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Recycling of li-ion Battery for E-Mobility transportation

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ABSTRACT

Due to the rapid growth of the electric transportation industry, it is necessary to propose the required demand for future consumption. Therefore, widespread production of batteries has considerably become popular and familiar in use.

With such extended use, Environmental problems have been encountered which impose urgent practical measures to be overcome. These problems may cover waste materials and components which have been considered as hazardous in the framework of this industry. Typical components may include aluminum, copper, transition metal oxides or phosphates, graphite organic electrolytes with dangerous lithium salts, plastic, polymer separator and metallic cases. To accomplish such proper measures, careful recycling processes have been Adopted and followed with a great deal of attention.

In this thesis, a literature review on the recycling of lithium-ion battery and its current state of the art is presented. Various factors such as environmental pollution, Battery dysfunction, incident reasons which have influences on the Recycling process are also discussed.

A full description of the problem statement can be followed by understanding the impact of the recycling process on the environment, safety, economic. Moreover, another fundamental issue, namely, reactivation of battery back and its effectiveness on the battery life cycle is also considered. Scientific researches have shown that battery life can be prolonged by upgrading SOC and BMS. With such procedure, application of batteries in Electric vehicle, electric Bicycle, a scooter can effectively be enhanced.

Within the scope of the present work, the above – mentioned parameters were thoroughly investigated and analyzed to assure a certain contribution to a more sustainable environment.

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Chapter 1

Introduction and Reviews

This section introduces the overview of lithium-ion batteries and the most common types and applications and what are the pros. And cons. of battery to enter with the problem statement. Furthermore, the purpose and investigated research questions are defined, and lastly, the scope of the most faults on the current situation on battery recycling methods.

1 INTRODUCTION

1.1 Motivation for the present work

Currently, A well designed about the Fire and explosion problems incidents in an electric car presented from several authors who published their studies in 2019, nowadays, the problems play a major part of greatest danger with an essential element to the consumer.[1]

The higher amount of E- mobility consumption as the high rate of lithium-ion batteries attracts much attention in the recycling process in the future. [2] [2, 3], [chapter 1, p. 33].

All factors make the R&D in the recycling processes of lithium-ion batteries for E-mobility transportation as part of a big challenge nowadays and in the future. The new market share for new Batteries that manufactured with higher safety specifications (high power density, prolong the battery life with the higher rechargeable state) are more completive in the new market in Austria and Europe.[5]

In the battery pack recycling researchers, it is necessary and more capable in its current know-how. The recycling of the dysfunction cells and electric applications require clarification nowadays and in the future, which in turn will reduce the risks of environmental harm. There is the growing concern of replacing the high cost of battery pack recycling by deactivating the malfunction cells of the battery pack.[6, chapter 14 p 2]

1.2 Introduction to characteristics of Batteries

The battery is an experiment that represents a chemical interaction happening in a little box. The chemical reactions start by connecting the battery's poles to a terminal such as flashlights. The conducted inside the Battery resulted from a series of slow but systematic disintegration. The harmonization of these chemicals to produce other compounds. [7]

Positive-charged particles named ions and negative-charged particles called electrons generated. Inside the battery, The Ions and electrons move in two different paths. The Ions passes through the battery and in the circuit the Electrons passes through the wires. This process provides the electrical power needed to turn on the light. [8]

The limitation is that this chemical process could occur in a unidirectional manner and only one time—generally, the use of electric power in simple-to-navigate format. As little as a problem is that almost batteries are damaged quite fast unless the user an expert charger based on types of battery. The fiscal method is expensive and environmentally unfriendly. Rechargeable batteries help overcome the issue of chemicals condition used in rechargeable batteries. The chemical reaction of rechargeable batteries are reversible until the battery is discharged, it charges in one path, and the battery saves energy. This category of battery is being used by the mobile device, laptop and media device (lithium-ion battery). [9]

From the year 1991, this kind of batteries has widely used. In 1912, Gilbert Lewis (1875-1946) the American chemistry scientist firstly invented the batteries. When the battery charges, it absorbs energy as a result of reactions generated by an opposite electrical field. Hundreds of times, these interactions could appear in both directions. Thus, rechargeable ones usually last for 2 or 3 to 10 years (based on the utilization intensity). The best rechargeable batteries are the lithium-ion types. [10]

1.2.1 Overview of Lithium-ion battery

Lithium-ion battery referred to simply as LIB are types of the battery that are recharged mostly from the negative electrode to the anode when discharging and returning while charging [1]. In comparison with the lithium metal component of the non-rechargeable battery, the battery used inter material as an electrode material [11, 12].

Electrolytes are the major elements of an individual cell in batteries, that permits ion, anode, cathode movement. Lithium-ion batteries are standard in home electronics. It is one of the most rechargeable batteries used to portable power electronics, with a high energy density (a large energy release in the aspecific area) with small storage impact and low self-discharge. [9]

In electrical transportation and space applications, the use of lithium-ion batteries has been notably increased. In the markets, the Lithium-ion battery has the best density power. With the associated life and useful life, its usage will upgrade from mobile electronics to electric vehicles and storage of fixed power systems. The reusability of automotive battery in attached power storage facilities is other aspects. [13]

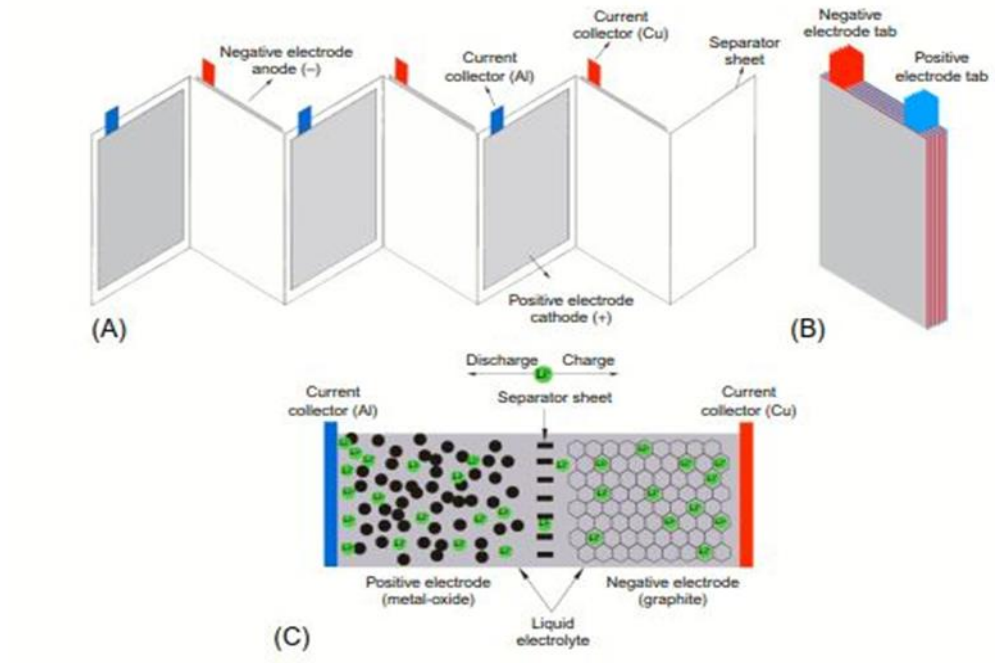

Figure 1 the most commonly commercialized li-ion battery component [20]

This study focuses on the study of cellular safety and li-ion new activated [14]. The reduced function of the older models and cells verified utilizing short outer overload as well as overload criteria in comparison with the properties of the new batteries and modules [1].

The goal of determining the lithium-ion overview is to determine if safety changes with the ageing of the life cycle if it is necessary to characterize some parameters after the first life and before entering the explanation at the Second Life application. However, settings must focus on improving the battery recycling method close when used in Second Life. [15]

Lithium-ion battery (lithium-ion battery) has widely used for storage of renewable energy and motor vehicles, due to their many virtues associated with high energy density, environmental tolerance, and long service life, all the parameters of the development of cathodes and materials of high power and high energy.

Such high capacity lithium-rich contents suffer from life cycle stability and lower speed properties. This stability hinders its successful commercialization in the field of high energy density as a result of lower cyclic performance and more significant operational potential. [1]

1.2.2 Common Types of Batteries

Regarding the electronic and portable electrical devices, photographic instruments, lighting, headphones, personal digital assistants (PDAs), communication equipment, backup memory, watches, toys, and other applications, the primary battery is the central resource of energy to them. [12] They provide the freedom of power. Practicality, simplicity, and usability, low maintenance requirement, reshaping and redesigning these batteries according to the application, are the significant advantages of the primary battery. Moreover, these batteries have a long lifetime, intelligence-powered energy, and dense energy, reliable to use, and not pricy. [16]

Chemical name	Material	Short form	Characteristics
Lithium Cobalt Oxide[a]	$LiCoO_2$ (60% Co)	Li-cobalt	Its high capacity makes it ideal for mobile phones, laptops and cameras.
Lithium Manganese Oxide[a]	$LiMn_2O_4$	Li-manganese, or spinel	This is the safest kind of battery, with a lower capacity than Li-cobalt but a high specific power and long life. Used in power tools, e-bikes. EV, medical, hobbyist.
Lithium Iron Phosphate[a]	$LiFePO_4$	Li-phosphate	
Lithium Nickel Manganese Cobalt Oxide[a]	$LiNiMnCoO_2$ (10–20% Co)	NMC	
Lithium Nickel Cobalt Aluminum Oxide[a]	$LiNiCoAlO_2$ (9% Co)	NCA	
Lithium Titanate[b]	$Li_4Ti_5O_{12}$	Li-titanate	Gaining importance in electric powertrain and grid storage.

Table 1 Types of material and characteristic of primary Battery [15]

Although several anode-cathode types used as central battery systems, only little had real successes. Electrolytic behaviour, high electrochemical equivalence, compatibility with aqueous electrolytes, because of the practice leads Battery to Good life, low cost, and availability. [17]

Now it is considered rechargeable in a mechanical manner or Rechargeable aluminum/air battery and battery backup system. On the other hand, Magnesium also has advantages and low-price electrical characteristics. It has utilized with success in Active-hand batteries, in particular for applications such as military ones, because of its dense power levels. [15, 17]

Furthermore, good life commercial benefit has restricted. Magnesium is also well-known as the anode in the preserving batteries. Currently, we are focusing on lithium, which has the highest gravimetrical density power and standard potentials of entire elements. [18]

The use of several different non-aqueous electrolytes in which lithium has stability and diverse cathodic materials offers the possibility of more dense energy power and more performance advancement properties of the primary system. Its similar in the traits and applications of the several kinds of primary batteries concluded in the table below. [5]

1.2.3 Battery Design Module

In-vehicle applications, not only cell level shapes of legitimacy, are considered. Yet additionally at the modules (a mechanic cells get together of, frequently having power/warm detecting and facets) and level of battery packs (modules automated gathering, regularly providing electric as well as friendly controller equipment and programming) [11, 19]. Despite packs and modules, structures might shift significantly. They entirely include extra size and weight that adequately dates the cell level execution esteems [19].

The cells and modules get together in this way pack is the thing that represents the equipment essential to a car architect and client. Precisely, to coordinate the current vehicle crash structure, battery packs are needed. [18]

Packages are additionally required to deal with the electronically controlled interfaces and the remainder of the car-controlled modules also to keep up their internal cells foreordained working settings forever as well as wellbeing. Also, battery packs commonly have devoted, or vehicle inferred warm controlling parts, additionally for execution and security contemplations. [20]

The affectability of lithium-particle sciences to electrical, mechanical, and functional journeys outside plan specifications puts extra significance on a substantial battery pack structure. The electrified battery packs of the vehicle must meet various automotive technical needs, also satisfying the energy and energy requirements of the car. [21] The assembly of cells in modules and packages is the thing that constitutes the material related to using and designer of the automotive sector. Mechanically, the batteries integrate into the existing structure of the vehicle in the event of a collision. [22]

The batteries should manage the electronic control interface with the rest of the vehicle control modules and retains their cells in previously determined operating life settings. [23]

Components of Lithium-ion Battery: The element of a lithium-ion battery consist of the electrode with a positive charge (with a higher potential), and an electrode with a negative charge (with a lower potentiality), with an electrically insulating but electrolyte of electrical conduction [24]. While charging, the positive electrode is the anode with the reduction interaction, and the negative electrode is the oxidation interaction [25].

On the other hand, while discharging, the feedback is inversed. Therefore, the positive becomes cathode while and negative becomes an anode electrode. [26] It is worth noting that cathode and anodic materials are conventionally known for the positive electrode and negative electrode active materials. In a closed-cell, the liquid electrolyte is kept in a separator to avoid direct short circuits in the electrodes pair [25] The separator also used as extra electrolyte storage, ammonia trap (in a Ni-MH battery), space saver for electrode expansion and safety device to prevent breakage because of dendrite production. [25]

Principle of lithium-ion battery work

One or more power generation units named cells. The cells use in manufacture lithium-ion batteries. Every cell contains triple essential parts: a negative electrode (compared to a negative (-)), a +ve electrode (attached to a positive or end battery (+)), and a chemical named electrolyte among them. [27]

In other types, lithium iron phosphate (LiFePO4) and lithium cobalt oxide (LiCoO2) and are chemical compounds usually used for the anode. Generally, Carbon (graphite) applied to the made cathode. From one kind of battery to another, the Electrolyte has differed as well. However, it is not so crucial in the way that the fundamental principle of how the battery operates. [8]

The entire lithium-ion batteries share similar working principles. The anode-cobalt oxide component compared in charge potential in some of the lithium ions types [28]. These ions are moving through the electrolyte to the graphite cathode and stay there. At this point, the energy absorbed and stored in the battery. Through the electrolyte, lithium ions return backwards to the anode when the battery is not charging. [28]

That produces heat powering the battery. In any instance, the electrons run in another direction of ions circulating the exterior circuit, anyhow the electrons do not run through the electrolyte. [25] The operating principle of a typical LIB demonstrated in the next figure.

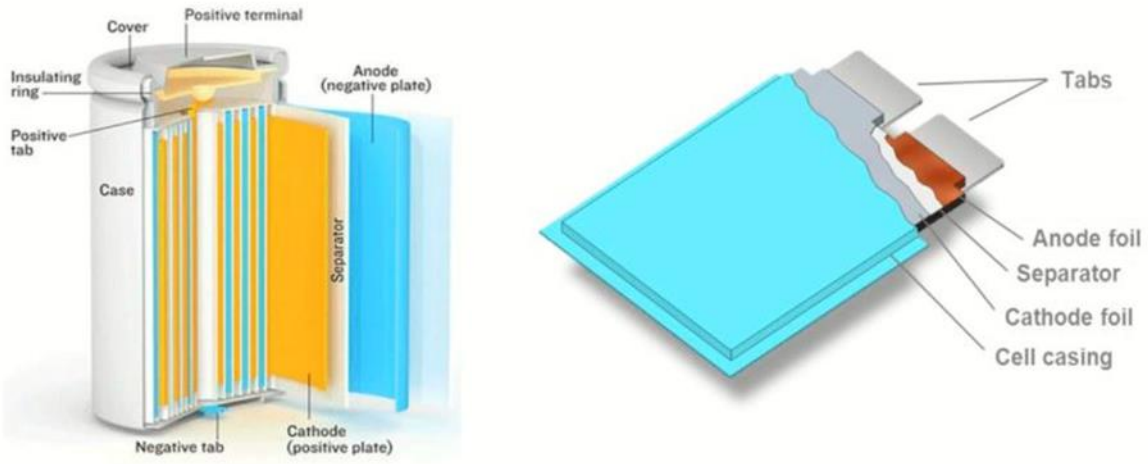

Figure 2 the operating principle of standard li-ion battery cell [24].

