ThePowerof3
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Driving the future further

Overview

Issue 4 of *The Power of 3* posed the question: can batteries – and lithium-ion batteries in particular – save the planet? Perhaps … but much depends on what happens at the end of their lifecycle, now and well into the future.

Rather than being disposed of in landfill sites, rechargeable lithium-ion batteries (LIBs) should be chemically neutralised and re-used. However, many things can influence this appropriate recycling, not least the fact that almost 90 per cent of LIBs are sold with, or in, the products they power and thus disposed of still within their 'hosts'. Further, a battery's life depends on the frequency with which it is used, and this affects the time gap between it entering the market and being ready for disposal.

Consumer hoarding of superseded or defunct consumer electronics presents another obstacle, as do non-standard battery labelling, issues of transportation, handling and physical sorting, and the chemical processes involved in the end-stages of LIB recycling.

Moreover, the proliferation of plug-in hybrid electric and full electric cars (HEVs and EVs), as well as other forms of electrically powered transport, will compound recycling challenges in the years to come (more on this later and in the next edition).

There is no doubt, however, that the recycling of rechargeable batteries has the potential to not only reduce possible environmental and human health hazards but also provide valuable resources.

Recycling rechargeable batteries: an industry imperative – part 1

Why LIBs die

In time, LIBs lose their capacity to hold a charge. Put very simply, it's a function of extended exposure to high temperatures, repeated charging and discharging cycles that eventually disrupt the progress of the lithium ions travelling between the electrodes, and factors like corrosion and other unwanted chemical reactions.

To make LIBs more efficient, researchers are seeking electrolyte additives that reduce harmful reactions between the electrodes and electrolyte, so they perform better for longer. Experiments with new and more stable components and electrolytes are also ongoing.

In addition, LIB manufacturers and EV producers are working on the battery packs themselves, to devise thermal management systems that keep the lithium-ion cells they contain at a constant, healthy temperature.

LIB types

Six types of high-performance LIB are currently commercially available (cobalt being the main active material in the cathodes of the highest-capacity batteries).

- Lithium cobalt oxide (mobile phones, tablets, laptops, cameras)
- Lithium manganese oxide (power tools, medical devices, electric powertrains [1])
- Lithium nickel manganese cobalt oxide (e-bikes, medical devices, EVs and industrial applications)
- Lithium iron phosphate (portable and stationary devices in which high load currents and endurance are required)
- Lithium nickel cobalt aluminium oxide (medical devices, industrial applications, Tesla electric powertrain)
- Lithium titanate (UPS [2], electric powertrains (e.g. Mitsubishi, Honda), solar-powered street lighting).

Recycling LIBs in EVs

One of the great recycling successes of the past 100 years has been the conversion of the lead-acid and nickel-based batteries used in most conventional vehicles into reusable materials. However, electrically powered transport uses batteries of an entirely different type.

It's predicted that EVs will comprise more than 7 per cent of the global transportation market as early as 2020, with significant time, effort and resources being expended on improving their performance and lowering their cost. To illustrate the point, on April 1 Elon Musk tweeted that orders for Tesla's latest and most 'economical' EV (the Model 3, priced at a cool US$35,000), unveiled a day earlier and due for delivery in 2017, have already exceeded 232,000!

But are such vehicles really as 'green' as they're touted to be? Of particular import in this regard are:

- what powers the grid that charges the vehicle's battery (a coal-fired power station, for example, has the potential for negative environmental impacts), and
- what type of battery propels the vehicle.

In 2013, an intense US study [3] focused on the latter point: not only the 'cradle-to-grave' aspects of the LIBs that drive HEVs and EVs – that is, the materials and processes involved in their manufacture and use through to the end of their life and recycling – but also ways in which the environmental and public health impacts of those batteries might be reduced.

Researchers examined the cathodes of three different types of LIBs – lithium-manganese oxide, lithium-nickel-manganese-cobalt oxide and lithium-iron-phosphate – and at battery anodes containing single-walled carbon nanotubes [4].

Batteries with nickel and cobalt in their cathodes, and electrode processing involving solvents, were found to be the worst in terms of potential environmental impacts (including resource depletion, climate change and ecological toxicity), as well as potential impacts on human health (respiratory, pulmonary and neurological effects).

To mitigate such impacts, the study recommended substitution of the cathode material, solvent-less electrode processing and recycling of the metals contained in the batteries.

At present, even when disposed of correctly, only about 2 per cent of LIBs are recycled. This is due in part to the lack of standardisation of chemical components, and of system complexity, both of which amplify the difficulty of achieving a high recovery rate for the materials they contain.

