Recycling cars’ lithium batteries is more complicated than you might think

Enlarge / Challenges scale considerably when the battery pack weighs 300kg.

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Lithium batteries have become incredibly popular for electronic devices, and the emphasis on weight and size for those batteries means that the amount of raw materials tied up in them isn’t too large. But that’s absolutely not the case for the other growing use of lithium batteries: electric vehicles. These lithium batteries weigh hundreds of kilograms and contain a substantial amount of raw materials, some of which can be quite valuable.

Due to the relative youth of the automotive electrical-battery market, however, an organized recycling industry is only just now developing, and it faces significant technical hurdles before recycling becomes both widespread and economical. In today’s issue of Nature, a group of researchers take a look at possible means of recycling and considers how to get the most value out of electric-vehicle batteries after they’re no longer performing well enough to run a car.

Before recycling

The authors of the analysis make one thing clear up front: the majority of the cost of a lithium-ion battery isn’t in the raw materials. Instead, the cost is in the manufacturing needed to transform those raw materials into something that can function in a battery, then getting them into a structure that combines durability, performance, and safety. Thus, there’s more value in having a lower-performing battery than there is in breaking the battery apart to get at its materials.

The primary issue with lithium batteries is a loss of capacity over time. Eventually, this will lead to reduced range for any vehicles that rely on them. But the same batteries may still be able to function for many years longer, even as their capacity continues to go down and even if that function isn’t sufficient for an electric vehicle. In contrast to cars, grid-scale electricity storage isn’t sensitive to either the amount of space taken up by batteries or their weight. As such, a battery that’s no longer appropriate for a car could still work perfectly well on the grid.

Thus, the authors argue strongly that reuse should be given a much higher priority than recycling. While grid-scale storage is relatively rare, it’s growing, and a number of US states have mandated that their utilities provide on-grid storage over the next few years. That timing works out pretty well given that lithium-battery-powered vehicles are relatively recent developments and most of the batteries used in them won’t reach end-of-life for several years.

That said, this is a temporary situation. The batteries will eventually reach the point where they won’t even make sense for grid storage, and the expected growth of electric vehicles means that the number of batteries being pulled from cars will increase dramatically over the next few decades. And even now—long before there should be many at the end-of-life

stage—the authors note that some lithium batteries have found their way into metal recycling facilities, where handling them inappropriately has set off fires.

So while it may not represent an urgent immediate need, developing the technology needed to handle immense quantities of lithium batteries will eventually be essential.

Unleaded

The recycling system for lead-acid batteries would seem to indicate that handling lithium batteries shouldn’t be a problem. But lead-acid batteries have a number of simplifications that simply don’t apply to electric vehicle batteries. To begin with, they’re all made in a limited number of formats; often, if a larger battery is needed, manufacturers will simply link up a number of standard-sized lead-acid batteries.

That’s completely unlike what’s happening with lithium batteries. The authors highlight the power packs for the Tesla model S, the BMW i3, and Nissan Leaf, which differ by over 200kg and have significantly different shapes. The individual cells in the batteries are also different sizes and shapes, and the chemistries of the cathodes are distinct. All of this rules out a single process or automated system for handling electric vehicle batteries.

Still, there’s great potential for limiting the impact of gathering the raw materials needed. Each tonne of lithium typically requires over 250 tonnes of ore or 750 tonnes of lithium-rich brine to obtain. In contrast, an equivalent amount of lithium could be obtained by recycling about 250 automotive batteries. That’s certainly nowhere close to making the industry sustainable during the rapid growth we’re expected to see over the next few decades, but it can play an increasing role as the electric vehicle market matures.

At the moment, however, some battery chemistries rely on cobalt, and its supplies have been limited and volatile. That may mean recycling's economics will be driven by something that's a relatively minor contributor to the final mass of the battery.

Hazardous non-waste

The review notes that batteries will probably arrive at recycling centers containing various amounts of charge, which could pose a hazard to people and equipment. Discharging a half-full battery onto the grid could generate enough electricity to power a home for two hours, so this could actually help offset some of the cost of recycling. Alternately, the power could be discharged into water, producing hydrogen and oxygen.

Once discharged, the issue is one of whether to simply shred the battery or to disassemble it. The former offers low cost and time efficiency, while the latter preserves more of the raw materials in their native form.

Shredding runs the risk of shorting out any residual charge in the batteries, which may have flammable electrolytes. As such, it's best performed under water or an inert atmosphere (the latter is currently favored). While a crude separation is possible, the simplest thing to do with a shredded battery is to put it in a furnace for what's called "pyrometallurgical metals reclamation." This produces a metallic alloy of some of the major components of the battery, as well as a slag that contains its aluminum and lithium. Things like the electrolyte and graphite electrodes simply get burned, lowering the total energy cost of the process.

That still leaves chemical purification of the metals and reconstitution into a chemistry that's suitable for battery use. But the simplicity helps with the overall costs.

Purity and risk

Disassembly is at the opposite end of the spectrum. Because of the different structures used by batteries and the low cost of labor in industrializing societies, battery assembly is still a largely manual task; disassembly would be the opposite of that. As parts are removed, a combination of magnetic separation, filters, and other equipment would help produce relatively pure streams of individual components. This isn't a perfect solution, however. Some things, like the graphite in electrodes, are tough to separate from the metallic current collectors they're attached to. Some of the materials may also be toxic, requiring extensive precautions to prevent exposure.

The advantage is that you end up with relatively pure materials that are already in the right chemical form to be used in batteries. There is a risk, however, that some contaminants from this process would cause problems when the material is reincorporated into batteries. Alternatively, whatever problems caused the battery's capacity to degrade over time may force extensive reprocessing of the materials before they can be used.

In any case, there's definitely potential for extensive reuse of battery components, even if there are some significant challenges to be solved before we're able to do so. Fortunately, this is a rare case when we have significant lead time before lots of dead batteries start pouring into recycling centers. Which means that we've got time for chemists and process engineers to get to work on finding solutions for the largest of these challenges.

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