The ions move through the electrolytes, and they are interrelated processes, and when one method is not running the other processes will stop running immediately [29]. The electrons cannot move through the outer circuit when ions stop moving through the electrolyte as a result of battery entirely discharged, similarly, the electrons and ions flowing halts if you turn off any battery. Batteries stop discharge process when the device is disconnected but remains very slow. Unlike simple batteries, there is an electronic controller in lithium-ion batteries used to regulate how these batteries charge and discharge. The explosion, in some circumstances, can be prevented by these controllers, which might cause as a result of overcharging and overheating that can cause lithium-ion batteries. [29]

Mechanical component: Battery packs should likewise put in, and a physical manner inside the automobile protected in case of accidents and during typical vehicles use what more, vibrations are. A run of the mill vehicle traveller zone can be defined as the region resides in between the inside the rocker boards and wheel axles on any side. Installing a battery pack out of this area is conceivable.

However, it commonly requires a significant auxiliary rein requirement to be put on to guarantee to smash respectability, including weight, high cost, and size weights to the pack. Because of the prohibitive idea of size restrictions on battery's packs, the building of the battery bundling pack is consistently a primary component in the electrical automobile plan. [30]

Electrical component: The pack /cell /module voltages and flows estimated and constrained by the battery's pack, the executives' framework (BMS). The BMS regularly referencing query tables or potentially previously defined calculations to make cell voltage/current just as pack vitality/control bounds for the battery dependent on elements, for example, condition of charge (SOC), age, and temperature. [31]

In typical designs, a lithium-ion battery has negative electrode composed of graphite and a positive electrode especially in conversion of metal oxide in layers such as LiNiO2 and LiCoO2 or mixes as a result of this such as LiNi1 / 3Co1 / 3Mn1 / 3O2. A permeable membrane treated with an electrolyte, which is a blend of the conductive salt LiPF6 and solvents such as organic carbonates, isolated from the electrodes.[4]

While the charging process is running, the lithium-ions moved away from the positive electrode, the electrolyte transfers them to the negative graphite electrode and intercalates there. While downloading this process, inversed. [26]

Lithium is the lightest of metals, and it provides the maximum specific energy by weight, has the maximum electrochemical potentiality. Therefore, batteries of lithium-ion have properties of extreme energy density and energy density and less influenced by the memory effect than other kinds of batteries. [26]

These features render lithium-ion battery as the high potential nominee to help sustainable movements, such as electric vehicles, electric bicycles, hybrid vehicles, motorcycles, and scooters. Some of the advantages of lithium-ion batteries are long lifetime, fast charging, and low self-discharging (fewer than 50% than Ni-MH) and high charge capacity. [32]

Thermal component: The electrified batteries of the vehicles usually use a thermal management system which is in normal operating range, the lithium-ion battery implemented to sustain the cell temperature degree [33]. Design settings of the lithium-ion battery cells, such as the composition of the electrolyte, would profoundly affect the desired running temperature range.

In practice, In the field of 10 to 40 C, most chemicals can reach to a desirable combination of existing energy and power for air-conditioning systems,and this degree range is as same as to the driver's vehicle my natural preference is the cabin with which the package sharing the airflow. [24]

1.2.4 Battery Cell Design

Unlike, Due to the design of Lithium-ion cells made as a sealed system, many nickel hydride batteries and lead-acid batteries that have reusable pressure valves. As a result of the decomposition of its components, a defective lithium-ion cell will usually produce gases. The prismatic and cylindrical cells use ventilation holes used only once. Problems related to the byproduct degassing with batteries mounted near the passenger compartment prompt some car manufacturers to use gas delivery ducts through the ventilation port of each cell. [12]

Because of the nature of the cells seals, it may be more challenging to predict the location of the ventilation in the cells of the bag. To better guide potential ventilation events, cell manufacturers may define weaknesses in bag design to create a preferential leaf failure zone. [31]

1.2.5 Advantage and Disadvantage functions of lithium-ion Battery

Typically Lithium-ion batteries used in daily life. Lithium Cobalt Oxide ($LiCoO_2$) preferred for mobile phones, laptops, and digital cameras. The battery has cathode of cobalt oxide CoO_2 in separate layers. At the same time, the anode made of graphite, and during use, lithium-ions move from the anode area to the cathode area while charging the battery. The different process will be repeated similarly. [29]

The next points refer to the disadvantages of lithium cobalt battery:

- The life span is somewhat short.
- Thermal stability is low.
- Bore capabilities are limited.

When high currents applied to the battery to charge quickly, it raises the temperature. Still, its battery improved by adding some elements to the battery, such as nickel, manganese or aluminum [29].

The battery pack contains a large number of batteries in parallel and series.
The performance of the battery cells (SOC, RUL, and OCV) is inconsistent when using these kinds of batteries. The cells have a significant impact on the efficiency and longevity of the battery. [4]

Take the example of the LiFePO4 cylindrical battery: 20% mismatch of parameters reduce the life of 40%, compared to the individual battery, but its life significantly diminished. Thus, enhancing the consistency of the battery settings is of highest priority to improve the of the battery's performance. [34]

The voltage and state of charge (SOC) of each cell changes, while the current of each cell remains the same. The issues of reliability and safety and restrict the range of operating voltage of single cells between the load and discharge cutoff voltages. The complete serial connection will stop downloading when a single cell in a serial connection has reached the discharge voltage. Therefore, many cells are never entirely charged or discharged, and the available battery capability depends on the individual cells. [35]

Advantages of the lithium-ion battery: The Lithium-ion batteries have higher safety than the NiCad and the "memory effect" (nickel batteries). It seems to be more hard-charging unless completely discharged already) is not appearing in this kind of batteries. [36]

Theoretically, lithium-ion batteries are better for the environment as they are cadmium-free (a toxic and heavy metal). It can be observed that the batteries – consist of plastic, heavy metals are essentially harmless while throwing into the garbage. These batteries (i.e. lithium-ion batteries) are somehow, not substantial for the quantity of energy they hold in comparison to the heavy rechargeable batteries, (for instance, lead-acid battery utilized in power cars). [9]

Disadvantages of lithium-ion batteries: The disadvantage of using rechargeable batteries has been obtained a small amount of energy. Substantial total energy(energy per unit mass) is extremely less than liquid fuel and also it has decided why the fuel incapable of an operating vehicle must be resupplied. It is known the refuel gas consumes a few minutes, while the battery pack recharging consumes hours in an electric vehicle. [9, 37]

Safety is the biggest problem: Li-ion types are flammable in the case of overcharging these batteries or in the case of an inside fault results in a short circuit.

It's worth noting, that the “thermal runaway" has been generated when the battery thermal heats up and that causes the ignition and explosion. The avoidance of the thermal problem has been determined as in develop device called a "current interrupt device" which obtaining the maximum charge. To validate the results from the thermal runaway problem, a group of researchers at Stanford University allocate a fire-retardant chemical inside the battery, a diphenyl phosphate (TPP) that placed inside the battery frame with liquid electrolyte. It's recognized that the shell starts to fuse and releases TPP, When the average temperature crosses 150 (302°C), furthermore, the overheating has been solved. The prevention from fire caution or explosion of the battery is in good agreement with their experiment. [9]

Lithium-ion batteries cost Samsung more than $ 5 billion in losses due to the explosion of the Samsung Note 7 battery. The problem is due to irregular-sized batteries and some mechanical issues. Samsung placed 3,500mAh batteries in a 7.9mm phone. These problems caused some explosions and overheating of the devices sold in the first round between August and September 2017. This situation was not good for the company's position in the stock market, and the company quickly withdrew all devices around the world, but some remained. [38]

1.3 Battery pack composition

1.3.1 Component and Design

Battery design relies on the kind and model of the car. The electrochemical cells can represent in the range of 50-75% of the price, size and weight of the package.
The battery modules combined electrically (mostly in series) to meet all the energy needs of electric vehicles. [14, 39]

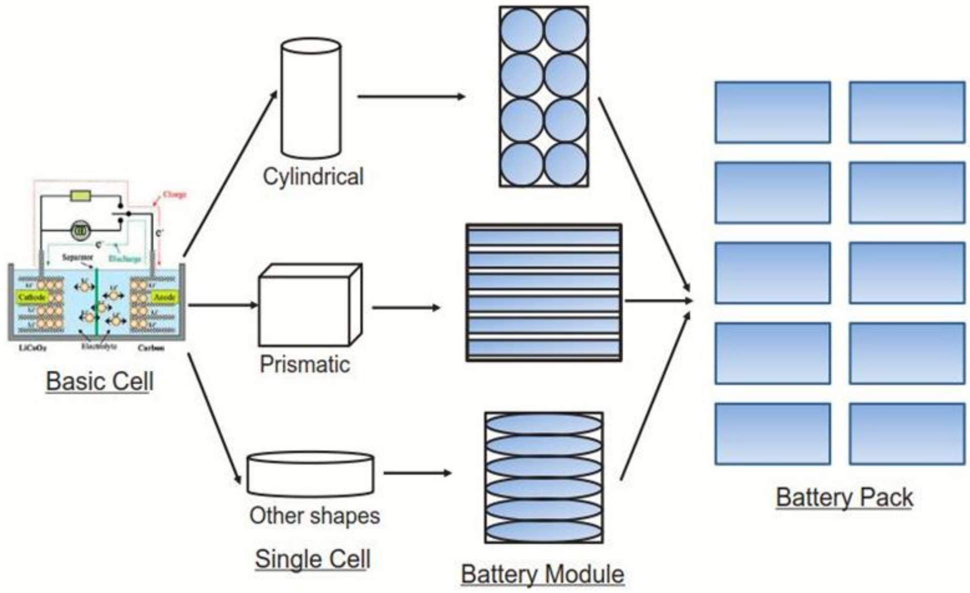

Figure 3 the configuration of cells in battery pack design [12]

Therefore, the particular battery system performance. It is often lower than that of the modules and the modules lower than that of the cells. Thus, the objectives of the electrified vehicle battery are generally defined at the packaging level to make them more related to designers of automotive. [14]

This battery's cell is susceptible. Risk of overheating and ignition causes because of overcharging short circuits or physical damages. Electrical devices such as mobile phones, notebook PCs, medical equipment, and power-tools need the safest batteries. Also, it requires an Increasing energy density. [40]

The materials used in the components of lead-acid batteries and LIBs.

Component	Lead-acid batteries	LIBs
Cathode/current collector	PbO_2/Pb	$LiMO_2$ (M = Co, Ni, Mn), $LiFePO_4$/Al
Anode/current collector	Pb/Pb	Graphite/Cu
Electrolyte	H_2SO_4	$LiPF_6$ + organic solvent (EC, DMC, EMC, DEC, etc)
Separator	PE or PVC w/ silica	PE/PP
Case	PP	Al-plastic film, Al, SS

Table 2 Common component of lead-acid batteries and LIBS [28]

1.3.2 Chemistries of different Battery type

Several chemical products for batteries proposed as a source of energy to boost electric cars since the 1990 zero-emission California cars became mandatory. 10% in 2005 and 14% of zero-emissions cars are sold. [16]

Nickel-cadmium, improved lead, NiMH and Li-ion batteries, this chemical composition and others have their pros and cons. towards the part of the bargain century, the competitiveness between fundamental Motor decisions of Ni-MH for its EV-1 unadulterated electrical cars with battery sciences. Later on, the HEV innovation created by Honda and Toyota developed and picked up prominence via its mix of mileage, adequate estimating, and clean [12].Wellbeing records. Later than the year 2011, the primary battery science in these EVs stayed NiMH because of the worries about ozone harming the substance [11].

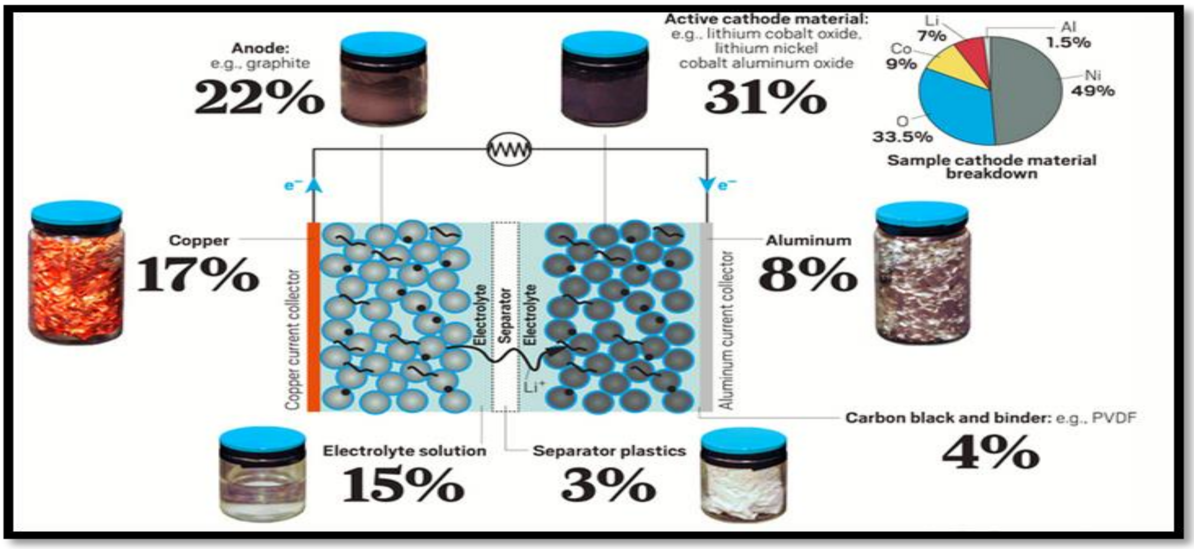

Figure 4 Lithium nickel cobalt, Aluminum oxide used to make the cathode material component [41]

Emanations and fossil vitality deficiencies develop as of late; the advancement goal has moved from HEV to PHEV, besides the inevitable objective being a simply battery-monitored EV. [25] The prerequisite of a more vitality thickness in EVs and PHEVs revives the exchange for car battery innovations, giving Li-particle battery science one more shot at getting in the electric vehicle battery showcase [25]. Within this segment, the fundamental standards, the present market status, and the future advancement patterns of Li-particle battery examined [16].

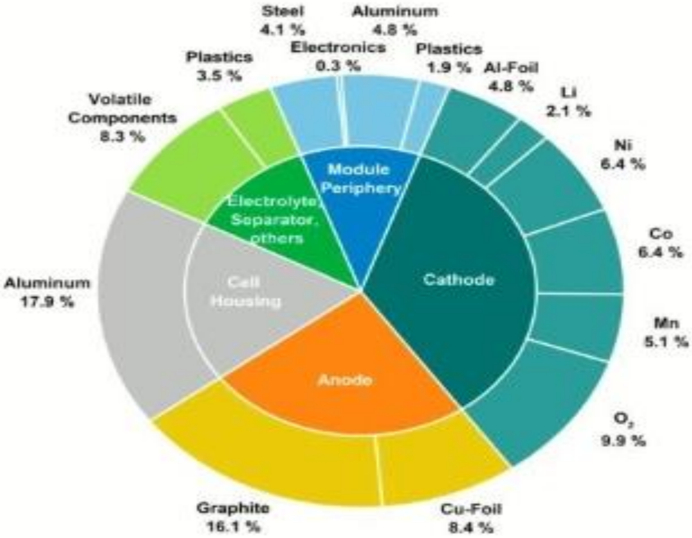

Figure 5 General battery composition [4, p. 103]

1.3.3 The Applicability of Battery chemistry

Battery engineers could design packages that meet energy needs. The use of battery chemistry is required for each vehicle function correctly. Several kinds of batteries (, nickel-metal hydride, lead-acid and lithium-ion) marketed into specific types of electric vehicles according to cost, energy, and power, weight, and volume requirements. The application of lithium-ion technology has appeared. [12]

	BEV	PHEV	HEV
	VW e-Golf	VW Passat GTE	AUDI Q5 Hybrid
System			
Modules			
Cells			

Table 3 Battery pack in a different module, cell system [43, p. 60]

Batteries are machines that transform the energy produced from chemical sources included in an electrochemically. Immediately the redox interaction comes from active matte into the power of an electrochemically. In terms of rechargeable batteries, chemical energy could accumulate in a specific amount and could also recharge when the electrochemically active matter has changed. There are many kinds of rechargeable batteries, such as mature lead-acid to many other technologies, at various levels of implementation. [36]

1.3.4 lithium-ion battery Market size in the Global Market

In 2012 the global lithium-ion battery market was worth 11.70 billion dollars and predicted to be $ 33.11 billion in 2019, with 14.4% of a compound annual growth rate [25]. Fig 6 presents a segment of the lithium-ion battery market for consumer device retailers, manufacturers of industrial products, sections of Renewable energy storage and network and car manufacturers [5].

