VERTIV WHITE PAPER

Addressing Common Misconceptions Surrounding Lithium-Ion Battery Recycling

Executive Summary

Lithium-ion (Li-ion) batteries have become increasingly common in the data center, but skepticism regarding the costs and sustainability of recycling Li-ion persists thanks in large part to inaccurate or out-of-date information and total cost of ownership (TCO) calculations. The common belief is that most Li-ion batteries end up in a landfill, and those that are recycled are done so using a furnace process that melts everything down and leaves everything but the reclaimed metals totally unsalvageable.

While this process may have been commonplace five years ago, a growing number of companies are using recycling processes that recover more of the valuable elements in the battery while minimizing or eliminating waste byproducts. Not only do these companies provide a viable option for recycling Li-ion batteries sustainably, but in many cases, the value of those salvaged elements found in the batteries can offset the overall costs of the recycling process.

This analysis will discuss what trends are driving these new recycling processes, how they work, how they compare with other battery recycling methods, what makes certain Li-ion batteries more valuable, and other considerations for recycling Li-ion batteries.

Background

Li-ion batteries are a common power source for millions of consumer devices, powering everything from cell phones, laptops, and power tools to hybrid and self-driving vehicles. The research of three scientists in the 1970s and 1980s led to the development of today's Li-ion batteries. Americans M. Stanley Whittingham and John B. Goodenough developed the initial chemistries used in the batteries, and Akira Yoshino of Japan, created the first commercial rechargeable Li-ion battery, which was adopted in 1991 by Sony for powering hand-held camcorders. In 2019, all three received the Nobel Prize in chemistry.

While the technology has been around for decades, Li-ion batteries first appeared in data centers approximately five years ago. Li-ion batteries are used with uninterruptible power supply (UPS) systems as a means of ensuring uptime for mission-critical infrastructure in data centers. Year after year, Li-ion batteries are becoming increasingly popular for their reliable performance, low maintenance, small footprint, reliability at high temperatures, and high power density. Li-ion batteries can last as much as four times as long as valve-regulated lead-acid (VRLA) batteries, which results in fewer battery replacements and lower labor costs. With their smaller size and weight, Li-ion batteries for UPS systems save space, improve location flexibility, and address limited floor weight thresholds. However, because Li-ion is a relatively new technology in the data center, the need for recycling those Li-ion UPS batteries is in its infancy compared to the automotive sector.

Li-ion battery recycling technology first gained traction when the volume of batteries used in the automotive sector became too significant to ignore. At the moment, Asia produces more than 90% of the world's Li-ion batteries, and China alone owns 44% of the world's electric vehicles. To keep pace with that consumption, China was an early mover on Li-ion recycling technology. It's important to note that while Li-ion batteries are tailored to specific applications (so those used in data centers aren't exactly the same as those used in cars or laptops or cell phones, for example), the recycling process can be the same for all types. Those facilities built to recycle all those automotive batteries can just as easily recycle Li-ion batteries from data centers.

While Europe is a significantly smaller producer and consumer of Li-ion than Asia, the EU Commission is looking to increase its Li-ion recycling efforts, a move that falls in line with the European Union's long track record of environmental and regulatory progress. If this plan were to come to fruition and there were more regulations centered on Li-ion recycling, we could expect to see greater investment and innovation in developing the technology.

Compared to China and Europe, the United States has been slower to mandate Li-ion battery recycling, particularly in the data center sector, but the economic benefits of recycling the valuable metals within Li-ion batteries is spurring more innovation.

It's also important to remember that Li-ion batteries remain relatively new to the data center space, and the first generation of those batteries are still in use and likely years away from retirement. There is time to build the recycling infrastructure needed for Li-ion.

The Recycling Process for Modern Li-ion Batteries

When a Li-ion battery reaches the end of its life and is transferred to a recycling facility, the battery is first discharged so there is no residual energy being stored. Then, the battery is broken apart either by manual disassembly or by placing the battery modules in a mill where they are crushed. No matter the process, what remains is a pile of small granules that go through a filtering process of shaking powder through sieves to separate materials by particle size. Materials used to build Li-ion battery electrodes like copper and aluminum are recovered during this process.

