

Environmental Impacts of Battery Recycling

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Abstract: The production of rechargeable batteries, particularly lithium-ion batteries, can have significant environmental impacts. These are recycled by grinding them, neutralizing the acid, and separating the polymers from the lead. The recovered materials are used in a variety of applications, including new batteries. The lead in a lead–acid battery can be recycled. These include the environmental cost of mining lithium and other materials, the energy-intensive production process, and the challenges associated with recycling. Recycling provides many benefits to our environment. By recycling our materials, we create a healthier planet for ourselves and future generations. Conserve natural resources: Recycling reduces the need to extract resources such as timber, water, and minerals for new products. This article will primarily describes the impact of battery recycling and the benefits of battery recycling.

Key Words: Batteries, Recycling, Impact and Benefits on Environment, Remedies to Reduce.

I. Introduction

As the world shifts towards sustainable energy, lithium-ion batteries (LIBs) are increasingly being used in electric vehicles (EVs) and grid-connected storage applications. India is no exception, with the government pushing for local manufacturing of lithium cells to meet the growing demand. However, there are several challenges in making the LIB value chain sustainable, including limited resources, environmental hazards, and geopolitical risks. Promoting recycling can overcome these challenges and create a circular economy for LIBs in India.

Battery recycling offers significant environmental benefits by conserving resources, reducing pollution, and promoting a circular economy, but it also presents some environmental challenges that need careful management (Bai, 2020). Recycled batteries mean fewer materials going into landfills. Recycled batteries conserve natural resources. Recycled batteries can be used to produce energy. Furthermore, lithium mining processes are responsible for: **Water and air pollution:** brine extraction can lead to pollution of air and water in the areas surrounding the operations. **Land degradation:** usage of huge amount of lands and deforestation might occur to sustain the business and need for lands. Batteries that end up in landfills may eventually corrode and decay, releasing dangerous chemicals into the environment—including battery acid! These chemicals can seep into our soil, water sources, and even the air. This is bad for both our environment and our health. Most batteries contain hazardous materials and can pollute the environment when disposed of in landfills or when thrown out elsewhere. Materials like lead, cadmium and mercury can poison people and animals and contaminate soils and water, and they stay in the environment for a long time.

Recycling batteries also helps to conserve natural resources such as rare earths, zinc, copper, iron and manganese, reducing the need to mine new materials (Vartha, <https://www.varta-ag.com/en/>) Recycling can be considered as one of the ways to control pollution because recycling is the key to reducing the wastage of some useful materials. Recycling aims at environmental sustainability by substituting raw material inputs into and by redirecting waste outputs out of the ecosystem. Recycling batteries also helps to conserve natural resources such as rare earths, zinc, copper, iron and manganese, reducing the need to mine new materials. This helps to preserve the environment and reduce the carbon footprint associated with mining and manufacturing new batteries. Recycling helps boost the broader economy by creating more productive and cost-effective industries. Some vital economic advantages include job creation and expansion of different markets,

Recycling batteries offers numerous advantages, primarily centered around environmental protection and resource conservation. It reduces landfill waste, conserves natural resources by recovering valuable materials, and prevents pollution by keeping toxic components out of the environment. Furthermore, battery recycling can create a circular economy, reduce reliance on mining, and even generate cost savings and new job opportunities.

Significant Environmental Impacts of Battery Recycling

As we move towards a more sustainable future, it is crucial to look closely at all aspects of the supply chain and resource management. Lithium-ion batteries are the most commonly used battery type used, and recycling lithium-ion batteries reduces energy consumption and greenhouse gas emissions and results in considerable savings of natural resources compared to landfill. This article will primarily describes the impact of battery recycling and the benefits of battery recycling.

Negative Environmental Impacts

Rechargeable lithium-ion (Li-ion) and lithium-polymer (Li-poly) batteries have recently become dominant in consumer electronic products because of advantages associated with energy density and product longevity. However, the small size of these batteries, the high rate of disposal of consumer products in which they are used, and the lack of uniform regulatory policy on their disposal

means those lithium batteries may contribute substantially to environmental pollution and adverse human health impacts due to potentially toxic materials.