In recent years, in terms of developing new energy vehicles, Chinese lithium batteries showed considerable advancement in comparison to South Korean production. The fast improvement of the Chinese output after the number of enterprises increased the production rate, made a threat to the South Korean petrochemical, automotive electronic IT, steel, iron and other primary exported industries.[25]

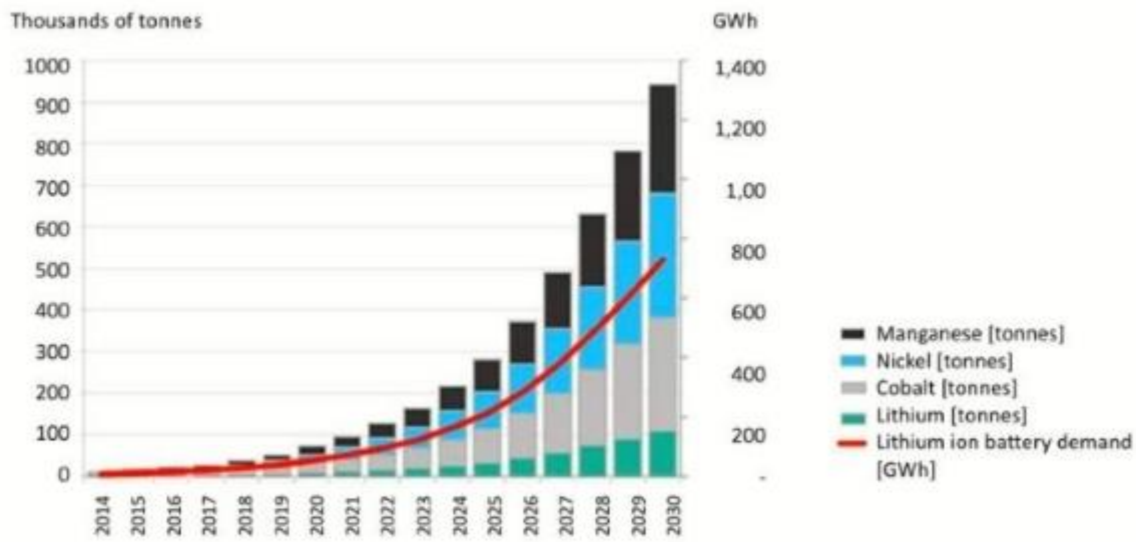

Figure 6 The future forecasting of the Battery pack in the global market[42]

Developing industries in the future will be a significant threatening for the Chinese industry [25]. Some of them, the rapid development of the battery industry not only Chinese GCL solar enterprises' fast growth. In terms of market research agencies studies, China's smartphones cargos for four following years of rapid growth in 2015 predicted to increase by 11.6%, substantial gain. In particular, in the field of smartphone trade share of brands in China which recorded an increase of more than 40% pulling the implementation of accessories related to it, for example, the lithium batteries. Lithium battery producers were 60% of requirement. [24]

The essential materials of lithium batteries in Chinese factories, like the negative plate, electrolyte, anode plate, and separator, are also necessary for the field market. The reason in this explanation indicates the fast improvement of China's lithium battery manufacturing worldwide.

The lithium battery producers include Korea for cost-saving, maximize the usage of cheap Chinese raw material manufacturing, with the significant increase of information technology and Chinese automobile business, gradually increasing the need for lithium batteries. [8]

Lithium batteries have more efficiency and are more economical than other battery types. Thus these traits are essential in the current generation of electric cars and vast energy-saving systems business. It predicted that in the future of the new energy market, South Korea and China would launch fierce competition subjected to the fast development of Chinese lithium batteries. [5]

The standard lithium batteries need for cellular phones and computers as representative of the fundamental trend of constant growth, whereas the future manufacturing growth. Besides the current energy cars and energy-saving markets, the (unscrewed Aerial vehicle) UAV and other new fields of business need little by little has increased. The lithium battery fastened the penetration of lead-acid battery types in the electrical bicycles markets share. [25]

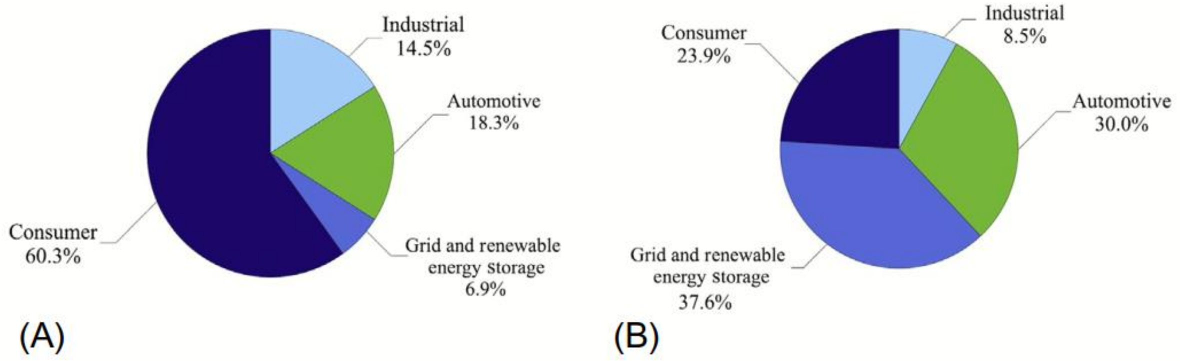

Figure 7 Li-ion batteries Market part. (A) 2013 and (B) 2020 [2]

Development of lithium batteries production and investment values study report the usefulness of the model related to the lithium battery, a battery constructed of lithium or lithium alloy as a cathode matter and utilizes a no aqueous electrolyte solution. In 1912, the first proposed lithium metal battery studied by Gilbert N. Lewis while in the 1970s, MS and Tingham recommended and started to research lithium-ion battery. [43]

The chemical characteristics of lithium are highly active, leading to creating lithium material preservation, processing, use, and environmental needs are very high. Thus, lithium batteries aren't utilizing for a long time. Generally, the Lithium batteries classified into two types: metal lithium battery and a lithium-ion battery. [21]

Lithium-ion battery doesn't have lithium in a metal pack and might charge. In 1996, fifth-generation rechargeable lithium batteries invented. The safety, particular capability, self-discharging rates, and performance-cost rates are better than lithium-ion batteries. Due to high technical needs, only countable enterprises in the country currently producing lithium batteries. [44]

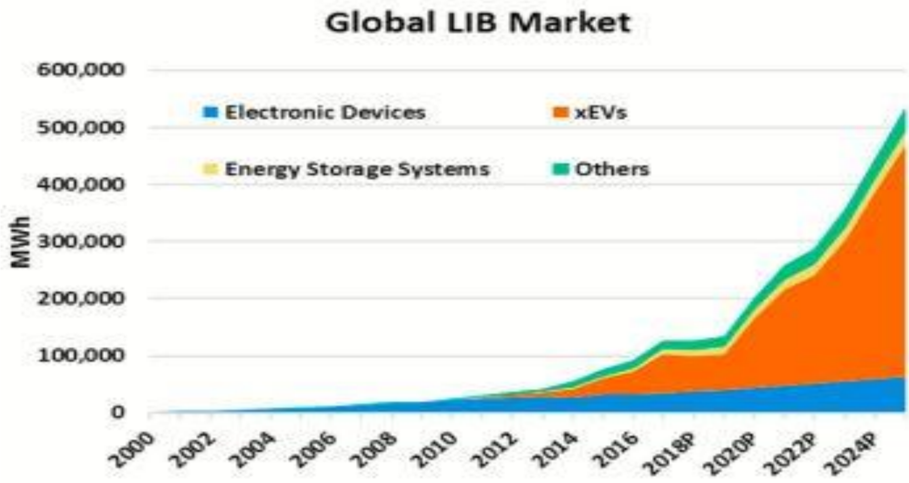

Figure 8 the global market of Li-ion battery.[2]

Climate change, the decrease in fossil fuel reserves, and energy safety require alternatives to the current energy rate consumption and use. There is a comprehensive agreement that the implementation of energy efficiency and sustainable energy technologies is a necessity today rather than a luxury to differentiate from the distant future. [1]

Sustainable energy technologies are of particular interest:

(1) Boost electric cars that could be competing with inside combustion cars (IC) machines and solved the problem of CO2 emissions.

(2) Fixed storage of electrical energy from renewable energy resources.

Globalization and industrialization contribute to the rapid increase in carbon emissions. In turn, vast amounts of emissions hurt our climate, leading to devastating environmental changes and health problems. However, the question is, how can implement the quickly sustainable energy solutions to face climate change. [28]

The increase in transport electrification and renewable energy storage is a way to address the challenges we face as we transition to a low carb economy. Through the previous two points, the lithium-ion batteries have proven to be a promising technology for efficient energy storage. It compared to other rechargeable battery, and lithium-ion batteries have favourable characteristics like the high operating voltage, high specific energy, and long service life. However, lithium-ion storage energy has many environmental benefits. [25] The increase in battery production will create waste management problems and put pressure on the existing recycling infrastructure. Therefore, a proactive approach to managing future waste streams from waste batteries is essential [25].

As the lithium-ion battery market continues to grow, it becomes necessary to recycle batteries to ensure rare and valuable raw materials [28].

Battery recycling is currently associated with high costs and a lack of efficient technology. Also, lithium-ion batteries are more difficult to recycle than other batteries because of the complexity of the composition of their components. This kind of battery classified as diverse hazardous materials, hence the importance of complying with regulations. [35] From sustainability, an ideal recycling system would allow a closed circuit in which battery at the end of their useful lifetime reuse in the production of new ones.

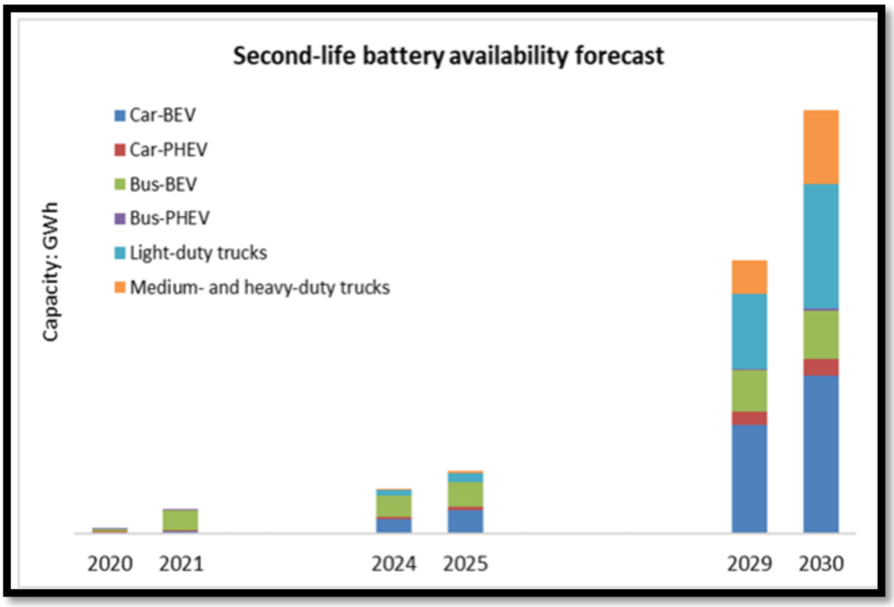

Figure 9 The ten- year's prediction on the existing second-life batteries capacity used in standard electrical vehicles

The most expensive parts of electric cars are the batteries. At the last of the advantages of mileage in electrical mobility, the removed ones might still keep 70-80% of their generic capacity. Ultimately, it is essential to recycle. [45] Beforehand, giving a "second life" to depleted batteries that are still usable in applications that are less power consuming. For example, fixed energy storage might bring considerable value to a wide range of automotive and energy [45]. By the year 2030, second-life batteries' capacity would reach more than 275 GWh per year, representing significant chances for storing energy. Nonetheless, companies will prevent from taking advantage of second-life batteries cells as a result of a lot of technical, economic, and regulatory problems. [45]

The Second-Life Electric Vehicle Batteries 2020-2030, which is the latest IDTechEx report, explains detailed analysis of essential technologies, players, market interests and challenges in terms of the Second Life battery value chains. Second Life batteries connect the value chains of electric vehicles and energy storage. The second-life batteries' potential value relies on the topology of their design and their usage since the first time in electric cars, how they are gathered and utilized in second-life purposes, and the recycling gain. In this report, the value chain analysis of batteries' life cycle is taken into consideration to assist stakeholders in defining potential value chances. Also, in this report, the study included the main technical challenges recognized and enterprises that develop techniques to enhance the value of the backup battery. [46]

1.4 Overview of the Recycling process

1.4.1 History of the Recycling process

With the rising demands for lithium-ion batteries with the battery in the power transmission sector, a vast number of lithium-ion batteries will phase out shortly. These all lead to critical disposal issues and negative influences on environment and energy conservation. The cells made of lithium-ion that are composed of phosphates, of transition metals, oxides or, aluminium, graphite, copper, organic electrolytes. All the cells are having polymer separators, lethal lithium salts, and plastic or metal fittings. Critical consequences might happen as a result of the lack of recycling spent lithium-ion batteries such as environmental pollution and useless waste. [47]

In recent years, there is an increasing trend in the recycling of spent lithium-ion batteries. Nonetheless, due to the search for the higher energy density of great diversity and evolve constantly.[4]

Recycling used -Ion batteries lithium process might have some difficulties. It is necessary to support technological innovations, and its government's intervention is inevitable. This research reviews recent advances in lithium-ion battery recycling technologies, including recycling products, development of recycling processes, and the influences of recycling on the environment. Also, future work and the remaining limitations are explained. [48]

1.4.2 The Aim of lithium-ion battery recycling

The most common reason for recycling is to reduce the expense associated with eliminating our endless waste stream. Waste disposal is a potential source of air and water pollution and is expensive. [7]

Besides, land competes with other area uses. Also, recycling can increase our supply of materials to reduce shortages and moderate the rise in raw material prices. Also, recycling is often less harmful to the environment than the use of virgin raw materials and can reduce energy use and emission of greenhouses gasses and other resource pollution. [39]

The generic term "Lithium Ion" is a problem in the state of LIB, described in a wide range of different chemicals that conform to specific applications. In the early 2000s, when LIB became more and more applications, the battery of batteries used for compounds of cobalt oxide and lithium (LCO) as a cathode material. [49]

The number of blended transition metal oxides such as manganese oxide (NCM) and nickel-cobalt has consistently bloomed by the years. The articles have enhanced.

In addition to the established graphite electrodes, the silicon (Si) will enter in the future as it predicted. [50] The result is that new technology and programs open the door to unique modern designs and other chemicals, therefore, improving the recycling LIB complexity [51].

