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Recycling Li batteries could soon make economic sense

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Twenty-five years after Sony launched the first commercial Li-ion battery in 1991, the rechargeable battery has found its way into billions of smartphones, laptops, and other devices.

The world's appetite for Li-ion batteries is on a steep rise. In the fall of 2015, the number of electric vehicles on the road passed the one million mark, their sales driven by growing markets in China and Norway. Millions more could be sold in the next decade. Electric carmaker Tesla Motors has promised to start mass production of lithium batteries at its Gigafactory in Nevada this year, and will also start selling smaller batteries for homeowners to store solar energy. Utilities, meanwhile, are beginning to install large batteries to store intermittent solar and wind power and to supply power at times of peak demand.

Unfortunately, unlike the lead-acid batteries used in the overwhelming majority of today's cars, nearly all Li-ion batteries could end up in the landfill once they cannot hold enough charge.

Almost 99% of lead-acid batteries in the G7 nations are recycled today, mainly because they are illegal to dump and there is a profitable system in place to collect and recycle them. Recycling lithium batteries is far trickier because of their varied chemistries and packaging. And while a handful of companies are doing it, today's lithium battery recycling processes might simply not make economic sense for new battery chemistries. That's because they strip the batteries down to their elemental building blocks, many of which have little economic value.

Besides, the world does not produce enough lithium batteries yet. "Right now, the tonnage of Li-ion batteries is miniscule," said Timothy Ellis, president of RSR Technologies, a part of the EcoBat Group, the world's largest recycler of lead-acid batteries. "The lead industry uses 12 million tons of lead a year. The total for lithium ion, all active materials combined, is about one hundred thousand tons a year."

But the use of active Li-ion materials is expected to more than triple to over 300,000 tons by 2025. With rising demand, experts believe that the economics could soon reach a tipping point in favor of recycling lithium batteries. Tipping the scale will require economically viable recycling technologies and battery designs that keep recycling in mind.

Safely collecting and recycling lithium batteries could mitigate environmental and safety hazards. The batteries contain potentially harmful metals such as and cobalt and nickel; flammable electrolytes; and fine particulates like graphite and metal oxides. "We don't want to find out what happens after they've been in the environment too long," said Ellis, who is also chairman of the Society of Automotive Engineers' (SAE) Battery Recycling Committee.

Smoking batteries aboard airplanes and fires in laptops and hoverboards have prompted investigations into the safe construction and packaging of lithium batteries. But that concern does not go away at the end of the battery's life. Discarded batteries may retain some charge and could be hazardous in sizeable numbers in storage facilities or landfills. Recently, Li-ion batteries have wound up in lead-acid battery recycling plants, causing explosions.

A growing market for lithium batteries will also step up demand for materials. Recovering usable metals and compounds from batteries would alleviate the need for mining raw materials, which would "take some volatility out of pricing," Ellis said.

A small fraction of lithium batteries are recycled today. In the United States, California is the only state that bans batteries from the trash, but most are still believed to end up there. Even in Europe, where a Battery Directive was made law in 2006 to encourage Member States to collect and recycle all batteries, about five percent of Li-ion batteries are collected for recycling. By September this year, EU member countries are supposed to collect 45% of batteries sold, but at least 14 countries will miss the target.

"They have a clear policy and they're not doing all that much better," said Linda Gaines, a transportation systems analyst at Argonne National Laboratory. "Environmental regulation in Europe is very strong because they believe it's the right thing to do. In the US, we tend to look at economics. So we need a financial incentive."

That is the crux of the issue: how to make lithium battery recycling profitable.

To understand the challenges of recycling lithium batteries, it's worth a look at their 150-year-old workhorse cousins. Lead-acid batteries are recycled more than any other consumer product, largely because lead is toxic and its disposal is heavily regulated. But the technology itself, and hence its recycling process, is simpler. The batteries come in a uniform size and shape and contain only lead plates, sulfuric acid electrolytes, and polymer cases, which are all easy to pull apart and recycle; the lead and plastic go back into new batteries, while the electrolytes may be reused in batteries or converted into sodium sulfate for use in manufacturing. Simply put, said Gaines, "when you chop it up, the plastic case floats, lead sinks, and the acid washes away."

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Recycling lead is also big business. Lead forms 60% of the battery's mass and a significant part of its cost. "Dead lead-acid batteries are worth money because the lead, plastic, and fluid can be easily recycled," said John Howes, principal of development and consulting firm Redland Energy Group in Washington, DC. "A lead-acid battery made with recycled materials costs less than one made with virgin materials."

