and other components of used batteries. Worldwide [7, 9–15] a number of recycling methods and technologies are used to harness the useful elements in used batteries.

2. METHODOLOGIES

In April 2019, the European Parliament and Council adopted Regulation (EU) 2019/631 introducing CO_2 emission standards for new passenger cars and light commercial vehicles (vans) in the European Union. This regulation set reduction targets of –15% and –37.5% for the tailpipe CO_2 emissions of newly registered cars for the years 2025 and 2030 respectively [6,8]. The 2030 target set for vans was –31% [6,8].

Alternatively–powered vehicles (APVs) are vehicles powered by technologies alternative to, or supplemental to, conventional internal combustion engines using fossil fuels. The main types of APVs, and how they differ from each other, are explained in table 1.

New car registrations in the EU, by fuel type is presented în figure 3–4.

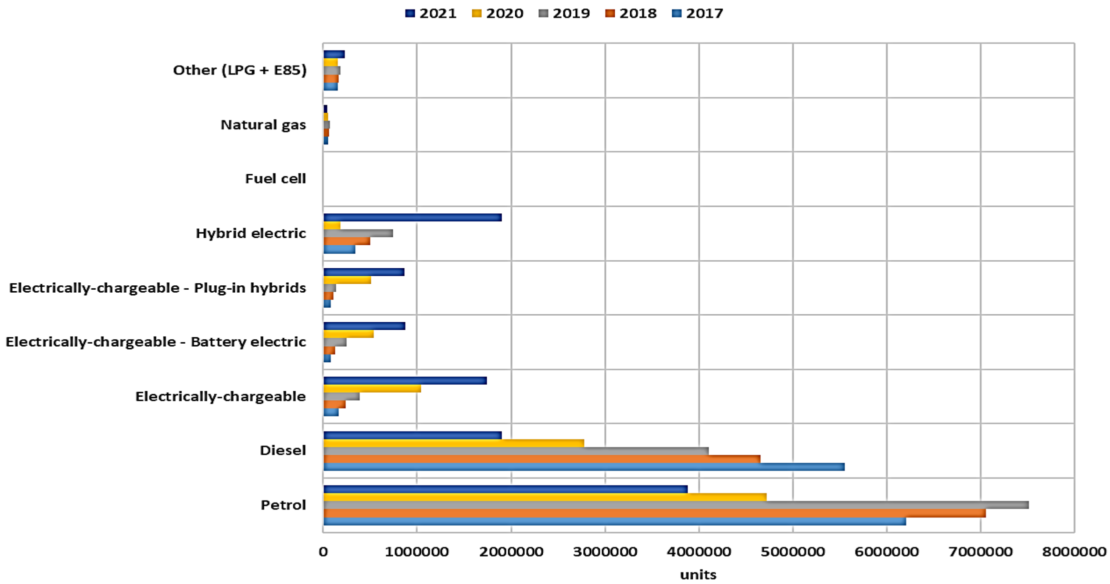

Figure 3. New car registrations in the EU, in units, 2017–2021

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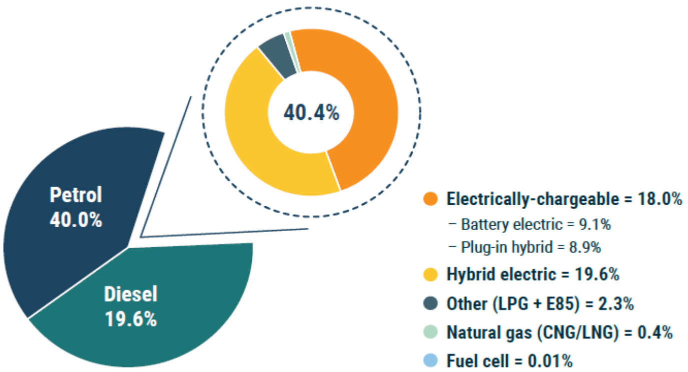

Figure 4. New car registrations in the EU in 2021 [8]

Table 1. Alternatively–powered electric vehicles [8]

Electrically–chargeable vehicles (ECVs)	Battery electric vehicles (BEVs) are fully powered by an electric motor, using electricity stored in an on–board battery that is charged by plugging into the electricity grid.	BEVs Battery electric
	Plug–in hybrid electric vehicles (PHEVs) have an internal combustion engine (running on petrol or diesel) and a battery–powered electric motor. The battery is recharged by connecting to the grid as well as by the onboard engine. Depending on the battery level, the vehicle can run on the electric motor and/or the internal combustion engine.	PHEVs Plug-in hybrid electric
Fuel cell electric vehicles (FCEVs)	Fuel cell electric vehicles (FCEVs) are also propelled by an electric motor, but their electricity is generated within the vehicle by a fuel cell that uses compressed hydrogen (H_2) and oxygen from the air. So, unlike ECVs, they are not recharged by connecting to the electricity grid. Instead, FCEVs require dedicated hydrogen filling stations.	FCEVs Fuel cell electric
Hybrid electric vehicles (HEVs)	Hybrid electric vehicles (HEVs) have an internal combustion engine (running on petrol or diesel) and a battery–powered electric motor. Electricity is generated internally from regenerative braking, cruising and the combustion engine, so they do not need recharging infrastructure. The hybridisation level ranges from mild to full. • Mild hybrid electric vehicles are powered by an internal combustion engine, but also have a batterypowered electric motor that supports the conventional engine. These vehicles cannot be powered by the electric motor alone. • Full hybrid electric vehicles are powered by both an electric motor and a combustion engine, each of which (or together) can power the wheels.	HYBRIDS Full and mild hybrids
Natural gas vehicles (NGVs)	Natural gas vehicles (NGVs) run on compressed natural gas (CNG) or liquefied natural gas (LNG), the latter mainly being used for commercial vehicles such as trucks and the former for passenger cars. NGVs are based on mature technologies and use internal combustion engines. Dedicated refuelling infrastructure is required.	