The recycling used batteries appear as the most suitable goal for this kind of byproduct. Recycling is necessary as it will be contributing to the good of the upcoming generations and the retention of raw materials. In the specific case of batteries, it is still essential to establish effective ways to collect and receive used batteries worldwide. The most convenient endpoint for this kind of wastes is by recycling used batteries. [52]

Waste recycling is vital as it could be contributing to the preserve resources for future generations and also keeping of the raw materials. In the specific case of batteries, it is still crucial to developing systematic gathering systems to accumulate used and consumed batteries in entire the world. [19]

1.5 Battery pack Recycling

1.5.1 The Aim of Battery pack Recycling

The Recycling of battery pack deals with profit on the spent of high-value metals. The profit from the sale of recovered metals is less attractive from an economic point of view. Currently, a lot of research has concentrated on the spent expensive metals such as cobalt, nickel, or a small portion of lithium recycling, therefore, lithium recycling and other lethal materials of the slag (in the course of pyrometallurgy) electrolytes, and active anode materials. At a lower cost, the recycling of the dysfunctional battery will develop and cycle the goal. [28]

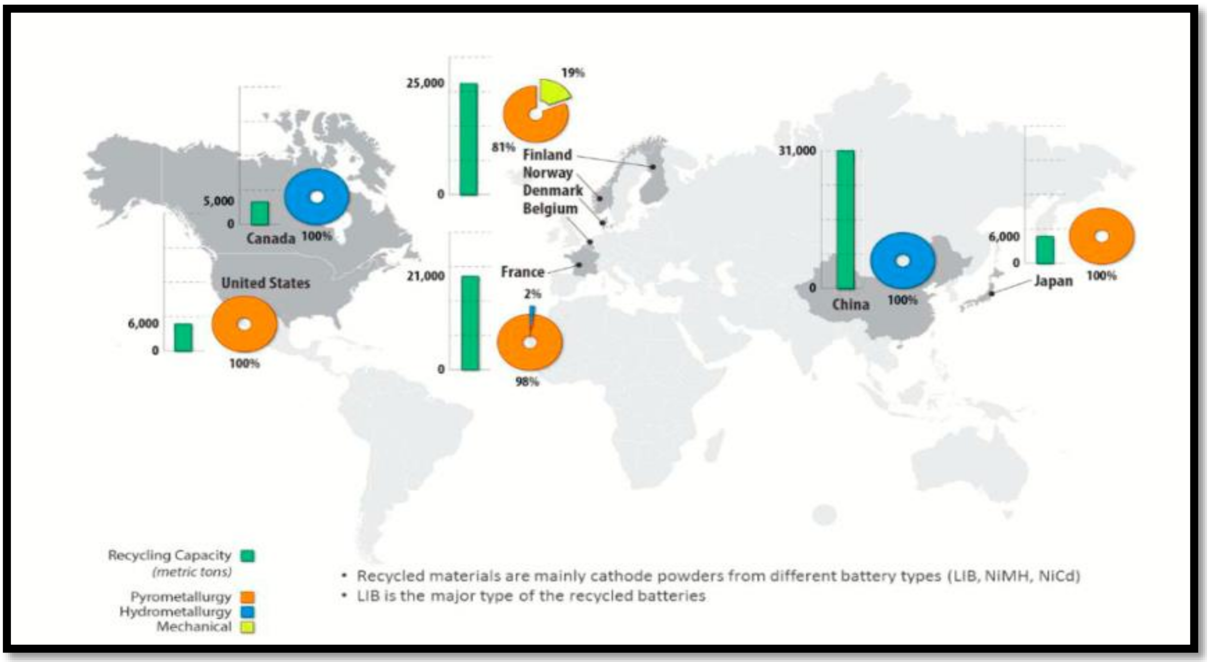

Figure 10 spent batteries in Metric Tons of recycling capacities [39]

One of the practical solutions recommends that used batteries might return to the production factory. Recycling lithium-ion batteries utilized. Similar infrastructure might work merely. In recycling lithium-ion batteries in the future, all works will lead to the same circle. [48]

1.5.2 The advantage of Battery pack recycling

The advantages of the recycling process for spent LIBs have been considered and demonstrated in the framework of many research studies. [53] The pretreatment process of these Batteries was looked upon As essentially effective as far as the leaching efficiency of the hydrometallurgical process and application of the recycling industry is considered [54].

The possible benefits of the hardest technical process have been investigated, as far as several development stages of the recycling process have been reached. An economically important has been shown in the chemical precipitation as essentially low cost and energy consumption endless with the environmental friendliness. [28]

A major current focus in LIBs recycling process is how to improve the environmental and sustainable issues. A worthwhile that the recycling of the materials plays a major role in increasing in recyclable value. [55]
Anna Boyden et al. shows in their studies that the electricity generation is vital for plastic to cremate and landfilled waste. The recycling process is considered a powerful method for plastic recovering in such a special pretreatment. [56]

1.6 The objectives of the present work

The thesis emphasis on the Recycling process of a lithium-ion battery, Due to the higher demand for li-ion battery recycling, coupled with the higher numbers of Battery pack producing, both are playing a vital role in the global market. The Li-ion battery recycling process is the commercial interest in the future, but due to the problems caused by this process, which addressed in the following chapters. This work presents the character of the three main factors that influence on central market problems. The problems are unresolved on recycling processes, the demand clarification in future research well known on the new challenges to manage these problems.

1 - Uneconomic state for recycling on damaged batteries and replace with the new one.

2 - The recycling processes mostly effect on environmental pollution.

3 - Unclarified the flammable and safety incident reason, which has resulted from battery dysfunction.

Chapter 2

Problem statement

The Li-ion battery recycling methods will be introduced, concerning how the battery pack recycling will impact the three components (Environment, the cost in the present market, power efficiency). According to the elements and how they can build up the looks into the future.

2 PROBLEM STATEMENT

2.1 Lithium-ion battery recycling process in routs

Currently, in terms of recycling of large-format lithium-ion batteries, there are no standards set. One may think that this condition is suitable for recyclers, which would not be subject to any restrictions in the design of the process. However, this process could be confronted with a considerable chance of setting limited standards after this fact. Thus, methods ought to be implemented to comply with predicted standards. Also, the science behind the battery continues to evolve. For approximately five years, Lithium-ion batteries for vehicles have only used commercially. It would take more time to be used for mass amounts. Also, the batteries will not reach the end of their lives to support extensive recycling facilities with its long service life (typically the lifetime of the vehicle). [57]

Nonetheless, lithium-ion battery in electronic user devices, and process waste, are handy and can provide raw materials to the emerging lithium-ion battery recycling industry for cars. Different recycling processes behave suggested, each with their pros and cons [57].

Battery recycling processes mainly involve two stages:
Waste the metallurgical process and preparation. In the later, the stage starts with sorting the waste, separating it by type of chemical. The ranking could include several steps to improve the Effectiveness of isolation. [58]
These stages could have manual separation and separation using instrument specially invented for this purpose. The material acquired for this purpose uses various techniques, such as mechanical separation, X-ray images, optical sensors and magnetic separation, to observe barcodes in waste. [59] The material recycled set out for the metallurgic process via physical adaptation processes after classification [3].

The operations based on the ideal activities of raw material processing units, it likes magnetic separation, crushing, dense media separation (DMS), electrostatic separation, and fragmentation. Crushing has waste fragmentation, and the primary objective is to isolate a large number of metallic and polymeric or internal material coverage that has the goal metals that need to be recycled. [43]

2.1.1 Recycling process on the Battery pack

Lithium batteries typically consist of organic electrolyte, separator, a cathode and anode that are compacted and laminated and to make the electrical connection between them. The cathode consists of an active metal material having particular electrical amounts. Common anodic materials are natural and artificial graphite. [34] Generally, thin plastic sheets used to make separators.

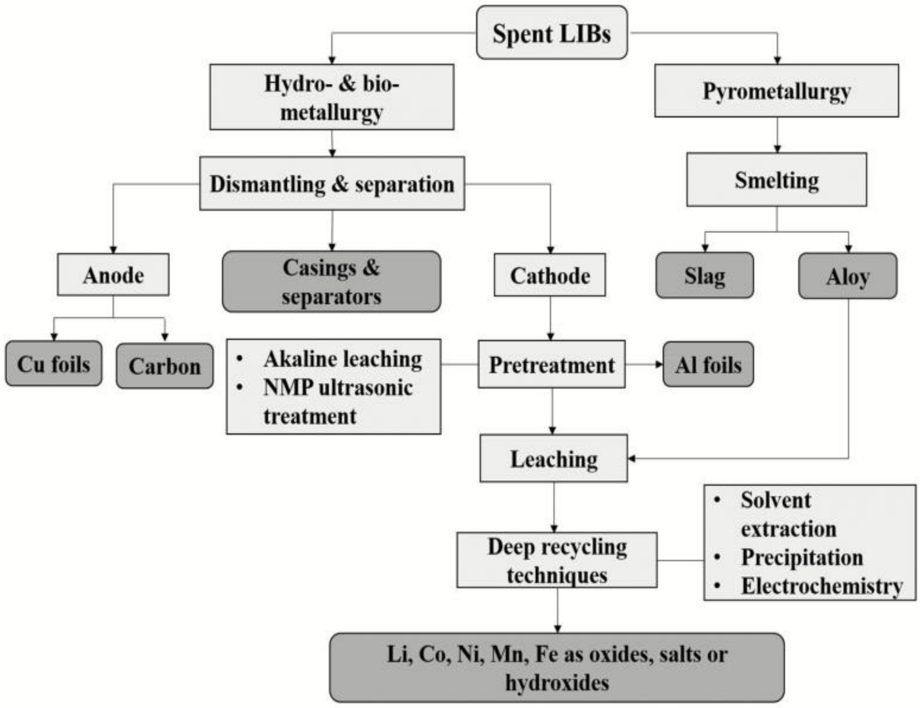

Figure 11 the flow chart shows a typical recycling process. [3]

In the battery, An electrolyte behaves as a filling part which has the stability opposite to the surfaces of the anode and cathode are the purposes of the function [28].

The various chemical composition and the different component of the electrolytic play the key role in LIB, involving a non-aqueous electrolyte, they consisting of solubilized lithium salts. In organic solvents, an aqueous lithium electrolyte of salts solubilized in water-based medium and polymer electrolyte. [48]

Commercially used for recycling LIB cars, consumer electronics, and others(pyrometallurgy, cry grinding (Li recovery) or other mechanical processes, hydrometallurgy, three technologies) used alone In combination are used. [48]

In direct recycling, to extract anode and cathode materials, a recycling method is adapted. This process is a solvent extraction based method where shallow carbon dioxide (CO_2) is utilized. [25] Direct recycling has a set of pros and cons of the elementary recycling operations of the LISs.[3]

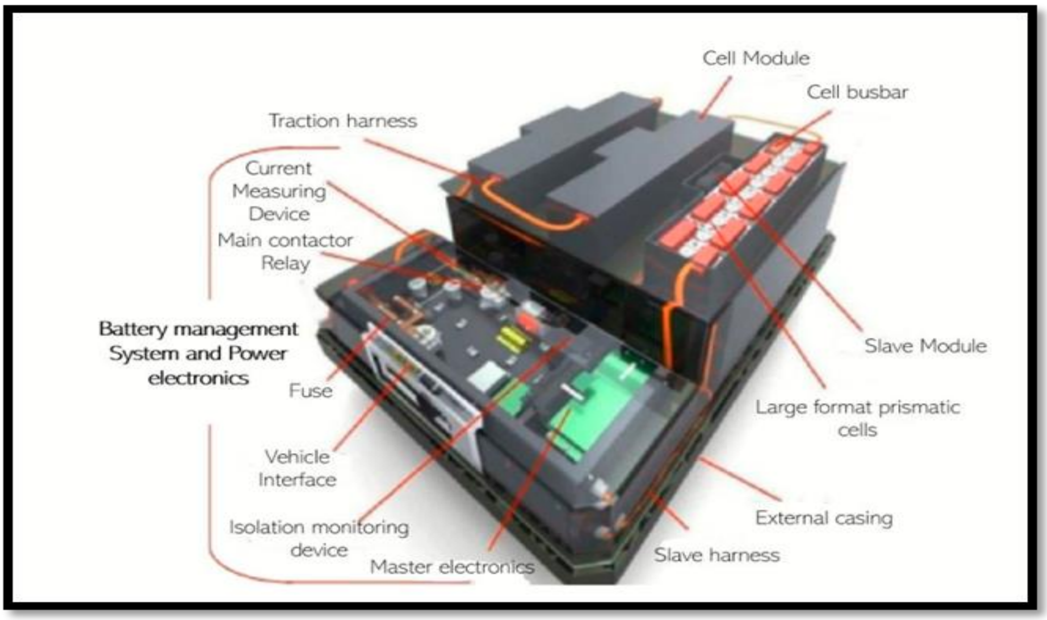

Figure 12 EV Battery pack component. [16]

New processes have generated problems with the typical systems in which futuristic recycle of lithium ions might model. Recycling lithium-ion battery with acid-leaded battery is a problem for smelters of secondary lead. Different existing lithium-ion batteries cannot distinguish acid-leaded batteries. Thus, their usage is explicit for motorcycles, SLIs, and other fields. Nonetheless, the insertion of a lithium-ion battery in the input flux of smelters secondary lead caused explosions and fire. The Vaporization of volatile organic electrolytes could cause the explosion of lithium-ion cells. Such events represent a dangerous and should avoid. [16]

This type of batteries finishes up in the incorrect direction of recycling because of apparent errors. Nonetheless, since acidic battery recycler Pb pays for the expected input material (and might also charge for other kinds of batteries), other objects may mask various types of batteries in Pb acid battery pallets to avoid have you pay for your disposal. [43]

2.1.2 Benefits from Recycling processes

Besides the expected economic outcomes, the recycling process could diminish the number of materials entering landfills. Cobalt, manganese, nickel, and other materials in batteries could easily seep into the internal battery case and sustain groundwater that might impose a threat to the ecosystem and general health, reported by Zhi Sun, a scientist at the Pollution Control at the Chinese Academy of Sciences. Similarly said of the solution of lithium fluoride salts (LiPF6 is common) in the organically based solvents utilized in the electrolyte of a battery which harms environment not only at the last stages of a lifetime instead. As Gaines de Argonne points out, more recycling means less extraction of virgin materials and less associated environmental damage. At the same time, they are implemented.[60]

For example, the removal of some Metals from the battery requires the processing of the metal sulfide-ore, which consumes much energy and diffuses Sox that might cause to acidic rain. Less dependence on the extraction of batteries material might also delay the isolation of these raw materials. Researched this subject utilizing computer-based techniques for modelling the effects of increased battery production on geological reserves of various metals until 2050. Recognizing that these expectations were "uncertain and complex, "the researchers discovered that preserves. [31]

The global nickel and lithium are appropriate to support the fast-growing of production of batteries. However, the battery industry might reduce globally available cobalt stores of more than 10%. [17]

2.1.3 Battery Pack Recycling methods

Mechanical process: The mechanical recycling process (also called the physically-based process) including crushing, disassembly, sieving, and separation. The goal of this operation is the return of lithium-ion battery from electric cars and the end of cells into compounds that could be recovered directly through a chemical treatment. [61] One of the benefits of mechanical operation is that nearest recycling operation Recovery Direct treatment appears while the battery components are isolated but not treated, and the outcomes are battery-grade output; batteries the best result is remanufacturing. It refers to the most effective way to manage the final stages of the lifetime. Batteries as they save the significant portion of energy by the reduction of the number of the needed operation. [62] Generally, low-degree recycling techniques are particularly useful. Fewer energy needs exist, and fewer materials transformations required. It refers to the outcomes in a more direct reusability/recycling of materials utilized in the batteries.