Recycling can also have negative environmental impacts. For example, the process of recycling paper requires the use of chemicals and large amounts of water and energy. Similarly, recycling plastic can release harmful pollutants into the air and water. While recycling batteries, especially lithium-ion, offers significant environmental benefits, it also presents several potential negative impacts if not handled properly. These include the release of harmful chemicals, fire hazards, ecosystem disruption, and missed economic opportunities. Recycling can also have negative environmental impacts. For example, the process of recycling paper requires the use of chemicals and large amounts of water and energy. Similarly, recycling plastic can release harmful pollutants into the air and water. The production of rechargeable batteries, particularly lithium-ion batteries, can have significant environmental impacts. These include the environmental cost of mining lithium and other materials, the energy-intensive production process, and the challenges associated with recycling.

Though battery recycling is crucial for mitigating the environmental impact of battery production and disposal, it's essential to recognize and address the potential negative impacts associated with the recycling process itself. Implementing robust regulatory frameworks, promoting safe and efficient recycling technologies, and raising public awareness are crucial steps in minimizing these negative impacts and maximizing the benefits of battery recycling. In some of the Li-ion batteries, the leached concentrations of chromium, lead, and thallium exceed the regulation limits. The environmental impact associated with resource depletion and human toxicity is mainly associated with cobalt, copper, nickel, thallium, and silver, whereas the eco-toxicity potential is primarily associated with cobalt, copper, nickel, thallium, and silver.

Benefit from Battery Recycling

Recycling of batteries can generate a source of rare metals, which are required for the cell component manufacturing but not readily available locally. By using recycling technologies, 95% of metals can be recycled for use in manufacturing new batteries, reducing the dependence on imports. However, India is not yet prepared for the waste that will be generated by the use of LIBs in EVs and grid-connected storage applications. The current pieces of legislation that are in effect do not include a strict set of rules for the safe disposal of EV batteries. Without a well-established recycling ecosystem, these batteries could end up in landfill and contaminate the soil and groundwater (MiniMines Cleantech Solutions Private Limited, 2022) Moreover, informal recycling could contribute to environmental hazards since toxic gases are released during pre-treatment and treatment processes. On the other hand, a well-established recycling ecosystem could help in price discovery for end-of-life (EOL) batteries, which in turn will encourage the key stakeholders along the LIB value chain to participate in the recycling and avoid the unsafe disposal of batteries in the country. Thus, battery recycling can help avoid the negative effects of batteries on the environment.

Recycling offers numerous environmental and economic benefits but also presents some challenges. It conserves resources, reduces pollution, and saves energy, but can be costly, inefficient, and may not always be effective due to contamination and limited markets for recycled materials. Scientific researchers have claimed that recycling batteries can save 51.3% of natural resources. The recycling of batteries will contribute towards conserving our natural resources, saving energy, and reducing greenhouse gas emissions. The used and old batteries can be repaired.

Recycled batteries mean fewer materials going into landfills. Recycled batteries conserve natural resources. Recycled batteries can be used to produce energy. Recycling is crucial for the Earth because it helps conserve natural resources, reduce pollution, and mitigate climate change. By reusing materials, we lessen the need to extract new raw materials, which in turn reduces deforestation, mining activities, and energy consumption associated with manufacturing. This helps protect ecosystems and wildlife habitats while also decreasing greenhouse gas emissions. In the chart below you will find a succinct collection of illustrative examples that highlight the beneficial results of battery recycling.

General Benefits of Battery Recycling

Battery recycling offers a wide range of benefits to everyone involved, from individuals to businesses and the environment. By participating in battery recycling efforts, everyone can contribute to a more sustainable and resource-efficient world (Fig.1).

Keeps harmful chemicals out of the environment

One of the main benefits of battery recycling is that it keeps the chemicals in batteries out of the environment. When batteries are disposed of in landfills, toxic chemicals and metals leach into the soil and groundwater. The lead, cadmium, and lithium contained in batteries are some of the worst environmental pollutants, and disposing of them in a landfill introduces them into the environment.

Conserves non-renewable resources

Batteries are made from non-renewable natural resources. Copper, lithium, silver, mercury, and cobalt are all non-renewable resources needed to make batteries. In addition, some of the resources used in batteries are scarce. If we are to increase the supply of lithium by 2030 and continue the EV revolution, recycling is urgently needed.

