ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 6, Issue 10, October 2017

Recycling of Lithium Ion Battery (LIBs)-An Analysis of Benefits and Challenges

D Saravanan

Department of Electrical Engineering, Galgotias University, Yamuna Expressway Greater Noida, Uttar Pradesh, India

Email Id: saravanan228@gmail.com

ABSTRACT: With the rapid growth of the electric vehicle industry around the world, the amount of lithium ion batteries expended has increased. Combined with current literature and market research, Lithium-ion battery (LIB) applications in consumer electronics and hybrid and electric vehicles are increasing rapidly, resulting in increased demand for resources, including cobalt (Co) and lithium (Li). Battery recycling would therefore be a critical step, not only to reduce energy usage, but also to reduce scarcity of scarce resources and remove emissions from unsafe materials, towards sustainable consumer electronics and hybrid and electric vehicles industries. This paper calculates the economic benefits of lithium ion battery recycling in terms of the unit of the LiFePO4 (LFP) battery and Li (NiCoMn) O2 (NCM) battery. Analyzing the recycling processes of LIBs, it is hoped that this initiative would stimulate more interest in and understanding of the benefits of spent LIBs recycling. This paper analyzes and addresses the recycling of lithium ion batteries with their estimate, the estimate of the quantity of spent power batteries, the recycling of economic benefits, the problems and the development of methods.

KEYWORDS:*Economic Benefits, Battery Recycling, Challenges, Energy Consumption, Electric and Hybrid Vehicles, Lithium Ion Batteries (LIBs)

I. INTRODUCTION

With the inexorably expansive use of electric vehicles, power battery industry encounters a spray of development, and in the interim yielding an expanding volume of spent battery. In 2012, the business volume of electric vehicle was only 11,375, yet it arrived at 409,000 of every 2016. Furthermore, Ministry of Industry and Information suggested that the creation volume of electric vehicles and module cross breed electric vehicle ought to be 2,000,000 by 2020. As the center segment of the new vitality vehicle, the force battery showcase shows a pattern of flare-up after the strongly ascent of new vitality car. The force battery creation bounced to 28 GWH in 2016 from 3.7 GWH in 2014, an expansion of in excess of multiple times. In China, under the normal driving condition that the yearly mileage of vehicles is around 16,000 kilometers, the lifetime of LiFePO4 (LFP) battery is assessed 4-6 years, while the lifetime of Li (NiCoMn) O2 (NCM) battery is around 3-5 years. Driven by the quick take-up of battery electric vehicles, batteries are progressively reused in fixed vitality stockpiling frameworks, and in the long run reused to recuperate all the esteemed parts. On the off chance that present patterns for taking care of these spent batteries hold, the vast majority of those batteries may wind up in landfills despite the fact that batteries can be reused [1].
Battery recycling is a recycling activity that seeks to popular the number of batteries disposed of as urban solid waste. Batteries contain a variety of heavy metals and hazardous chemicals, and are disposed of in the same way as normal garbage has raised questions about soil contamination and water pollution. Lithium-ion batteries and lithium-iron phosphate (LiFePO4) batteries also include, among other useful metals, high-grade copper and aluminum in addition to cobalt and nickel transition metals and rare earths, depending on the active content. In order to avoid a future shortage of cobalt, nickel and lithium and to enable a sustainable life-cycle of these technologies, recycling processes for lithium

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 6, Issue 10, October 2017

batteries are needed [2]. These processes need to recover [3] not only cobalt, nickel, copper and aluminum from spent batteries, but also a significant proportion of lithium [4]. These mainstream power packs contain significant metals and different materials that can be recouped, handled, and reused. In any case, spent force battery packs will hold roughly 80% of their vitality execution, and the reusing business visionaries can increase a few incomes by recuperating the gainful mental.

Regardless of whether the dies down or financial motivations are essential concerning the reusing battery's monetary advantages and what sort of arrangements ought to be taken to adequately understand the total reuse have not been talked about to date. To fill this hole, this paper expects to conjecture the financial benefit of reusing the spent force batteries at the present circumstance and afterward give explicit strategy suggestions. There are different sorts of intensity batteries, including LiFePO4 arrangement (LFP), LiMn2O4 arrangement, Li (NiCoMn) O2 arrangement (NCM), Li (NiCoAl) O2 arrangement (NCA), and LiCoO2 arrangement. Because of the security, solidness and high cycle limit of LiFePO4 battery and the high vitality limit of NCM battery, these two batteries represent about 95% in Chinese market in 2015.Therefore, it has been quite recently taken LFP battery and NCM battery as the intermediary to investigations in this paper [5].