Cathode–ray material plays an important role in overall battery performance and is also the most expensive component of a Li–ion battery, its cost accounting for 40% of the total cost of producing a Li–ion battery. The choice of cathode material is directly related to the safety and stability of Li–ion batteries.

The frequently used battery design is not optimized for disassembly easy (figures 5). Use of adhesives, soldering methods and fasteners it is not suitable for easy deconstruction either by hand or by car. All current commercial reported cell breakage processes use shredding or grinding with subsequent sorting of the component materials. This makes the separation of components more difficult than if they had been pre–sorted and considerably reduces the economic value of waste streams. Many of the challenges it presents for remanufacturing, reuse and recycling could be addressed if taken into account at the beginning of the design process.

Waste Li–ion battery recycling processes must necessarily aim to recycle 50% of the average weight of used Li–ion batteries [15]. The process of recycling used Li–ion batteries involves the following steps: Separation of fractions, belonging to the battery and recovery of metals, metal compounds, plastic, all useful products. The recycling process begins after the preparation for recycling of used batteries and ends after obtaining recovery compounds.

The main processes underlying these technologies are either physical or chemical processes, but most often it is necessary to combine several methods to achieve the desired result. The classic technologies for

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recycling used Li–ion batteries require at first complete discharge of the battery, it's dismantling and finally the application of advantageous physical and chemical processing methods [7, 9].

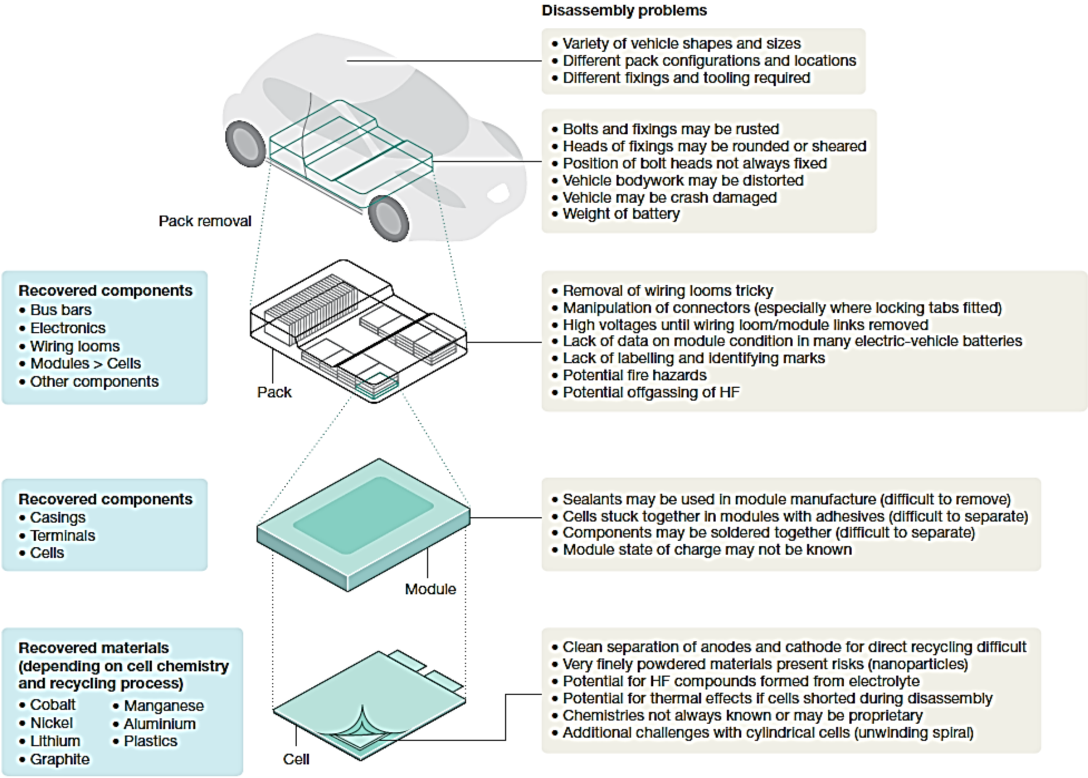

Figure 5. Diagram showing challenges of disassembly at different levels of scale [7]

3. RESULTS

The recycling process can be defined as the process. Starting after the collection and possible sorting and/or preparation for recycling of waste batteries and accumulators obtained by a recycling facility and ending when output fractions are produced for use for their original purpose or for other purposes, without further treatment and which have ceased to be waste.