The disadvantage of the immediate treatment is that it needs a power supply as normal as possible, that is to say, the same type of battery cell. Battery parts and a battery management system (BMS) are all put in a battery package that exists at the end-top of the electrical car. [28]

The battery module is attached in serially and paralleled with a lithium battery to ensure capacity and high voltage. In general, a module comprises hundreds of cells. During mechanical recycling operation, the battery pack dismantled into a battery package, and the battery package could be disassembled into an individual cell. At last, it ground granularly, and it filtered for subsequent recycling. With the rise of electric vehicles, a vast number of batteries containing millions of dead lithium-ion batteries which pose daunting challenges for humans soon. [62]

Metallurgy process

Pyrometallurgy: In particular, the methods define the recovery of the components in the LIB cells. The cathodic components could be categorized into metallurgy, pyrometallurgy, hydrometallurgy, and hybridization. The techniques Pyrometallurgy involves a heat treatment to break down the parts of used LIB. Two steps involved in this process. First, to reduce the risk of explosion, LIBS is supplied at small temperatures in an oven as well as evaporation of the electrolyte. Second, followed by the formation of slags and alloys, all Plastics and solvent materials burn out at high temperatures. [62]

Hydrometallurgy and metallurgy: At first, all depleted BIBs discharged, dismantled, and separated into an external housing, a separator, an anode, and cathode. At present, the primary goal of these operations is to recover precious materials out of the cathode; these are pretreatment, leaching, and deep recycling techniques. [63] The pretreatment, which includes the ultrasonic treatment and the alkaline solution by NMP solution, is first performed to separate the active material from the aluminium foil. Next, a bleaching treatment using acid leaching and bioleaching uses as an essential technique for bringing precious contents into the solution. [48]

At last, by deep recycling techniques, the minerals in solution are straightforwardly separated, such as precipitation, or electrochemical solvent extraction. [57]

2.2 Pros and cons of current Recycling methods

Recycling Method[a]	Pros	Cons	Recovered Materials	Examples
Mechanical Processes	Applicable to any battery chemistry and configuration. Lower energy consumption. Enhance the leaching efficiency of valuable metal	Must be combined with other methods (mainly hydrometallurgy) to recover most materials	Li_2CO_3	Toxco process
Hydrometallurgy	Applicable to any battery chemistry and configuration	Only economical for batteries containing Co and Ni	Copper, Aluminum, cobalt, Li2CO3. Anode is destroyed	Shenzhen Green Eco-manufacturer Hi-Tech Co. (China); Retriev Technologies (Canada); Recupyl S.A. (France)
Pyrometallurgy (smelting)	Applicable to any battery chemistry and configuration	Only economical for batteries containing Co and Ni; Gas clean-up required to avoid release of toxic substances	Cobalt, nickel, copper, some iron. Anode is destroyed	Umicore (Belgium); JX Nippon Mining and Metals (Japan)
Direct Recycling (supercritical CO_2)	Almost all battery materials can be recovered	Recovered material may not perform as well as virgin material, mixing cathode materials could reduce value of recycled product	Almost all components (except separators)	OnTo Tech[b] (USA)

Table 3 pros & cons of the recycling method [2, 60]

2.3 Factors influence on Battery recycling

2.3.1 The Cost factor

The reduction of the cost of recycled materials should be the primary driver of recovering at the final stages of its active life. The main areas where it can save money are costs, energy, and greenhouse gas emissions. Fees, as a critical economic engine, should lessen with economies of scales. The prices available are not exact, particularly with the dynamic costs of an unprocessed virgin, lithium, cobalt, and other materials utilized in the LIB. In the final stages of the useful lifetime, it's recycling and the expectation of saving much energy and emitting emissions. [2]

Nonetheless, directly-based recycling is a breakthrough recycling technique. It seems to be greener with fewer energy levels and emissions than hydrometallurgy and pyrometallurgy. [19]

Battery manufacturers buy Battery recycling products. Therefore, it might not be strange to know that the big Manufacturers of batteries have recycling enterprises, like Bruno, a lithium-ion battery recycling from Hunan. Although less, it comes from Singapore (TES-AMM, which operates a factory that uses a hydrometallurgical process implemented in France), via Belgium (Umicore) and South Korea (SungEel), in the United States. UU. Moreover, Canada (Recovered technologies). In Great Britain (Belmont Trading) and Australia (Envirostream Australia).

	Cost				Energy		$CO_{2\text{-}Eq}$			
	LCO	NMC333	NMC811	LFP	LCO	LMO	LCO	NMC333	LMO	LCO
Pyrometallurgy	38%	6%	5% more		35%		70%	78%		70%
Hydrometallurgy	41%	13%	1%		38%	18%			5%	
Direct Recycling	43%	27%	16%	15%	5%	76%		94%	10%	
Virgin Raw Materials	$ 62	$ 45	$ 40	$ 32	77 MJ/kg	34 MJ/kg	200 kWh/kg material	9 kg $CO_{2\text{-}Eq}$/ kg cell	5 kg $CO_{2\text{-}Eq}$/ kg cell	11 kg CO_2/kg-material
Source	[23]				[22]	[22]	[24]	[25]	[23]	[24]

Table 4 cost, energy, co2 in the typical recycling process [2]

Some other enterprises worldwide use LIB facilities for recycling. The list mentioned above is way far from exhaustive. The relationship in this context based on the increased BILs suction for electric cars, recycling enterprises are fast widening their factories, and new businesses are emerging in the field. [20]

2.3.2 The Efficiency of Battery

Item 6/6 of the European Parliament and the Council on 6 September relating to stones, storage and battery waste (cancellation of item 91/157 / CEE), which set in Annex III (Part B) the minimum recycling efficiency in which Recycling achieved the minimum recycling process.[4] The recycling efficiency will show in the next stages.

A. Recycling of less than 65% of the average weight of stones, and lead and acid stores.
B. The recycling process for 75% of the average weight of the rocks and the storage of nickel and cadmium.
C. Recycling of less than 50% of the importance of other wastes of stone and storage the batteries in hybrid and electric vehicles of the new generation that supply the Toyota Piraeus, BMW M3, are nickel-metal hydride batteries or lithium-ion batteries. [64]

Item 2006/66 / CI. The law on these batteries is more flexible than lead or nickel-cadmium batteries. Because the technology used in these batteries is more modern and it was necessary to leave a deadline for the recycling companies to comply with the methods and methods of collection and recycling to be compatible with these new batteries. In 2010-2013, it invested more than 6.5 million euros in increasing its treatment sites, with a 25% increase in its investment in cleaning. The environment in each year The cooperation of SNM with the car manufacturers, presented more effort in the investments and development since 2008 exceeded the minimum imposed as long as the level of recycling of nickel-metal hydride batteries can exceed 70%. The lithium-ion batteries are close to 70%. [58]

This gap comes from the awakening of this generation of batteries and the wide variety of electrochemical groups (lithium polymer, lithium iron phosphate, and lithium-ion. These Groups are why the company continued SNM Investment. [58]

The battery directive requires a specific recycling efficiency (ER) when handling battery at the final stages of their active life. Directive 2006/66 defines three objectives. They are valid for all types of chemical products used in batteries, as the consumer, industrial or automotive products. All output fractions from a recycling process cannot count in the ROE. Certain conditions must be respected to avoid misunderstandings. It would be useful to obtain the end of the waste status for specific fractions of the production. The typical battery recycling process involves many levels, not all of which are conducted by the similar recycler. [58]

2.3.3 The Environment effect

Although all know that recycling battery technology is useful to the environment via Raw material extraction avoidance, current recycling processes might possess a negative impact. Typically, these impacts ought to be minimized for reducing the general effect on the environment. The environmental effects of recycling of the batteries of lithium-ion assessed. In respect to the energy consumption, transport and particular processes. Then the elimination of discharging batteries are all compared. To the possible extent, the analysis in the battery recycling faults performed quantitatively using Principles of LCA. A more qualitative analysis of the assessment carried out if the data were not enough for the application of ACL. [65]

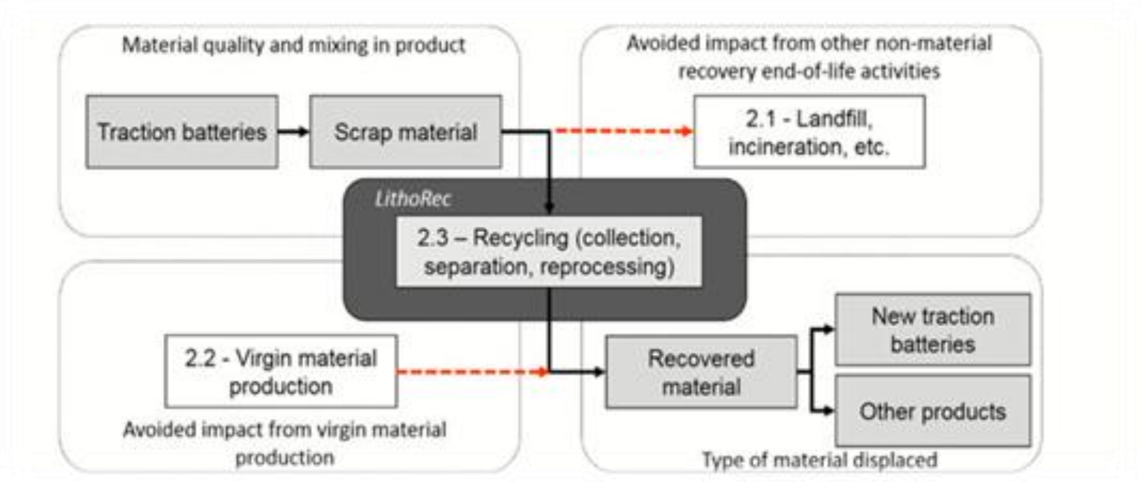

Figure 13 the analysis of the environmental effect in recycling

[4, p. 269]

2.4 Failures in the recycling process

2.4.1 Faults in the recycling process

Car electrification raises the energy efficiency of the transportation field, whereas reducing emissions. Nonetheless, batteries of electric vehicles would eventually get to their final stages of life if their capacity is insufficient to operate an engine vehicle. Currently, the battery usually not selected for recycling. This recovery process of the battery of the electric vehicles is unpractical because the storage capacity is still sufficient to be utilized in different vehicular consumers. [57]

Unluckily, many obstacles limit the adoption of reused electric vehicle batteries. When the lithium-ion battery in electric cars reaching the final stages of the activity, the recovery of some of the materials of these batteries could be recycled.[39]

Nonetheless, recycling battery is an uneconomic suggestion, since the components utilized to make EV type possess a fewer value material considered for recycling, with the transition to LiFePO4, and as EV ones, in general, keep 80% of the capacity of the energy storage that made at the removing.

Cars in operation. 80% of the estimated size is an approximate approximation used to determine approximately the state of an EV lithium-ion battery when it withdrew from a vehicle. [40]

Since electric vehicle batteries generally leave vehicles intact with the bulk of the capacity and energy, it is vital to develop other usages to use electric vehicle ones at their usage stage better [62].

For increasing the lifetime of the battery of the electric vehicle, the experience, the packaging could be reused for the second usage to delay the process of recycling batteries. For renewable energy purposes, the lithium-ion battery is utilized in some applications for storing energy, charging other electric vehicles, or backup power provision all that happens in a battery reuse scheme. [66]

2.4.2 Failures in the battery pack (Why do batteries fail)

Lithium-ion cells performance depends on operating voltage and temperature. Once out of the box, the cell will suffer permanent damage**.** For the application engineer who designs reliable products based on battery energy, it is essential to understand the possible failure modes of the cells used. The failure allows us to make sure that the cell manufacturer has implemented the expected failures outside the cells and thus improper or unmanageable operation situations can be prevented or avoided during the manufacturing and subsequent use of the cells. [2]

Battery and application designs using a cell system ought to relieve the effects of any unexpected error mode on cells and systems in where they applied. Furthermore, these systems have a containment strategy for addressing unexpected errors like thermal leakages that might be resulted from outside threats like extreme incidents or misusages out of the designer's power. [67]

2.5 Risks in Battery pack recycling

There are several dangers associated with lithium-ion batteries, which fall into three main categories: a) electrical, b) fire and explosion, and c) chemical. Batteries can cause electric shock and short circuits.

If the cells are damaged, additional precautions should consider. However, to know if the cells damaged or no when they reach the recycling unit will difficult. [63]

A summary of the potential risks shows in the next Table:

Category	Risks and Hazards
Electrical	Electric shocks Short-circuit
Fire and Explosion	Flammable components Flammable reaction products Leakage Contamination
Chemical	Carcinogenic coating materials Toxic gases

Table 5 Summary of the potential dangers must consider in Battery. [4]

When designing a recycling process, several risks need to assess. A risk factor is that Lithium-ion batteries contain flammable components; in this case, hydrocarbon-based electrolytes, which can cause a fire. These cause means refers that lithium-ion batteries must treat with care. Therefore, a challenge is to eliminate the electrolyte safely and find a solution for reuse. [63]

Another risk is the leakage of the battery during the treatment, consisting of toxic gases released by the ventilation and hazardous metals that pollute the air.

Hazard means refers to cause serious environmental problems and health problems. Ignitions may also occur during the grinding of cells pretreatment. The process generates heat while the flammable components evaporate. [49]

The contamination of unwanted materials is also a challenge because the separation processes design for the input material and its components. Typically, processes are designed to handle a specific waste stream.

The undesirable elements must, therefore. Avoiding contamination between process steps is also desirable from a quality point of view. For example, dust or small particles released during crushing maybe. [68]

2.5.1 Thermal Runaway problem

Several stages are involved in thermal runaway and more permanent damages to cells. The first step is the decomposition by the elevated temperature or physical procedure of the passive SEI good layer in the anode [69]. Beginning of the higher temperature might be caused due to high currents, overload, or extreme outside ambient [70]. The degradation of the SEI layer occurs at a somehow not high temperature of 80 ° C. The electrolyte interacts with the process of formation of the carbon anode, but at an upper temperature and unregulated as soon as this layer is perforated [71].

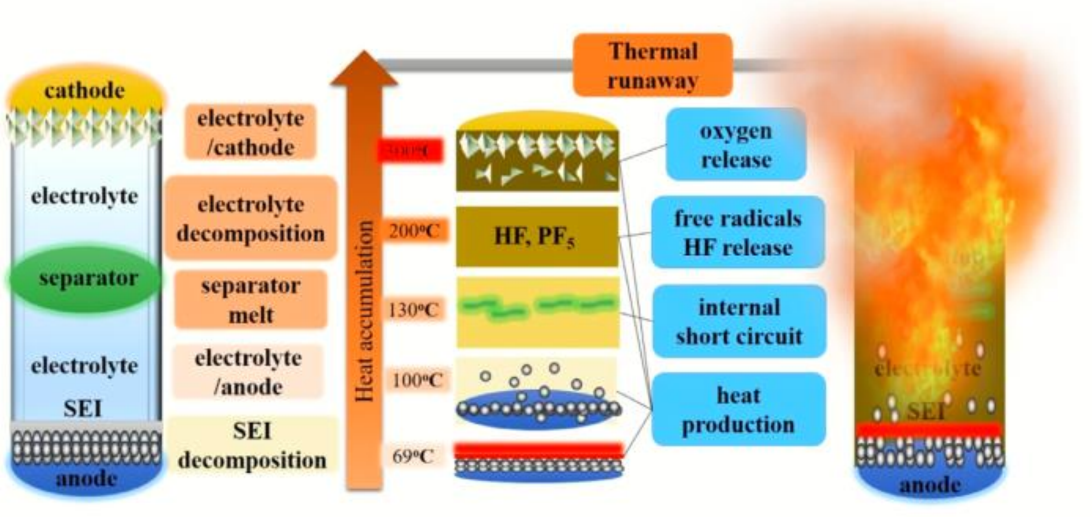

Figure 14The Thermal runaway process of LICoO2. [1]

When the temperature increases, the heat of the anodic reactions results in the decomposition of the organically based solvent materials utilized in the electrolyte which releases flammable gases of hydrocarbon (methane, ethane, etc.), without oxygen. For instance, it usually begins at 110 ° C, but with many electrolytes, it could be as little as 70 ° C. Gas might be produced as a result of electrolyte to be broken-down causing an increase of pressure inner the cell.