What's left after this step is what's known amongst the recycling industry as the "black mass," or a black, grainy powder that's finer than sand, but doesn't float in the air. Black mass contains all the active, high-value materials that make up much of the cost in manufacturing Li-ion batteries. Recycling companies will often use a chemical process known as hydrometallurgy, which is a process of using aqueous solutions to separate and recover metals from the black mass. This approach is able to recover up to 98% of the battery's elements, and through chemical separation, the materials reach the purity level of battery-grade materials that are needed to make new batteries.

Common Valuable Materials Found in Li-ion Batteries

Four key, valuable metals used in Li-ion batteries in the data center are cobalt, nickel, lithium and manganese.

In recent years, cobalt has received the most attention, mainly because, as one article states, half of the world's reserves of cobalt are in the Democratic Republic of Congo, where child labor issues pose ethical and sustainability concerns. The same article mentions that half of the world's lithium resources are in South America's "lithium triangle," where mining companies have been accused of exploiting workers and destroying local habitats. Therefore, efforts to source cobalt and lithium responsibly have greatly increased its price.

Manufacturers looking for alternatives have turned to recycled cobalt, or "urban mining," which allows them to source cobalt from used batteries, rather than the earth. Unlike cobalt and lithium, nickel and manganese are not so geographically concentrated and therefore easier to source.

In terms of monetary value to recyclers, nickel is a distant second to cobalt. However, nickel remains valuable for its increasing role in energy storage systems. Battery manufactures are also moving towards high-nickel, or cobalt-free, battery design to increase energy density and reduce the reliance on cobalt, which further increases demand for nickel and pushes up prices.

Lithium is obviously the common thread found in all Li-ion battery chemistries, but it is still less valuable to recyclers than cobalt and nickel. That's because there is often only small traces of it in each battery. But to address the previously mentioned concerns regarding lithium mining, we may see more organizations looking for recycled lithium as a way of sourcing it through more ethical means.

Manganese is not as geographically concentrated and not as valuable at the previously mentioned metals, so from a recycler's standpoint, there is less of a business case than that of cobalt, nickel and lithium.

Most Common Battery Chemistries in Today's Market

For recycling companies, the more cobalt and other valuable materials found in a battery after it is processed, the more money they can make by recovering it and selling it back to the supply chain. Therefore, it's important to note the three most common Li-ion battery types found in the market and what their value is relative to their chemistries.

- **NMC** (nickel manganese cobalt oxide) has the highest recyclability value, because of the presence of cobalt and nickel. Current recyclers are already making profit recycling NMC batteries.
- **LMO** (lithium manganese oxide) holds modest value because it lacks cobalt and nickel.
- **LFP** (lithium iron phosphate) holds the least value of the three, with lithium being the only valuable material. While Li-ion batteries provide many cost-saving benefits, in some cases the value of the materials of an LFP battery may not cover all the recycling costs.

Environmental, Health, and Safety Impact

Over the years, much more attention and resources have been paid to the recycling process of VRLA batteries, for two reasons: (1) the well-documented health and environmental effects associated with the lead found in these batteries; and (2) the preponderance of VRLA batteries, which are used in most automobiles and in most UPS systems in the data center industry. To better meet public safety requirements related to lead, there has historically been a much stronger push to mature and improve VRLA battery recycling technology and processes.

Li-ion batteries may not be as environmentally harmful as lead batteries, but a staggering number of Li-ion batteries currently end up in landfills. In 2019, of the 180,000 metric tons of Li-ion batteries available for recycling, more than half ended up in a landfill. The vast majority of those were used in discarded consumer electronics, which presents a different challenge, but the point remains.

Sustainably minded companies will need to work with emerging Li-ion recycling companies to develop scalable recycling plans and Vertiv has already started.

Leading Players Moving Li-Ion Battery Recycling Forward

As previously discussed, government pressure and world-leading Li-ion battery consumption rates have kept China at the forefront of developing recycling technology and infrastructure. So, it should come as no surprise that China was the first country to build a modern Li-ion battery recycling plant to scale. In 2019, CATL, the world's largest producer of Li-ion batteries, invested in its Li-ion recycling subsidiary, Guangdong Brunp, to offer a closed-loop system for battery production. The plant underwent an expansion earlier this year and currently has an annual waste-battery disposal capacity of 120,000 tons.