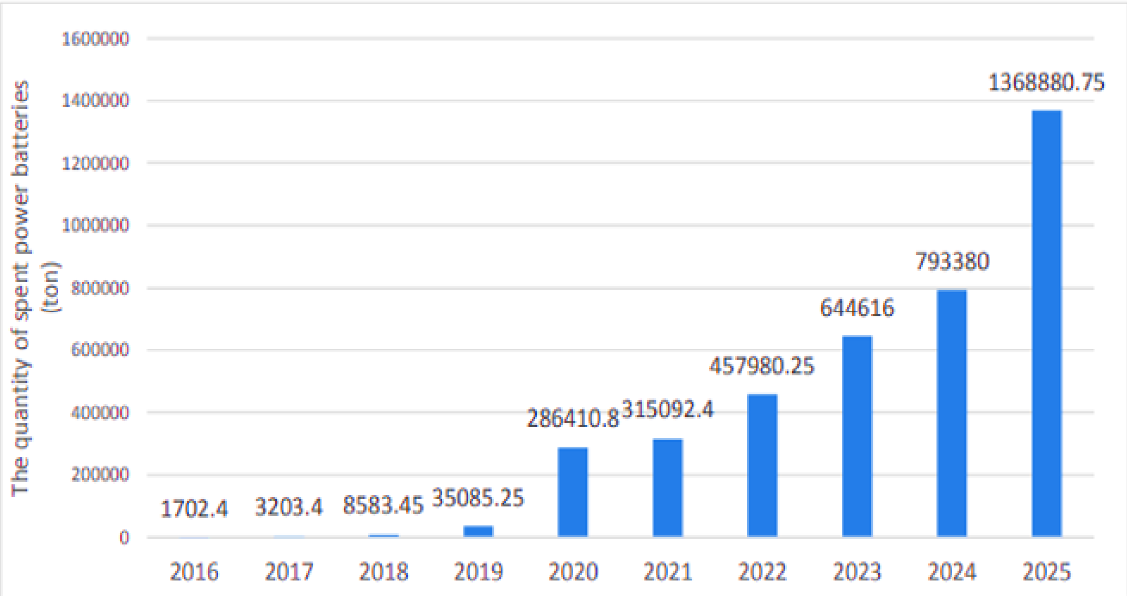

Figure 1: Estimation of Spent Power Battery Quantity

II. SPENT POWER BATTERY QUANTITY ESTIMATION

Lithium particle batteries are broadly utilized in cell phones, workstations, camcorders, and other current life apparatuses. Because of their attributes of light weight, high vitality and great execution these batteries are progressively filling in for different batteries. The life expectancy of a LIB is 1-3 years. The colossal development in the utilization of LIBs has brought about the age of a lot of squanders as spent LIBs. Inappropriate removal of these batteries may cause genuine ecological issues. The assessed amount of the spent force battery is 28.6 thousand tons in 2020 and 1.36 million tons in 2025. In spite of the fact that the substitution from understudy ignition motor to control batteries is viewed as vitality sparing and ecological amicable, and the LFP batteries and NCM batteries don't contain mercury, cadmium, lead or other poisonous overwhelming metals, this doesn't imply that power batteries are totally

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 6, Issue 10, October 2017

non-dirtying items. The stunning amount of intensity battery contains a lot of nickel, cobalt, manganese, poisonous electrolytes, natural synthetic compounds and plastics, representing a hazard on human wellbeing, water and soil contamination if not appropriately discarded. In this manner, how to adequately reuse the huge measure of spent batteries is a critical undertaking to determine. As a developing natural and social issue, the reusing arrangement of spent [6] force battery has not been adult, consequently, government guideline is a basic part of building up the reusing system. Consolidated existing literary works and the market overview investigation, this paper assesses the nature of spent force batteries, as shown in figure 1.