The burning doesn't occur since there is no enough oxygen in the cell to sustain afire, although the temperature rises above the flashpoint of the electrolyte. [71]

- The heat generated by electrolyte decomposition results in cathode disintegration of the material into a metallic oxide that releases oxygen, which allows the combustion of the electrolyte and gases within the cell. [69]

2.5.2 Transport of lithium-ion batteries problem:

The lithium batteries transportation. During transport, Li ones or instrument involving Li type are more likely to be hazardous cargo. It is only allowable to move them when it is completely sealed and packaged, and verification standards are applied. Batteries considered as "Dangerous Goods for Transportation" (all ways of transportation, rail, air, road, maritime) by UN Subcommittee on the Transport of Dangerous Goods. [72]

Technologies Classified includes nickel-cadmium and acid- leaded batteries of category 8 (acid- leaded ones as they have an acid electrolyte and nickel-cadmium ones as they have alkaline batteries). Lithium and electrolyte batteries (lithium and lithium metal ions) and nickel-metal hydrides categorized in class 9 for covering their double electricity. Also, hazards chemical characteristics that are uncovered by other levels. [59]

Chapter 3

Analysis and conclusion

In this Chapter, the answer to the following questions will present:-

Q- How can the faults of the lithium-ion battery recycling process repair?

Q- What are the cases to Deactivate the lithium-ion battery when battery LOC still active?

3 ANALYSIS AND CONCLUSION

3.1 Battery Pack safety requirement

While each vehicle manufacturer aimed to manage better and safer electric-powered vehicles, many of them are only now beginning to assess the end - of –a life in the recycling process. Each electric vehicle powered by an abundant amount of energy from a battery pack. That battery is typically lithium-based chemistry, each or sometimes nickel-based chemistry. Each manufacturer has a different configuration size and design for its battery. It is this variation in battery design and chemistry that the recycling of these batteries more specialized. [73]

To achieve a logical range, battery requirements for electric vehicles (EV) High capacity batteries are required. About 150 to 250 watts/mile consumed by a typical electric car concerning the Loads and driving styles. The battery ought to be able to operate at a normal deep discharging (80% DOD). [74]

A fundamental requirement, the design made to consider to maximize energy contents and providing maximum power, even in the instance of a deep releasing. A pattern of abilities will be established to accommodate vehicle demands of different types and shapes of the use of preference. [25]

If regenerative braking is needed, the acceptance must be extreme pulsing repeated load currents (above 5 ° C). Without regenerative braking, least 2C desired).

- Receive a complete charging regularly.
- It usually gets to the discharging almost wholly.
- The fuel gauge is extreme near the "empty" stage.
- Battery management system (BMS) is required.
- Thermal management is needed.
- Ideal voltage is more than 300.
- Ideal capacity is more than 20 - 60 kWh. Ideal discharging > 3 C for a short cycle.

[36, 61]

3.1.1 Battery Cell design and safety defects

Cell designing defects, like poor mechanical design, insufficient pressure vents and seals, poor material standards, and poorly determined tolerances may be in charge for different expected errors.

The application engineer cannot do anything to ensure the quality of the design of the cell. Unless you have enough qualification in physical chemistry and have expertise in component designation and reaching to many data on cell design and specialized tools like mass electron microscopes and spectrometers. However, what can do is to try to accelerate the life of the cell samples to check that they achieve the minimal reliability prerequisites for the suggested application. [74]

3.1.2 Voltage defect (overvoltage)

It is evident that the two problems are the effect of two excessive charging voltage, It has happened when the battery voltage is higher than recommended, ideally 4.2 volts [29].

- **Lithium plating**

Lithium-ion didn’t adjust quickly enough between carbon and concretion with high currents. lithium-ion is then deposited on the top of the anode at which they are contained in lithium metallic form. The result is a diminishing of freely present lithium ions and thus a loss of irreversible capacity. The coating could cause a short circuit between the electrodes, as it is not essential to be homogeneous, but dendritic.[75]

- **Overheating**

Excessive current also increases the heat transfer of the cell, along with an increase in temperature [75].

3.2 Battery Cell protection and safety requirements

The target of cell protection is to provide critical management and control for protecting cells against any out-of-tolerance situations, environmental and for protecting the consumer from the unpleasant events caused battery errors. The cell protection could be out of the battery, which is one of the main functions of the battery management system. [4]

The security of cells should take into account all the following unpleasant situations:

- Extreme currents while load or unload modes.
- Overloading and Overvoltage with a short circuit.
- Energized: exceeds predefined discharge depth limits.
- The temperature of high ambient.
- Excess heat levels that might override maximum cell level.
- Accumulation the pressure within the cell.
- When an accident happens, the system might be isolated. [31]

3.2.1 Safety requirement in the Battery industry

The most common Manufacturing process faults in the battery manufacturing level are:-

- A primarily automated plant with a famous name of the brand for protection.

A cell can be designed in the right way. However, its destination determined by the plant manager once it leaves the design lab and comes in the factory. In well-run businesses, this has not been an issue, but a poorly controlled production facility can impose many possible sources of cell outages. It is unlikely to become an issue. [76]

- Manual production methods

It is complicated for obtaining repeatability and accuracy using manually based mounting techniques, leaks, contamination, unreliable connections, and lack of efficiency means short circuits.[73]

Components outside of tolerance create problems similar to those of the imprecise set mentioned above.

- Burrs on the electrode current collector blades cause short circuits.
- The short circuit prevents cell capacity to reduce, increasing impedance, and to avoid heat to be dissipated. [75]
- The active chemicals contamination causes undesirable impacts that can lead to various cell failures, such as overheating,

Increased pressure, reduced capacity, increased impedance, self-discharge, and short circuits [71].

- Lubricants remain in the package materials.
- Use of alternative substances are not approved that leads to unnecessarily visible, but it indeed happens, Samples of tests may be required to prove it [77].
- Welding / sealing quality: This can lead to weak and unreliable connections and localized heat accumulation [78].
- Separator damaged during welding.
- Mechanical limitation Electrolyte release id the most likely issue in an individual cell. More giant cells will be more prone to cracking or splitting, which will also cause leakage or distortion, which means the cells may not fit inside the enclosure provided for this purpose.
- Poor sealing causes leakage and loss of active chemicals or water infiltration, corrosion, and possible safety issues.

- Quality systems and quality management. - After the design of the cell itself, these are perhaps the most critical factors that affect cellular failures. [1]

3.2.2 Battery Protection demands during manufacturing

Disassembly: The materials inside the disassembled battery are toxic and hurts the skin and damaged because of the poisonous substances.

Short circuit: The vital safety aspect isn't trying to short a battery. This short safety could damage the product and generate heat that can cause burns.

Battery Discarding in water or fire: Throwing batteries into a fire could result in rupturing and in avoiding the placement of the battery in the water as causing a fail.

Welding: The essential safety function in the welding process could not be able to solder any object directly to a battery, this process would damage the security functions of batteries by destroying the security ventilation in the inside cover. Soldering labels can make permanent connections to an energy cell to the terminals. Then, soldered respect for the name can make.[78]

The battery inserts in reversing polarities situation: it is ought to not put the positive and negative poles of the battery in an inverted fashion, as this actions might permanently destroy the battery, that could cause it to swell or break.

Charge: An unidentified charger or a specified charger that has changed, must not be used for charging. In this case, it could produce battery failure or its size swells and breakage. Never try charging a physically damaged battery.[79]

Overcharge with strong currents and reverse charge: It should never reverse the load or overload with high currents (i.e. higher than those with a nominal value). This situation will cause rapid gas generation and increased gas pressure, which will cause the batteries to swell or break—leaving batteries attached to the charger as soon as it is completely charging.[79]

Deactivate the Batteries: Applying the new and dysfunction batteries together Have to avoid. Also avoid the mixing between different chemical composition Also, such as ordinary dry batteries, and any other battery manufacturer's batteries.

The differences between several characteristic values may damage the batteries or the product and the storage space**.** It should keep up the battery in a cold place as well as avoid using them in environments that may overheat. (For example, direct sunlight in a closed car) Differences between several characteristic values may damage the batteries or the product. [80]

Warning and Other precautions: Batteries must always charge before use. It should make sure to charge it correctly. It must always be aware of including this safety cautions in entire rules of operation to limit driving to ensure safety. [15]

3.3 Battery management system BMS

BMS. For some, it merely is battery monitoring, which verifies the main operation settings while the charge and discharge processes, including current and voltage parameters, as well as the battery's ambient and inside temperature. The controlling chips are usually provided input to the safety applications that might produce warnings or disconnecting batteries from the loading or the charger if any of the settings are out of range. [81]

Design Battery management system: The controlling of the performance and safety of the battery, it is necessary to understand what should control and why it should control it. This requirement refers to the understanding of the fundamental chemistry of the cells, action properties, and modes of failures, specifically lithium-based ones. The battery would not be realized merely like a black box piece. [64]

BMS (Battery Management System) Functions: Protect battery cells from damages, Prolonging battery lifetime, Keep batteries in a status that meets the operational application specifications that characterized for this purpose.

The BMU develop ways for protecting battery-cells from functioning out-off the limited settings. Also, it makes an equilibrium of the charging status of each battery-cell for maintaining an equally-modulated voltage distribution on all battery-cells, avoiding overloads and discharges. Historical data collection may include in the BMU operational range that could be utilized to assess the situation in the event of maintenance of the battery system. [82]

BMS implementation: The main functions of BMS represents in three main components functions of the battery monitoring unit (BMU), the battery management system, the battery control unit (BCU) and the communication network of the CAN bus vehicle, as well as their interaction besides the reminder of power managing system. Other elements are likely to come along with the integrated business management system in the cell-to-battery interconnections. [71]

The powerful battery ought to be secure and be inside a protecting shield that can merely be accessed by suitable people, like electricians and installers. The batteries ought to be examined to determine the power of the battery management system and the risk of thermal leakage, overload, and overheating before being utilized in a given application.[79]

The safe use of recycled lithium-ion batteries in industrial purposes has listed as an International Electro-Technical Commission (IEC 62619 Ed. 1.0) standard. Since these secondhand-used batteries used in systems for which they implemented, other kinds of controllers have to be used and restarting the building management system to protect it against errors. [71]

In practice, the thermal management system or devices that deactivate the battery can also connect to the thermal management system via the CAN bus (see below) [83].

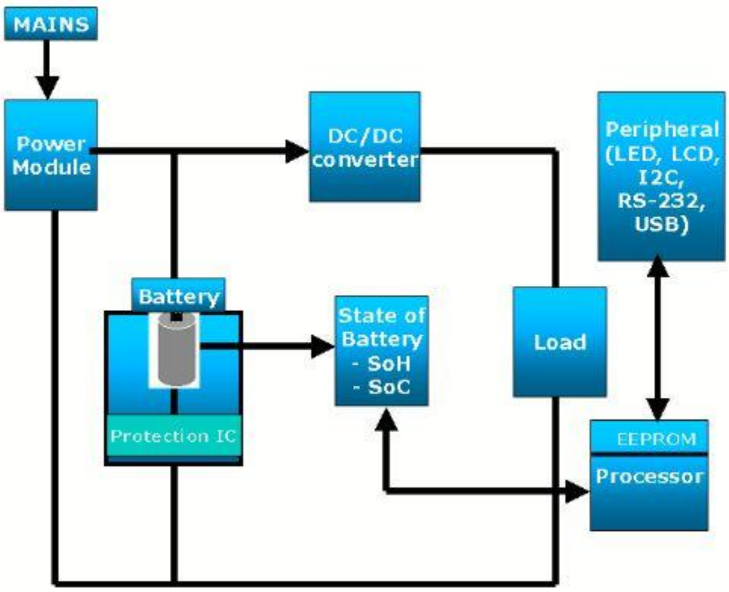

Figure 15 General structure of Battery management system [37]

Many other newly designed codes are created for the usage of lithium-ion battery types in fixed energy-saving facilities these recently developed prerequisites for instalment and energy usage saving systems. [71]

3.4 Battery Pack Recycling Repair

Most important features to improve repurposed battery pack.

3.4.1 The life cycle on Li-ion batteries LOC

The life cycle of lithium-ion batteries has explored by focusing on the comparison of recent acts for EV battery type at the end of its useful life, consider the potential for other useful applications. [20]

There is a significant reduction of greenhouse emission by 56%, or 24 tons of CO2 equivalent, during the total battery life of 18 years when reallocating battery for fixed energy storage applications. The sources of greenhouse gas reduction come mainly from the use of plug-in hybrid vehicles on conventional gasoline vehicles and the decline in the usage of natural gas facilities and coal with the expected use of renewable energy backed by an electric vehicle battery dual-use. [84]

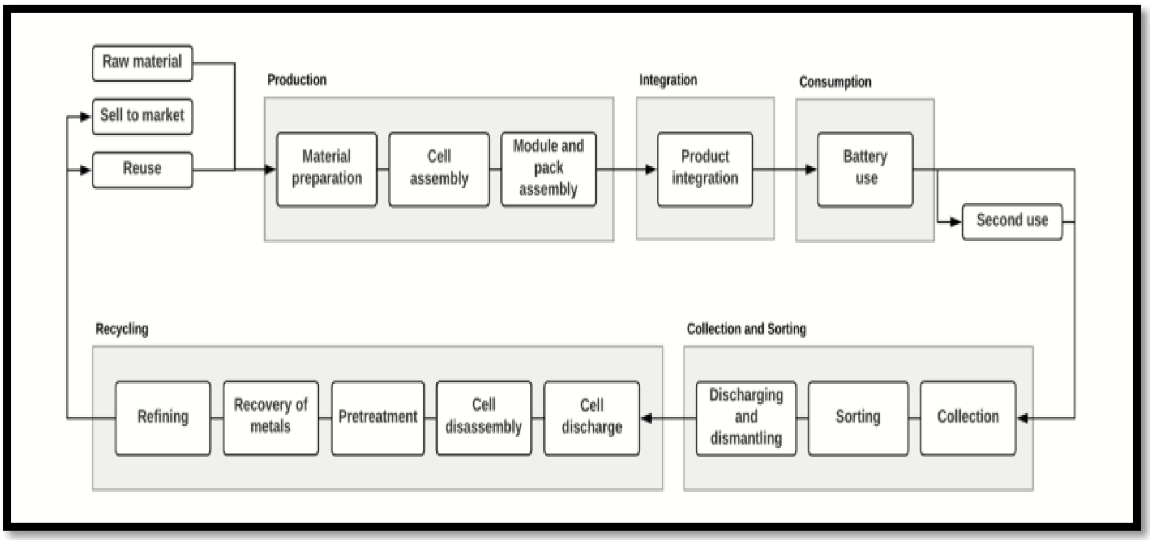

Figure 16 The life cycle of a li-ion battery diagram

Applied to other users, it offers high stability of configuration for electric vehicle batteries. Lithium-ion batteries must meet the changing needs of acceleration and deceleration that depend on the driver during the life of the car. However, during the next usage, fluctuations in demand and energy load are less critical, which allows the battery to keep longer its energy storing ability. Besides, when battery utilized in specific applications. [85]