The situation is nearly the opposite for lithium batteries. Their various applications have led to a gamut of sizes and chemical flavors. At least five different compounds are used in today's battery cathodes, the electrode that stores and releases lithium ions. Recovering the whole cathode compound for reuse in a battery would be financially advantageous. Researchers and recyclers are now trying to develop such a process, called direct recycling.

In February, the United States Advanced Battery Consortium—a collaborative organization of Ford Motor Company, General Motors, and Fiat Chrysler Automobiles—awarded a USD$1 million contract to Yan Wang of the Worcester Polytechnic Institute, to scale up his novel recycling technology.

One of the two main lithium-ion battery recycling processes used today involves pulverizing the modules and then using a screen to separate components. For Tesla car batteries, this process gives a copper cobalt fluff (left) that is sold to recover useful metals, and a slurry that is processed into a cobalt filter cake (right) that can be reused in appliance coatings. Credit: Tesla Motors.

"Our technology takes a mixed battery stream of any size, shape and chemistry and synthesizes a refurbished cathode material that battery makers can reuse," Wang said. In the method, the batteries are shredded, and then magnetic fields and sieves separate the pulverized cathode material, which is dissolved in acid to filter out the insoluble carbon particles. Then comes the final key step: adding the desired ratio of virgin manganese, cobalt, and nickel, and fabricating the material to give a cathode with the formula $LiNi_xMn_yCo_2O_2$.

In laboratory studies, Wang has been able to recycle up to 80% of the cathode materials from unsorted batteries. Calculations show that the process could cut the cost of cathode materials by a third, Wang said. He plans to commercialize the process through his startup Battery Resources. The company can now process 50 kilograms of cathode materials, and a larger pilot plant will come in two years if he gets the necessary funding.

Firms including EcoBat, Retriev, and research lab OnTo Technologies in Bend, Ore., are all working on a direct recovery process that involves physical processes to separate spent cathodes and then restore their properties. OnTo has made cells from several recycled cathode materials that in early lab-scale tests seem to perform just as well as new cells. Meanwhile, Surrey, Canada-based American Manganese Inc., is partnering with lab-testing provider Kemetco Research to test its patented lithium cathode rejuvenation process.

Rethinking the battery's beginning, and not just the end, would also help. "Unlike lead-acid batteries, Li-ion batteries have so far only been designed to perform and be sold," Howes said. Better design could make recycling easier and more cost-effective. In an ideal world, said Gaines, Li-ion batteries would have standard sizes and materials, a minimal number of different materials, no toxic materials, and use nuts and bolts instead of welded cases.

To improve safety in the near term, the SAE is now proposing standards for manufacturers to label their batteries with the cathode compound it contains, which would help sorting for recycling, RSR Technologies' Ellis said. "There's an opportunity to design material sets that make recycling better."

Lithium battery recycling is on car and battery companies' radars. At the International Battery Seminar in March, Tesla Motors' Director of Battery Operations Kurt Kelty said that the company plans to have an on-site recycling facility at its Gigafactory. He said that they will first recycle production scrap and then move on to recycling used battery packs in five years. The extracted nickel, cobalt, aluminum, copper, and lithium will go back into new cells.

When the G7 Alliance on Resource Efficiency met in March, representatives from several major automakers in the United States, Europe, and Asia said their companies are realizing that incorporating recyclability into battery design is becoming increasingly important. Several lead-acid-battery manufacturers also have lithium battery research programs, Howes said, "and they're talking about the need to design with recycling in mind."

Gaines is skeptical. She said that people have talked about design for recyclability for years but not much has come out of it. Effective recycling would also need mechanisms in place to return batteries at the end of their useful lives and route them safely to recycling facilities, which is easier for automotive batteries than small, dispersed consumer cells. Making lithium battery recycling a reality will require intensive research and planning, and a commitment from the government and industry.

Incentives and penalties for consumers could also help but might not be the best way forward. Rather than a ban on batteries from being thrown in landfills, Howes said, "the more important policy objective is to intensify design and recycling research." The US Department of Energy today spends a fraction of its energy-storage budget on battery recycling research; most is spent on battery performance and design. Soaring demand for lithium batteries and a growing awareness of recycling might change things. "More is being said and written about the need for recycling," said Howes. "There's growing recognition that it needs to be done." A good time indeed for lithium to go the way of lead. □