While North America has yet to build anything to scale, recent industry news has many people feeling optimistic about the future of Li-ion battery recycling in the region. As demand for Li-ion batteries grows, several manufacturers working to lessen dependency on mining for precious metals have garnered serious attention over the last few years. In North America, Li-Cycle, a company that recovers Li-ion materials and reintroduces them back into the supply chain, made its debut as a public company in 2021. Last year, Ascend Elements, a manufacturer of advanced battery materials using valuable elements reclaimed from spent lithium-ion batteries, secured more than $780 million in funding to assist with the commercialization of its closed-loop process. Another emerging company making a splash in the industry is Redwood Materials. Founded by Tesla co-founder, J.B. Straubel, the company is already the biggest Li-ion battery recycler in the U.S. and plans to build a $1 billion, million-square-foot factory that, upon completion, would make it one of the largest battery materials factories in the world.

North America is also moving further along in the realm of end-of-life battery transportation with companies like Veolia, which handle and transport a number of different waste streams, including Li-ion batteries, and are working to become a logistics provider for the industry. All these companies and the money they've raised in private and public markets clearly indicate that the industry is, indeed, becoming a more viable business model and will likely undergo massive growth in the coming years.

End-of-Life Li-ion Battery Transportation

Typically, recyclers want full truckloads of batteries with common chemistry to arrive at the same time, because it's more efficient for their operations. Currently, there are few companies that will collect and transport small volumes of Li-ion batteries. Additionally, transporting large numbers of recyclable Li-ion batteries presents the same regulatory challenges found with transporting new Li-ion batteries.

As the recycling processes mature, Li-ion recycling companies will be able extract more materials from each battery, which will offset costs related to transportation. Therefore, we can expect to see more investment in transportation and logistical operations, which will reduce costs and increase convenience for data center operators looking to dispose of their batteries.

Disassembly Advantages for Data Center Li-ion Battery Recycling

Compared to the automotive industry, data centers have some distinct advantages when it comes to disassembling used Li-ion batteries prior to recycling them. The first thing to consider is that the battery of an electric vehicle is held within a large, watertight enclosure, making it cumbersome to extract. There are also a considerable amount of electronics and a cooling system in an electric vehicle battery. These components add considerable weight to the battery, and when it is brought to a recycler there's a larger share of unwanted materials the recycling company must manage.

In the data center, individual Li-ion battery modules are placed in a cabinet. The control system of the battery is physically separated, so when the battery modules are ready to be recycled, removing them from the system is much easier and there's less of a burden for the recycler because there's less non-battery content to segregate. These advantages improve the economics of Li-ion recycling of data center batteries in comparison to those from electric vehicles.

Conclusion

Industry experts predict the number of electric vehicles on the road will increase from 10 million in 2020 to upward of 145 million by 2030, and while the exact figures are not yet available, we can expect Li-ion demand in the data center to see a similar rise.

The technology already has claimed a significant share of the data center UPS market. Additionally, Bloomberg anticipates a "Golden Age" for battery recyclers as battery retirements are expected to grow by the millions. And while Li-ion recycling is still in its early stages in North America, the need to lessen our dependency on mining for these precious metals is already driving stronger investment in developing this new kind of recycling technology.

For data center operators, the material value of recycling Li-ion batteries has caused some recyclers to start paying for used NMC battery modules, but other chemistries may still involve a modest cost to recycle. Fortunately, the recycling of both contribute to an organization's sustainability efforts by diverting these batteries away from landfills. However, these initiatives will depend on emerging recycling companies to scale-up processes that make economic sense for both sides, such as closed-loop business models, reliable logistical networks, and adherence to regulatory standards.

Li-ion battery recycling is possible, and the combined efforts of all the major players in China and North America have made it clear that there is serious demand and investment opportunities in this technology. With so much intrigue building around Li-ion battery recycling, it is only a matter of time before this process is convenient, profitable, and sustainable for all parties involved.

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