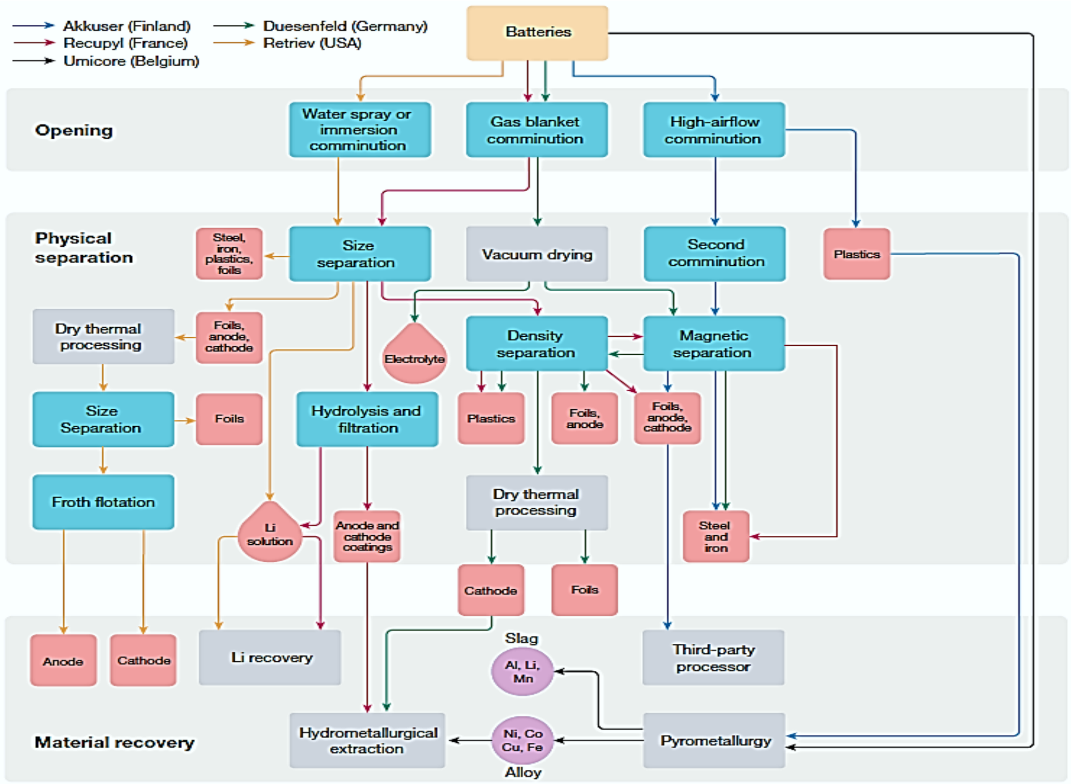

Figure 6. Flow chart representing potential routes for the circular economy of LIBs, detailing second–use applications, re–use, physical recovery, chemical recovery and bio recovery [7]

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As the volumes of batteries to be recycled increase dramatically, effective techniques and methods must be applied for their recycling (Figure 6).

Currently, hydrometallurgical and pyrometallurgical processes are the most used. Most focus on the recovery of cobalt and nickel, as these are the most economically performing elements. While there is a number of research aimed at developing more efficient recycling techniques, there is still no real circular economy in the battery sector.

Electric vehicles can prove to be a valuable secondary resource for critical materials. Moving toward greater automation and robotic disassembly promises to overcome some of these obstacles. Binders problems are still untested, and acid, alkali, solvent and applied treatments have harmful effects on the environment. Recycling Li–ion batteries will have a significant positive impact on the environment, by avoiding the emission of greenhouse gases, which will be used to reduce emissions it would normally be produced by mining and processing minerals.

4. CONCLUSIONS

Most of the techniques and methods used in the recycling of used batteries affect the environment, following the procedures applied for the recovery of useful elements resulting in a series of pollutants (harmful gases, acids, bases, organic solvents, etc.). Particular attention should be paid to minimizing the amounts of pollutants and resulting waste and to finding innovative solutions for recycling or neutralizing them. The methods used are energy intensive, use chemicals, so the costs are high.

Recycling used batteries is an increasingly important step both to mitigate waste management and environmental concerns regarding materials used in Li–ion batteries. Recycling reduces costs production by recovering recovered valuable raw materials such as cobalt, nickel and lithium from end–of–life batteries.

The recovery of raw materials used in the manufacture of batteries is essential if we take into account their scarcity and high cost. Recycling technologies are becoming increasingly widespread in battery manufacturing plants, but now the process requires quite a lot of energy and capital and the process needs to be sustainable.

Worldwide there is interest in research and innovation, progress has been made in setting up large–scale recycling plants. Also, fluctuations in raw material prices generate long–term uncertainty as to the economic feasibility of recycling batteries on a scale.

Research needs to focus on innovative solutions, using eco–friendly solutions and creating natural recycling cycle.

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