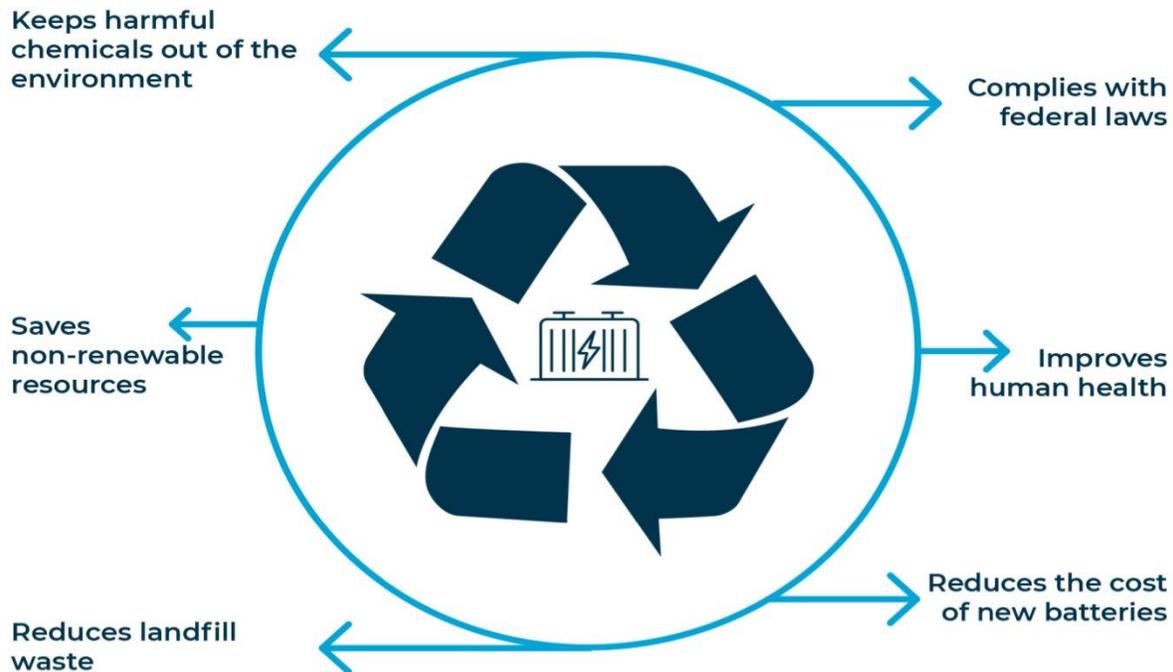


Fig.1 General Benefits of Battery Recycling

Reduces landfill waste

Batteries are often replaced before they're fully used. Too many of these batteries end up in landfill. The waste of lithium-ion batteries means that as we move towards EVs, we're using up our lithium reserves before we have even started the transition.

Complies with federal laws

Federal laws in some countries require sealed lead-acid (Pb) and nickel-cadmium (Ni-Cd) batteries to be recycled rather than dumped in landfills. The problem with small batteries is that they are easy to throw away. Many companies offer a service to recycle batteries when you return them, and some landfill sites have battery recycling schemes.

Improves human health

Heavy metals are toxic and harmful in your home, in the environment, in manufacturing plants, and in the mines where they're extracted. The more we have to mine and process these raw materials, such as mercury and lithium, the greater the toll they take on human health and communities from start to finish. Worse, when we throw batteries away and allow them to leak into the soil and water, we contaminate the resources we need to survive with heavy metals and acids.

Reduces the cost of new batteries

As with all recyclable items, new materials made from recovered materials cost less than those made from virgin materials. It is much cheaper to recover materials than to mine, transport, and refine new materials. Furthermore, if materials recyclers are located near factories, there is minimal transport costs associated with reusing the materials.