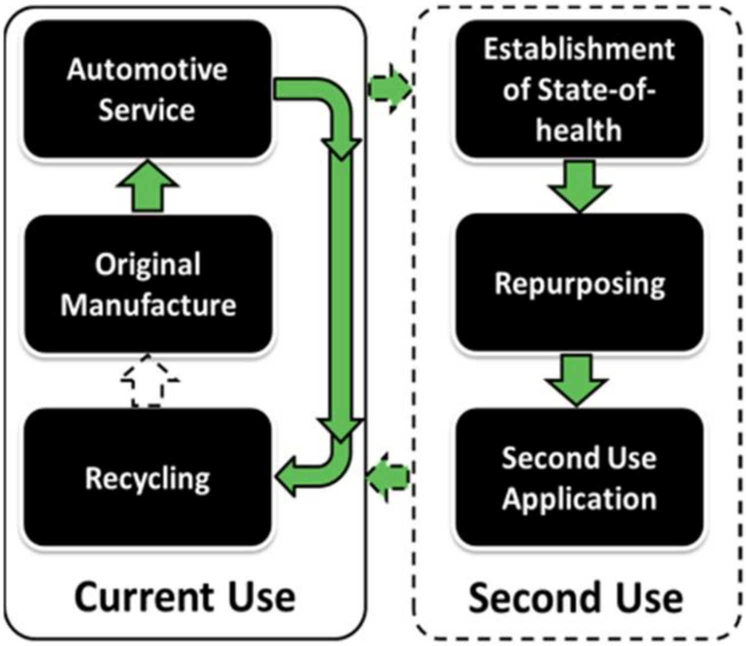

Figure 17 Electric Vehicle battery life cycle[18]

3.4.2 Battery pack status of charging SOC

The determination of batteries charging status is considered following the efficient functionality of the battery management system. SOC is deemed necessary for indicating the fuel measure. Moreover, to verify that the individual cells are not overloaded, BMS systems monitor and calculate the SOC of each battery cell in the battery. [21]

The SOC indicator again can be determined at the final stages of the loading and unloading cycles. Overloads, as well as excessive discharges, are a couple of the leading factors of battery's failure. The battery management system has to keep the battery-cells under the goal times of DOD. Operation thresholds. Hybrid vehicle battery systems need capabilities of high power for regenerative breakage and skills of high discharging power for assistance or launching impulse. [73]

For that purpose, the batteries of them have to be kept in SOC capable of discharging the required energy while maintaining sufficient margin to accept the necessary regeneration energy without the risk of overloading the cells. The full charge of the HEV battery for cell balance would decrease the charging acceptance capacity for regenerative breakage and, therefore, the efficiency of damage. [37]

Several new modules invented for the usage of lithium-ion battery types in fixed energy-storing facilities. These current setup prerequisites for installations and usage of energy storing systems. [49]

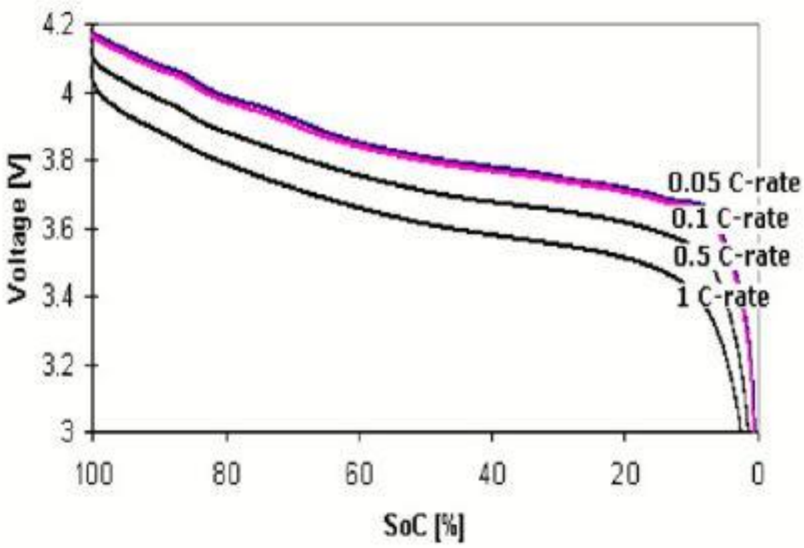

Figure 18 The Discharge rates in Li-ion cells. [37]

Lithium-ion State of Charge (SOC) measurement describes by Coulomb Counter.
[86] Panasonic group using HRL (Heat Resistance Layer) with the Technologies that improve the Lithium-ion batteries safety remarkably. Which contain insulating metal oxide on top of electrodes, that signifies that the cells would not reach to overheating even in cases of where short-circuit might occur. [37]

The SOC indication also determined by the end of the loading and unloading cycles. Overloads and excessive discharges are a couple of the leading factors of battery failure, as well as a battery management system has kept the cells within the goal of operational DOD boundaries. Hybrid vehicle battery systems need capabilities of high power for regenerative breakage and skills of high discharging power for assistance or launching impulse. [36]

For that purpose, the batteries of them have to be kept in SOC capable of discharging the required energy while maintaining sufficient margin to accept the necessary regeneration energy without the risk of overloading the cells. The full charge of the HEV battery for cell balance would decrease the charging acceptance capacity for regenerative breakage and, therefore, the efficiency of damage. [37]

The battery pack functions are same as to an "engine map" which saves the amount of the curves of engine performance subjected to variant operational situations utilized in the controlling systems which are deployed in modernized internally combustive engines. A small limit is set up to increase fuel consumption and to avoid excessively wasted discharges that would reduce the battery's lifetime. Therefore, specific SOC input is required for hybrid vehicles for keeping the battery running within the desired safety standards. [37]

3.5 Recoverable material statement

Recovered materials might be varying according to the cathode materials and recent costs. For the regulations perspective, the European Batteries Directive only requires the percentage of reclaimed materials. Otherwise, it would not need the materials recovered. [87]

It is common to improve the high-value documents as there are no obligations that control recycling specific materials. The recoverable metals of lithium-ion batteries are copper, cobalt, nickel, aluminium, lithium, steel, and manganese regarding the composition agreed-upon in section 4.3. About 57% of the composition of the battery made up these materials. [88]

Besides these materials, carbon and plastic would also be recovered, according to the process. The pure electrolytic components recovery has not yet reported, but it is considered a good idea to inform that. Nonetheless, the electrolyte represents only 3.5% by weight of the battery. This goal achieved by recovering only metal. [15]

Chapter 4

Challenges in Battery recycling

In this chapter, the challenging design methodology for the usage of spent lithium-ion battery kinds for fixed energy storage applications will show as the challenging in the solution of optimization of the battery recycling method has shown.

4 CHALLENGES IN BATTERY RECYCLING

4.1 Challenging in the future Demand

Large numbers of Battery packs that electric power cars are having thousands of battery-cells gathered in groups. The packages also have sensor reactors, safety system, and chip observing battery functionality, which increases more the complexity and more expenses related to detachment and recycle operations. The entire battery parts and components have to be recycled to get worthy materials and other metals. [83]

In contrary, acid-leaded batteries of vehicles would straightforwardly be dismantled and lead, which makes for approximately 60% of batteries' weight. That has fast detached out of the other batteries' parts. The global problem of electronic waste continues to grow in number and size. The increasing electrical penetration and electronic components in entire products considered unquestionable. Smart clothing is gaining more and more popularity in as same as electric cars and photovoltaic vehicles. [42]

Increasingly important in developed countries. Developing and transitional countries currently having a long path to follow to saturate the market for EEE products, a situation that has reversed in (post) industrialized countries because of rapid product innovation. [89, 90]
The requirement of unique materials such as lithium, cobalt, and graphite is associated with the constant growth in LIB batteries usage for electric cars [48]. The Consumer Electronics and network saving will increase the insisting need for e-cars would be offset partially, but not, by transformations in the core of information technology [8].

This implementation stage used exist to identify faulty analytical techniques to indicate failures that might occur and find solutions for resolving them. Also, reference has made to current standards for fixed energy storage devices and batteries of lithium-ion determining other possible design specifications. The advanced designs were constructed, demonstrating the viability of the application. In their future work, they offer an extensive analytical study of performance as well as security verifications of several banking configurations. [91]

However, situations have begun to be changed. New enterprises are promoting new recycling technologies of batteries motivated by the vast amount of depleted lithium-ion-based batteries hoped to be generated from the ageing of electric cars and ubiquitous small e-devises. Moreover, an increasing number of researchers has investigated the problem. They are widening the group of newly-trained graduate interns and postdoctoral students into battery recycling. Also, some battery, production, and recycling personnel have started to form extensive multi-faceted collaborations to address the impending problem. [92]

Typically, looking for the optimal chemical and battery implementations would provide some that meet everybody's needs, and batteries of any particular kind made as uniformed as possible. At least, recycling personnel will be capable of distinguishing one kind's standard features.[83]

Also, a distinction might be made to make the difference between one type and another for applying different technologies for each kind. Methodologies could be established to render the entire batteries to the end of their (first or second) lifetime. It might be straightforward to take the used ones to the proper recycling facility safely and legally. Easy to use tagging would facilitate routing. The legislation would ensure safety in transportation, addressing and discouraging all forms of crossed contamination. Routing/sorting can be instant, through transferring stations or in a standard recycle factory. [93]

4.1.1 Climate changes development in Recycling

Beyond to obtain the null-environmental emission effect and accomplish a net + result, the challenges, Climate change or the recycling of resources and water face challenges. However, we commit ourselves to continue our efforts until 2050 with sustained initiatives to achieve sustainable development with sustainable development. [94] In the life cycle, the Zero CO2 emissions, it refers to hard-work to annihilate CO2 produced not only during production and driving but in the production, disposal, and recycling processes of cars. For example, there are new generated technologies that can reduce CO2 emissions when driven, but in reality, they lead to an increase in CO2 Emissions during the manufacture of materials and vehicles. [42]

The manufacturers aim to extend battery life in partnership with automobile manufacturers. However, the ageing of cells makes batteries expired, and energy storage is no longer sufficient for the conductor. These cells can use in other less energy-consuming applications during their "second use," which allows for the most considerable possible delay of final recycling, intended to return to feedstock. In this situation enables the reduction of pollution resulting from the manufacturing, transportation (batteries manufactured mainly in Europe) and the final multi-treatment of these batteries. [95]

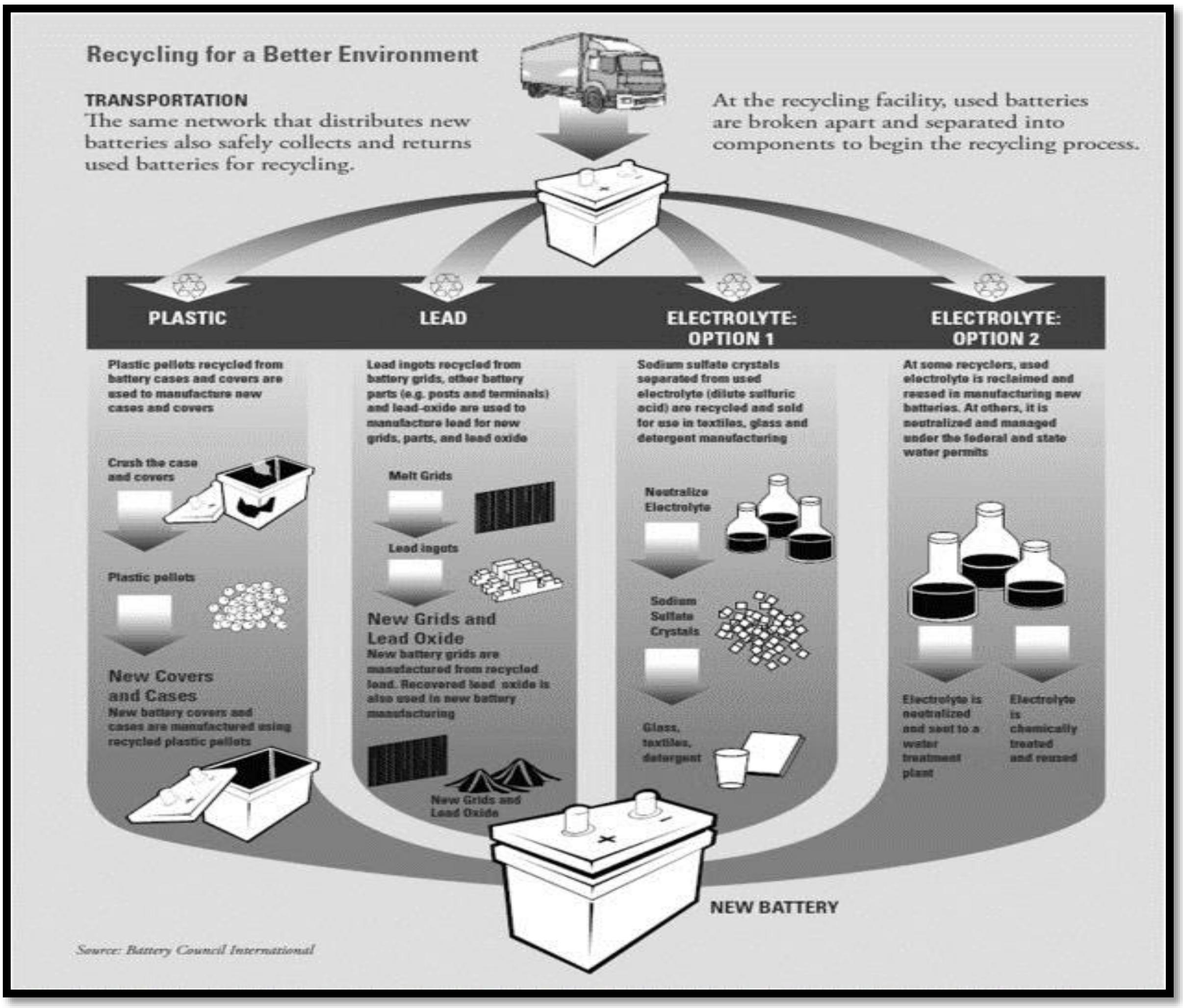

Figure 19 Recycling process for Better Environment impact

For this reason, it will continue to promote an ecological design, including the selection of appropriate materials. In this way, looking for a "better and better electric mobility." Ex. expanding and developing the use of materials that leads to less CO2 while. [96] Producing and reducing the number of parts and the number of components used in a vehicle. The adaption of the materials will also be recycled. For the production of vehicles and will strengthen initiatives to design vehicles that are easy to disassemble.

In this sense, since the launch of the Prius, the world's first electric passenger hybrid car, mass-produced in 1997, high-voltage batteries contain valuable resources such as nickel. With the purpose of battery recycling, to reuse these valuable resources in new batteries. [96]

4.1.2 Dynamic development on li-ion battery recycling

Lithium-ion batteries marketing raised significantly for another time in 2016, The 10,000 tons sold in Germany. This trend mainly drives by users' application listings, anyhow, many energy-storing applications built up its concerns in the industry field. The supply of automotive energy in Europe continues to contribute to moderate growth. Still, the potential market for SLI (rapid start-up and start-up of the vehicle) and electrical compulsions could be more in the user's market in a couple of years. [24]

The retention period between purchasing and collection was about 7 to 10 years for older battery applications such as NiMH and NiCad. Because of the technical properties of lithium-ion batteries and the short product designing time and, the total service life is shortened. Although lithium-ion batteries charging rates are predicted to remain below the obligatory goals: collection recycling systems must take into account the rapidly growing EOL cargoes. [2]

Accuracy is a medium-size recycling enterprise consecrated for battery recycling for 20 years. Accrue recovers industrial metals from 3,000 tons of NiMH and NiCad batteries per annum in its original installation, thanks to its latest-generation vacuum distilling technologies. To prepare for upcoming recycling obstacles, Accuracy begun an in-depth study into the lithium-ion batteries recycling in 2013. In parallel fashion, a new industry location was searched and found in Krefeld / DE to expand its capabilities and install its technique. [97]
After two years of approving, constructing, and installing a license, the facility of lithium battery recycling is prepared to operate from zero. More than 5 million kg of lithium batteries have been recycled since its inauguration.