III. BENEFITS OF RECYCLING

Battery experts and environmentalists have provided a tremendous amount of encouragement to reuse batteries. The materials recuperated could be utilized to make new batteries, bringing down assembling costs. As of now, those materials represent the greater part of a battery's expense. The costs of two basic cathode metals, cobalt and nickel, the most costly segments, have varied generously lately. Current market costs for cobalt and nickel remain at generally $27,500 per metric ton and $12,600 per metric ton, individually. In 2018, cobalt's cost surpassed $90,000 per metric ton. In numerous kinds of batteries, the centralizations of these metals, alongside those of lithium and manganese, surpass the focuses in characteristic minerals, making spent batteries likened to profoundly improved metal. On the off chance that those metals can be recouped from utilized batteries at a huge scope and more financially than from regular metal, the cost of batteries and electric vehicles should drop. Notwithstanding potential monetary advantages, reusing could decrease the amount of material going into landfills.
Cobalt, nickel, manganese, and different metals found in batteries can promptly spill from the packaging of covered batteries and taint soil and groundwater, undermining biological systems and human wellbeing. The equivalent is valid for the arrangement of lithium fluoride salts ($LiPF_6$ is normal) in natural solvents that are utilized in a battery's electrolyte. Batteries can have negative ecological impacts toward the finish of their lives as well as some time before they are made. As Argonne's Gaines calls attention to, all the more reusing implies less mining of virgin material and less of the related ecological mischief. For instance, digging for some battery metals requires handling metal-sulfide metal, which is vitality concentrated and transmits SOx that can prompt corrosive downpour. It has been contemplated that this issue utilizing computational techniques to show how developing battery creation could influence the geographical stores of various metals through 2050. Recognizing that these expectations are "convoluted and questionable," the analysts found that world stores of lithium and nickel are satisfactory to continue fast development of battery creation. Be that as it may, battery assembling could diminish worldwide cobalt saves by over 10%.

IV. ECONOMIC BENEFITS

It is understood that the recycling of lithium-ion batteries decreases energy usage, decreases greenhouse gas emissions and results in substantial savings in natural resources compared to landfills. However, it is not clear which recycling methods have the least environmental impact.

Recycling Revenue, Expense and Profit:
The spent power batteries include a quantity of cobalt, nickel, lithium and other precious metal. The recovery revenue was estimated by calculating the mental values of each battery.

$$\mathrm{R} = \sum_i^m P_i * \alpha_i * \beta_i$$

Where R denotes the recycling revenue of each battery; is the primary commodity market price for the mental one; is the mental composition quantity of that type of battery, and is the recycling rate of each mental one; m is the number of mental types; this paper includes cobalt, nickel, lithium, manganese, iron, aluminum and copper as a valuable mental one, i.e. m is equal to 7. Relevant criteria have been adopted. Recycled revenues of spent LFP batteries and NCM batteries It is noted that the content composition of spent batteries will vary between different types of batteries (Table 1):

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 6, Issue 10, October 2017

Table 1: The Recycling Revenue of Spent LPF Batteries and NCM Batteries

Metal	Prices (Rupees/Ton)	Composition (Kg/Ton 100kwh)		Recycling Rate	Recycling Revenue (Rupees/100k WH)
		LPF	NCM		
Cobalt	443,000	0	49.00	89%	0
Nickel	98275	0	81.00	62%	0
Lithium	860000	9.00	9.88	80%	6186
Manganese	10900	0	30.18	53%	0
Iron	660	72.00	0	52%	25
Aluminum	15380	65	87	42%	422
Copper	53510	83	112	91%	3950

To mirror the present circumstance, the estimation of materials is acquired from the present product metals costs from the site of Shanghai nonferrous metal work. The arrangement parameter and recuperation are acquired by writing audits and the examination of makers. The vitality limit of an electric vehicle is around 50 KWH, with its 500 kg mass. Yet, while computing the cost, he doesn't unmistakable the battery types and not take the capacity cost and transport cost into thought. In light of the writing sees and the statistical surveying of battery makers and reusing ventures, this paper gauges variable expense and fixed expense of spent LFP batteries and NCM batteries individually [7]. The reusing expenses of spent force battery incorporates two sections: variable expenses and fixed costs, fluctuating from power battery limit, reuse innovation level, geographic area and different components.

Variable expenses are subject to the volume of reused batteries while fixed expenses allude to the work compensations, rents of plant, and devaluation remittances of hardware and consistently keep steady inside a monetary year. In light of the other writing sees and the statistical surveying of battery makers and reusing ventures, this paper gauges variable expense and fixed expense of spent LFP batteries and NCM batteries individually. The material reuse cost implies the cost that recyclers pay to the battery proprietors. As indicated by this overview, the reusing of LFP batteries doesn't have to pay charges or the expense is sufficiently little to be overlooked at current circumstance. The expense to pay the spent NCM batteries embraces the half estimation of the cobalt and nickel organization. The embellishment material expense and fuel cost are taken from different written works. The pre-treatment cost and condition dealing with costs are acquired from different literary works and the examination. Fixed expenses incorporate the deterioration stipends of plant development, apparatus gear, reusing system development, and upkeep of hardware. The remaining an incentive for fixed resources is set as 5% and the depreciable lives are set as 10 years and 30 years for hardware and plant, separately.