Reduce the impact of batteries on the environment

Recycling creates a closed-loop system where unwanted products are returned back to manufacturers for use in new products. This prevents the pollution and destruction that occurs when virgin materials –like trees and precious metals– are extracted from the earth. Battery recycling plays a vital role in minimizing the environmental impact of lithium-ion batteries. By implementing efficient recycling programs, we can recover valuable materials from used batteries, reducing the need for extensive mining and minimizing resource depletion. The latest technologies in battery recycling sustainably optimise material recovery and reuse while reducing the impact on the environment (Illa Font and Carlos Henrique, 2023)

Challenges in Battery Recycling

Geopolitical risks are also a significant challenge in making the LIB value chain sustainable. China leads LIB cell manufacturing with around a 51% share in global cell manufacturing capacity. The country also manufactures a significant amount of cathode materials, anode materials, and electrolyte materials globally. Without current manufacturing facilities for cell components, India is expected to depend on imports from neighbouring and developed countries to cater to the growing LIB market. Metal prices

could fluctuate as a result of supply chain disruptions, political instability, pandemics, etc., which could directly affect the price of batteries and associated products.

India's Advantage in Battery Recycling

The pandemic has exposed business risks as a result of disruptions in the global supply chain, especially from China, resulting in a long lead time for raw material deliveries. However, India could take advantage of these situations by attracting both global and domestic recyclers to set up LIB recycling facilities in India. The recent war between Russia and Ukraine has also affected the supply chain of key battery metals like nickel and aluminium, along with crude oil. The dependence on imports for these key materials will certainly impact the local supply chain of batteries.

Challenges and Constraints in The Management of Recycling

Used battery processors must take the initiative for sustainable material management of waste batteries by implementing state-of-the-art monitoring and tracking technology (Thomas, V. M., and Popov, V., 2024). Although the current regulations are in place, application regulation is increasingly in demand. Recovery and reprocessing of batteries pose several challenges, but simultaneously, they give possible prospects for technological innovation. The biggest problem in this sector is the domination of an unorganised recycling sector that poses tremendous risks to safety and the environment (Orb et al., 2024). The significant issues are data management, asset tracking, safe transportation and storage, and disposal (Bhattacharjee and Roy, 2024). Fluctuating metal prices complicate the industry, making profit margins in recycling activities uncertain. For efficient and profitable lithium-ion, a plant must operate on a large scale, and it is estimated that for a 20,000 metric tonne plant, the required investment will amount to anywhere between Rs 270 to 350 crores (<https://www.cseindia.org/content/downloadreports/11803>). Therefore, priority investments are needed, and new, locally relevant technologies are essential for cutting costs. The two main issues linked with lithium-ion batteries are dependence on virgin material mining and the risks associated with landfill disposal. Hydrometallurgy, pyro-metallurgy, direct recycling, and integrated carbo-thermal reduction remain favoured recycling methods to minimise such issues. Hydrometallurgy is widely considered for higher recovery, as up to 96% of materials from a battery are without much emission (Chen, 2023). Among the EV battery recyclers in India, 80% of the units have adopted hydrometallurgy, while the remaining applies mechanical or chemical-free processes (Gahlaut et al., 2024).

II. Conclusion

In conclusion, battery recycling offers substantial environmental benefits by conserving resources, reducing pollution, and promoting a circular economy. However, it's essential to address the potential challenges associated with energy consumption, pollution from recycling processes, and the complexity of recycling different battery chemistries. Investing in research, development, and implementation of sustainable recycling technologies is crucial to maximize the positive environmental impact of battery recycling. Sustainable battery recycling helps decrease soil and water degradation, reduces air pollution, and reduces environmental impact. The latest technologies and the use of renewable energy can enhance these benefits. Informal recycling can harm the environment and public health. Therefore, stricter rules are needed. Improving battery recycling in India requires urgent financial support and incentives to set up new recycling facilities with clear rules, proactive partnerships between public and private sectors, and greater public awareness about the need for proper battery disposal.

More research is needed to understand the informal sector, explore new technologies, and learn from successful international models. This research shows India's battery recycling industry offers several commercial and environmental advantages. The government and recycling companies can build a sustainable recycling industry, supporting a circular economy and helping create a greener future. Battery recycling and reuse are crucial in creating a sustainable and circular economy for LIBs in India. By promoting recycling, the dependence on imports for rare metals can be reduced, and the negative effects of batteries on the environment can be avoided. A well-established recycling ecosystem can also help in price discovery, making it economically feasible for the key stakeholders along the LIB value chain to participate in the recycling and avoid the unsafe disposal of batteries. India must prioritize the establishment of a battery reuse/recycle ecosystem to achieve its sustainable energy targets and reduce its dependence on imports.

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