Besides the transfer of general office to Krefeld, Accuracy focused on future growth. The installation incorporates an array: a classification and packaging building and mechanical processing building for thermally deactivated lithium batteries. The investment of 8.5 million euros also covers a high-end safety saving construction, provision of 600 m3 / m3 of water, fire, infrared and single temperature controlling corresponding 24h / 24 and 7d / 7. Heat treatment, still done today at the cooperation with Bayer's industries will integrate until 2019.[87] Accuracy will invest an additional € 5 million in the thermal deactivation and processing of lithium batteries, in particular, to maximize the effectiveness of the material, the focus lithium and graphite. Taking into account the recently ready buildings, one of the most significant lithium recycling locations worldwide was made available by Accuracy. [87]

4.2. Challenges in the mechanical condition

The investments made by SNM have made optimal use of the high-value assembly steps in these batteries. These steps have led to the emergence of "bromide" (a proper recycling process for liquid thermal treatment of electrical elements), which combines the basic principles of technology in the recycling process, with cost control. [2]

These automatic processes (crushing machine, density measuring devices, magnetic separators) provide crushing, screening into more precise particles with metal separation. [33]

Thermal steps (thermal analysis furnaces, distillation, and fusion) damage organic matter, absorbing contaminants containing cells, separating metals according to the melting temperature. The alloys sent to the melting furnace and the treatment of liquids are the final stage that allows the collection and purification of fine particles of molecules such as cobalt, lithium or rare-earth metals. Several electric vehicle manufacturing personnel, with the majority of them, have a variant battery implementation. Some of them use the batteries made by themselves. These designs lead to a large number of different types of screws that have applied for EV battery connections, and all screws are not accessible in the same direction. In the other hand, the flexible components, such as cables and hard to get access connections, like the plugging-in connecting devices of warehouse management systems.

Thus, intelligent and automatic recovery systems are essential for disassembly processes. Set of industry standards for electric vehicles are needed by the government. [1, 82]

4.3 The supply chain challenging on li-ion battery

Used batteries and technologies of innovations of recycling have a growing supplement by time. A large fraction of materials required to manufacture the new LIB batteries could be provided at the end of their useful life. Addresses most of the problems associated with batteries at the final stages of their active life, and highlights the necessity of recycling LIB from the value chain and environmental aspects. [83] Similarly, the discussion expected the recycling gain in global LIB supplying chains. Most of the current knowledge and experience in LIB production developed by companies providing services in the user's electronic market. Even before the development of electric cars, these manufacturing companies have made reliable supplying chains and gained remarkable production expertise. The final demands clarification of engines, the majority of the experience has given to the manufacturing of large-versions of LIB cells. [98]

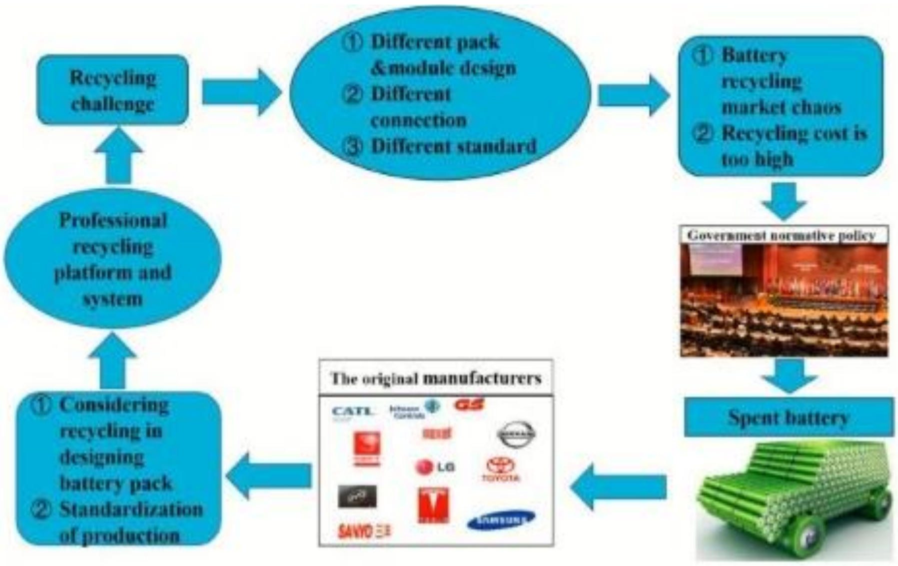

Figure 20 challenges the framework of Battery pack recycling. [3]

In the figure below shows the supply chain for PHEV battery cell and the recycling materials as the price in dollar currency of LIB package along with recycled parts.

Short-term LIB main challenges of recycling involve the shortage of environmental legislation for the collection and classification of LIB, the small sizes of batteries summed, the marginal level of government backup in a number nations and precarious balancing regarding the total recycling cost. By LIB. [99]

The restricted information existing on the economic aspects of recycling is one of the reasons that limit people number enthusiast in investing in this area. Contemporary recycling techniques assess high-value cathode components such as cobalt, nickel, and lithium and ignoring anodes and other parts of the pack. To ensure that all recyclable parts in dead batteries are recycled and not recycled, lessons learned from lead-acid battery recycling could be used to accommodate new environmental standards. [100]

4.3.1 Analysis of the supply chain

While recycling can provide an essential incentive for the future development of a primary component manufacturing sector, the battery pack manufacturer requires to handle a number of the issues confronting the new LIB supplying chains and propose a set of solutions for the short-term. To make sure for keeping the flow of raw materials, the sources via multi-year procurement agreements or direct collaboration with suppliers of essential materials. [96]

The challenges for short-term waste recycling involve the shortage of a useful battery collecting strategy, small sizes, and instability about the total cost of useless materials recycling. The recent lack of environmental legislation, the marginal backup from manufacturing personnel and the restricted information existent on the economic aspects of recycling caused in less BIL recycled at the end of its life compared to the number of lead-acid batteries –Acid. [46]

Recycled and NiMH and acid. Recently available recycling techniques evaluate valuable cathode parts while it does not include anode pole and other components. To ensure that all recyclable parts in used batteries are recycled or sent to monitored landfills or other locations where they might be neutralized to be less dangerous to the surroundings, regulations could be revised. [101]

The backed-up cathode parts might retain more than 20% in the total cost of LIB packages since the recovery of other materials, and parts of used batteries are potentially more profitable [102]. Nonetheless, the instance of acid-leaded batteries shows favourable economic factors might not be enough on their own as well as that an ordered engine might be vital for developing and maintaining the business [99].

4.4 The E-waste resources challenging

In recent years, producing and using electrical and electronic equipment (EEA) have increased, and recently, it became like part of our daily routine. It is observed that there is a reduction in the presence of household devices and a fast increase in the amounts of EEE waste (WEEE) thanks to the technological progression. Increasing quantities of WEEE, complicated materials resulted from mixing critical elements, and harmful materials in WEEE have been controversial due to its impact on the environment and health. In 2016, the global quantity of WEEE was 44.7 million tons and was predicted to be 52.2 in the year 2021. [103]

Enterprises around the globe are confronted with a large number of challenges in terms of waste management. In robust growing, current estimations reveal that about 20% or 8.9 Mt of produced electronic wastes are acuminated and properly recycled via the right ways. In the same context, about 4% (1.7 Mt) throwing in residual wastes in high-income nations. Concurrently, 76% (34.1 Mt) is unknown where it ends up. Anyhow, it is probably to be ignored, sold or being under recycling of less strict criteria, whereas lethal parts utilized in EEA are not possible. To be made available for regular uses, they might be risky at the final stages of their life: waste disposal and recovery. Therefore, attention must be given for the appropriate WEEE treatment. In these decades, the environmental policy of the European Union (EU) has drifted way remarkably from Recycling landfills, and reusability. [76]

In 1972, the Organization for Economic Cooperation and Development Cooperation and Development (OECD) had launched polluter pays principle (PPP). Recently, it is considered as one of the basic concepts of European waste standards and has deployed in WEEE standards. PPPs, as a global financial system, involving fees and taxes for consumers, producers, and waste management personnel. [104]

The situation in Europe the WEEE Directive (2002/96 / EC) was applied in 2003 in Europe to enhance the materials recovery of high-value materials and to lessen lousy influence on the environmental and health by raising the amounts of WEEE [100].

In this field, the quantity of WEEE in the EU27 could be in the range of 8.3 and 9.1 million tons in 2005 and the predicted presumption of the total yearly incremental rate of WEEE ranging between 2.5% and 2.7 %, it reaches 12.3 million tons in 2020. [105]

Currently, it estimated that about 9.9 million tons of WEEE (about 18.9 kg/inhabitant) collected nationally in the Member States by estimated that approximately 9.9 million tons of WEEE (about 18.9 kg/inhabitant) generated nationwide in the Member States by the UN University of Institute for Comprehensive study of Sustainability. [23]

Besides the different lethal substances, electronic wastes would also have several highly-valued materials. Indeed, more than 60 elements of the periodic table could look for in complex electronic parts like tablets and smartphones. The Environmental Management Group is a United Nations coordinating member for the environmental and man settlement invented in 2001. [100]

It has special programs, agencies, and UN organizations, involving secretariats. Multilateral agreements on the environment. In 2016, a Problem Management Group (IMG) on the treatment of electronic waste created by EMG. Using the knowledge and experience of GEM members, IMG involves the following goals:

- Strengthening the liaison and promoting policy initiatives and joint programmatic within the United Nations systems, in the field of electronic and electric wastes avoidance and its environmental effects control.
- Adding values to present mechanisms, programs, and projects, in particular by enhancing the ecological design as well as an approach to the IAS life cycle. [106]

Development:

The battery rechargeable technology introduces the use of electronic microprocessors to optimize performance battery and in the same time leads to a significant evolution, monitor charging, and discharging to improve safety and providing the consumer with all information regarding battery's state. The development process of the rechargeable Battery shows in the next points:

1. Load controlling. The microprocessors could control the battery while charging control, charging rates and charging transfer, through mechanical and chemical properties of the battery to cutoff charging or change with less charging rates or other billing methods. Always running currently a regularly based voltages load could control, The circuit integrates with the options into the channel for pulses load. [42, 73]
2. Download control also provided to manage conditions such as downloading. The cutoff voltage at the end of life (to avoid Overloads), equalization of the cells and

degree monitoring single battery-cells, and the complete battery, could monitor for maintaining battery-cell equilibrium. [107]

3. Indicator of charging Status. The remaining capacity of the battery can be estimated by these devices, which are named "gas meters," taking into account variables such as speed and discharge time, temperature, self-discharge, speed and charging time. [36, 73]

Chapter 5

Results and Outlook

This chapter presents the main Aim of the Thesis has been submitted and how can Lithium-ion battery recycling process developed through (Advanced lithium-ion materials, the market managed in the Global market, Zero impact on the environment)

5 RESULTS AND OUTLOOK

The new Batteries technologies with high energy density and lower cost with the better functions in deactivate battery pack is the essential demand in the future. There are in the thesis some solutions and technologies, include additives advanced materials to obtain the best features in SOC Battery. In which improve the performance of the new generation lithium-ion batteries, it presented more excellent stability and allowed batteries to work more safely, increasing range and reducing costs. And for the high-performance materials also respond to the requirements of other electrification applications.

S.Renault, D Brandell, and K.Edström quoted as clarifies that The Batteries effects on the environment negatively. This effect is not only appearing at the final stages of their active lifetime, but it also has a negative impact long before its make. By deactivating the Battery pack for the E mobility As in the previous chapters, the development of a process capable of recovering the material and Safety requirements of such safety applications are only possible to improve the deactivate battery pack [49].

All recycling methods demonstrate that they are economical at large size with the recent prices of raw materials, also the compositional structure of the battery. Nonetheless, the inverted supplying chains for electric vehicles ought to be optimized to maximize commercial recycling gain. Rather than the exploiting of raw substances, Recycling has less impact on the environmental. Instead of replacing the dysfunction Battery with a new one, the latest market demand will be launched. The New electrical and electronic applications can repair the faults in the battery. To improve battery functions, keeping in mind the manufacturing, recyclability, recycling and life-cycle footprint of all kinds of technologies, the strong and growing demand for Li-ion batteries, driven primarily by the market of electric and hybrid cars. In the current situation, the requirements for developing battery technology influence the electronic power component. Distinguish the added value needed. Early identification of key technology trends in battery packs and new battery applications will provide a competitive advantage to power electronics operators. The bottleneck of the EV / HEV feeder is the one that moves and shapes power electronics and battery supply chains.

Direct recycling can generate fewer emissions and energy than hydrometallurgy and pyrometallurgy. It could be utilized to restore used cells for recovering pure cathodes and anode powder material that requires minimal treatment before putting them back into the cells. From 2009 to 2014, the selling rate of hybrid and electric vehicles increased with increased fuel expenditure, which was raised by the state to make the fleet of cars free of carbon and clean by choosing some vehicles [28]. The members of E- mobility manufacturers have prepared contributions aimed at raising the maximum recycling of batteries at different stages of life.

Economic perception: According to the battery cell tested, to identify potential problems that can encounter during battery recycling. Precisely, if simple situations do not meet the specifications of Recycling processes, it leads to issues related to the safety of the people involved in the recycling process.

Production waste: The wastes contain heavy metals analyzed and treated as a result of the manufacturing process of batteries. These results mainly relate to dust and dust from the filtration process or sludge from the plant and facility cleaning plant.

Security: Damaged batteries will replace during the EV warranty period. For example, on Toyota experience, Toyota decided in 2013 to extend the battery warranty period of ten years instead of five years as before and for a distance of 175,000 kilometres.

Impact vehicles: Some vehicles that crashed during the accident (especially fire) have destroyed. The economically irreparable takes into account, the batteries are either collection the scene or the centres that deal with the vehicles, which are out of order which depends on the case.

End of operating life: A statements below published by the Directive 2000/53/EC of the European Parliament and the Council on End-of-Life Vehicles L 269/34 2000; Reuter et al. 2013) as the voltage reduction range utilized by 200 mV for every term raising cycle life remarkably [4].

Cycled modules that have not enough energy with more than 20% capacity leak would not go through dramatic temperature leakage. The modules and battery-cells from spent batteries could be reused for a second chance applications specimen cells from different places in batteries must go through prolonged meticulous physical (destructive) and electrochemical analysis to provide default changes in the cells. Damage to the electrode, separators or other cell parts, the cells and modules should not be reused if the changes are significant such as extensive delamination and lithium plating, besides, internal resistance, a baseline on capacity, charging/discharging curves, etc. should report in before another usage, and the properties monitored to verify the safety during the second life chance.[108]

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LIST OF ABBREVIATIONS

BEV Battery Electric Vehicle
ELV End of life Vehicle
Ev Electric Vehicle
E-Bike Electric Bicyclical
EVs Electric vehicles
HEV Hybrid-electric Vehicle
LCO lithium cobalt oxide
LIB lithium-ion battery
LFP lithium iron phosphate (Li Fe po4)
NMC Lithium Nickel Kobalt Manganerze
LFP Lithium Manganerze Phosphate
NCA Lithium Nickel Kobalt Aluminium Oxide (Li Ni-Co Alo2)
LMO Lithium Manganerze Oxide (LI Mn2 O4)
LCO lithium cobalt oxide (LI Co O2)
PHEV plug-in hybrid vehicle
RUL remaining useful life
NIMH nickel-Metall hybrid
NiMH Nickel-Metall hybrid
WEEE Waste electrical and electronic equipment
MMU Model Management Unit
RE reference electrode
SOC state of charge
SOH state of health
BMU Battery management unit
BMS Battery management system
EOL End of life Vehicle
LCA Life cycle assessment
PPP Pollution pays principle
EEA electric and electronic equipment

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