At current circumstance, the reusing of both spent LFP batteries and spent NCM batteries are gainful, with the benefits of 36144.67 rupees/ton and 1, 87,123.77 rupees/ton, separately. Note that the reusing benefits are firmly identified with metal costs. At present, because of the popularity of new vitality vehicle industry and shortage of assets, particularly cobalt, it has been accepted that the metal cost won't strongly decrease temporarily, in this manner, the force battery reusing is beneficial, in any event, is to adjust of installments [8]. Along these lines, with the huge scope spent force battery gathered and the procedure proficiency improved, the activity costs that have been circulated to unit battery would be lower. As far as monetary advantages, some different focuses as;

Economic Incentives Are Not Necessary:

As indicated by the above examination, the reusing of battery is gainful, in this way, there is no requirement for government to take no extra financial impetuses, as dies down or charge decrease. Driven by interests, the business visionaries would naturally take on the reusing and exhaustingly boost the recuperation rate. Be that as it may, if the additional financial impetuses were given, a few organizations were slanted to take casual measures, similar to sponsorships duplicity, which is ominous to the market rivalry.

Create the Mandatory Recycle Mechanism:

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 6, Issue 10, October 2017

Without the economic incentives, it does not mean any regulation is unnecessary. The government should establish compulsory recycling mechanism by legislations or regulations, to ensure the closed loop circulation of power batteries. During a normal life of an electric vehicle [9], it needs at least two batteries and the battery replacement is unavoidable. This paper suggest that power battery replacement should be complied with "old change new". Car makers and battery suppliers must collect the spent old power batteries before giving the new batteries to replace. Automotive scrappagestage is another key stage of spent battery collection. It has been suggested that only by the spent batteries remove from the automobiles to the recycling network, the scrap automobiles can enter the following dismantling process. Note that these regulations should be implemented on the basis of information trace back and management platform.

Stipulate Requirement For Recycling Companies:

Unlike all devices, power batteries pose a possible risk to human health and the environment if they are not adequately handled. So, the government should license qualified recyclers. The authorized contractors should be equipped with secure storage or disposal facilities and all recycling processes should comply with environmental requirements. It has been proposed here that electric car producers, battery producers and waste disposal contractors with an electronic waste management certification should be more conducive to licensing.

V. CHALLENGES IN RECYCLING BATTERIES

Similarly as monetary elements can put forth the defense for reusing batteries, they additionally present the defense against it. Huge vacillations in the costs of crude battery materials, for instance, cast vulnerability on the financial aspects of reusing. Specifically, the ongoing enormous drop in cobalt's value brings up issues about in the case of reusing batteries or repurposing them is a decent business decision contrasted and producing new batteries with new materials. Essentially, if the cost of cobalt drops, reused cobalt would battle to contend with mined cobalt as far as cost, and producers would pick mined material over reused, compelling recyclers bankrupt. Another drawn out budgetary worry for organizations considering venturing into battery reusing is whether an alternate sort of battery, for example, Li air, or an alternate vehicle drive framework, similar to hydrogen-controlled energy units, will increase a significant toehold on the electric-vehicle advertise in coming years, bringing down the interest for reusing batteries. A few batteries use cathodes made of lithium cobalt oxide (LCO). Others use lithium nickel manganese cobalt oxide (NMC), lithium nickel cobalt aluminum oxide, lithium iron phosphate, or different materials. Also, the extents of the parts inside one kind of cathode for instance, NMC can fluctuate generously among producers [10]. Cathodes for the most part comprise of an electrochemically dynamic powder (LCO, NMC, and so on.) blended in with carbon dark and stuck to an aluminum-foil current authority with a polymeric compound, for example, poly (vinylidene fluoride) (PVDF). Anodes typically contain graphite, PVDF, and copper foil. Separators, which protect the cathodes to forestall short-circuiting, are slender, permeable plastic movies, frequently polyethylene or polypropylene. The electrolyte is regularly an answer of $LiPF_6$ disintegrated in a blend of ethylene carbonate and dimethyl carbonate. The parts are firmly wound or stacked and pressed safely in a plastic or aluminum case.

VI. IMPROVING RECYCLING PROCESSES

A few huge pyrometallurgy, or refining, offices reuse batteries today. These units, which regularly run close to 1,500 °C, recoup cobalt, nickel, and copper however not lithium, aluminum, or any natural mixes, which get scorched. The offices are capital serious, to some degree in light of the need to treat the emanation of poisonous fluorine mixes discharged during purifying. Hydrometallurgy preparing, or concoction draining, which is rehearsed industrially in China, for instance, offers a less vitality serious other option and lower capital expenses. These procedures for removing and isolating cathode metals by and large run underneath 100 °C and can recuperate lithium and copper notwithstanding the other change metals. One drawback of customary filtering strategies is the requirement for scathing reagents, for example, hydrochloric, nitric, and sulfuric acids and hydrogen peroxide. Analysts running seat scale contemplates have recognized potential upgrades to these reusing techniques, yet just a bunch of organizations run reusing tests on the strategies at the pilot-plant scale. In the Vancouver, British Columbia, territory, an American

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 6, Issue 10, October 2017

Manganese office changes over 1 kg/h of cathode scrap to an antecedent that producers can use to blend new cathode material. Scrap alludes to off-spec cathode powder, trimmings, and other waste gathered from battery fabricating. As indicated by the vital specialist Paul Anderson, "an away from to support the monetary effectiveness of battery reusing through computerization". With that in mind, the group is creating mechanical techniques for arranging, dismantling, and recuperating important materials from batteries. Albeit the greater part of these methodologies stay at a beginning period of advancement, the requirement for them is developing [5]. As of now, the quantity of end-of-life electric-vehicle batteries is low, yet it's going to soar. Various obstacles disrupt the general flow of huge scope reusing, yet "openings consistently exist together with difficulties". It's an ideal opportunity to attack the issue in earnest and quit fooling around about reusing batteries.

VII. CONCLUSION

Highly growing demand for electric vehicles now and the growing usage of electronic equipment and electrical equipment and electric and hybrid vehicles eventually result in increasing requirements for the use of rare and costly materials, such as cobalt, lithium, copper or aluminum, used in the preparation of lithium-ion batteries, which are the key source of electrical power these machines and appliances. On the other hand, lithium-ion batteries used can explode or leak and cause damage to human health or to the environment in the event of improper disposal or further treatment after the end of the life cycle. By calculating the revenues and costs of recycling in the current case, the recycling of spent energy batteries has been found to be profitable even though the consumer value has marginally decreased or the composition of the consumer has changed. It has also been proposed that the government will not take any economic opportunities to promote recycling. What matters most for the government is the implementation of the relevant legislation and regulations, the creation of a mandatory recycling system and the prevention of illicit recovery. Creation and enhancement of the collection system for batteries which are subject to recycling should be improved, both from a technological point of view and from a legal normative point of view, in terms of legal regulations and other regulations.

REFERENCES

[1] T. G. Goonan, “Lithium use in batteries,” *US Geol. Surv. Circ.*, 2012, doi: 10.3133/cir1371.
[2] B. Huang, Z. Pan, X. Su, and L. An, “Recycling of lithium-ion batteries: Recent advances and perspectives,” *Journal of Power Sources*. 2018, doi: 10.1016/j.jpowsour.2018.07.116.
[3] B. Swain, “Recovery and recycling of lithium: A review,” *Separation and Purification Technology*. 2017, doi: 10.1016/j.seppur.2016.08.031.
[4] K. Richa, C. W. Babbitt, G. Gaustad, and X. Wang, “A future perspective on lithium-ion battery waste flows from electric vehicles,” *Resour. Conserv. Recycl.*, 2014, doi: 10.1016/j.resconrec.2013.11.008.
[5] W. Lv, Z. Wang, H. Cao, Y. Sun, Y. Zhang, and Z. Sun, “A Critical Review and Analysis on the Recycling of Spent Lithium-Ion Batteries,” *ACS Sustainable Chemistry and Engineering*. 2018, doi: 10.1021/acssuschemeng.7b03811.
[6] C. Liu, J. Lin, H. Cao, Y. Zhang, and Z. Sun, “Recycling of spent lithium-ion batteries in view of lithium recovery: A critical review,” *Journal of Cleaner Production*. 2019, doi: 10.1016/j.jclepro.2019.04.304.
[7] D. Lisbona and T. Snee, “A review of hazards associated with primary lithium and lithium-ion batteries,” *Process Saf. Environ. Prot.*, 2011, doi: 10.1016/j.psep.2011.06.022.
[8] M. Foster, P. Isely, C. R. Standridge, and M. M. Hasan, “Feasibility assessment of remanufacturing, repurposing, and recycling of end of vehicle application lithium-ion batteries,” *J. Ind. Eng. Manag.*, 2014, doi: 10.3926/jiem.939.
[9] G. Harper *et al.*, “Recycling lithium-ion batteries from electric vehicles,” *Nature*. 2019, doi: 10.1038/s41586-019-1682-5.
[10] A. Väyrynen and J. Salminen, “Lithium ion battery production,” *J. Chem. Thermodyn.*, 2012, doi: 10.1016/j.jct.2011.09.005.