However, arguments for widespread and effective recycling of new-generation batteries go beyond environmental and health concerns. With respect to the recovery and reuse of lithium and cobalt, for example, the risks associated with the supply, cost and accessibility of these resources are worthy of consideration.

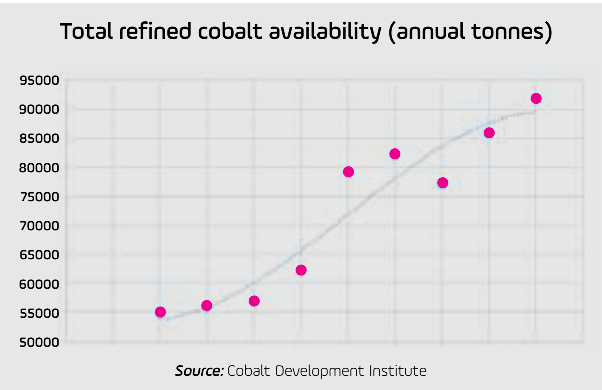
Lithium An alkali metal intrinsic to a number of industries (see *The Power of 3, issue 1*), lithium is also a key component in the production of the LIBs contained in consumer electronics, EVs and stationary energy storage systems. Indeed, growth in the latter three industry groups is boosting demand for lithium like never before.

Currently, notes Aswin Kumar, lithium supplies are meeting demand. That said, almost 70 per cent of global deposits are located in South America (Argentina, Bolivia and Chile), regions not known for their political stability. Geo-politics aside, environmental impacts from mining also have the potential to disrupt the availability and cost of this raw material.

Cobalt Cobalt is rarely produced as a primary metal; most often it's a by-product of nickel and copper production. With the nickel and copper markets currently depressed, however, there is little likelihood that global cobalt output will expand any time soon.

Historically, too, cobalt has been a conflict mineral; its sale by the war-torn nations of the African copper belt has financed arms purchases for, and atrocities committed during, numerous revolutions. Restrictions imposed by the US or other governments in order to promote ethical minerals trading in the eastern Congo are likely to further constrain its availability. The US government, for example, wants cradle-to-grave tracking of all battery materials consumed on home soil, to reduce consumption of those sourced from conflict zones.

At present, more than 40 per cent of cobalt ends up in batteries. Thus, if requirements for the LIB market continue to grow at around 11 per cent per annum, cobalt production will reach a tipping point. Clearly demand – driven by continued growth in the battery sector – will outstrip supply, meaning that here too recycling could be part of the solution.



Source: Cobalt Development Institute

Hence, while LIB recycling is in its infancy, it could in future help mitigate against the risks that result in wildly fluctuating prices.

Which Perth-based company is resolving many of these issues right now?

Seeking the right solutions

Currently, in Europe, the US and Japan, projects are underway to develop comprehensive recycling solutions for LIBs, and EV batteries in particular.

Linda Gaines, in her article *The future of automotive lithium-battery recycling*, is one of many to advocate designing **all** batteries with recycling in mind. Better battery chemistries and models are necessary, as is standardisation of the types that work best.

> *"Those that could be recycled together would have at least one distinguishing feature in common and, conversely, one to differentiate them from those [having] to be recycled in a different way. Mechanisms [are needed] to return all batteries at the conclusion of their (first or second) useful lives … to the appropriate recycling facilities in a safe and legal manner … [with] user-friendly labeling [to facilitate this]. Regulations would assure safe transport and handling, and discourage … cross-contamination. Sorting/routing could be immediate, via a transfer station or within a unified recycling facility. Separate streams would be processed to produce valuable, high-purity materials [to] be reused in batteries or in another high-value product … Accomplishing this … before large numbers of automotive propulsion batteries have reached the end of their useful lives requires research and planning to continue over the next 10 years or so. It is a daunting task, but if there is a broad commitment from industry and government it can be done."*

While comprehensive and efficient recycling of LIBs will no doubt be a long and arduous process, it is plainly an industry imperative.

The Power of 3 is sponsored by Lithium Australia.
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Notes

[1] The system of parts in a vehicle or device that first produces energy, then converts it in order to propel that vehicle or device, be it a car, boat or other machinery.

[2] UPS stands for 'uninterruptible power supply', also 'uninterruptible power source'. UPS, or battery/flywheel backup, is an electrical apparatus that provides emergency power to a load when the input power source, typically mains power, fails.

[3] Carried out by Abt Associates via a partnership with the US Environmental Protection Agency, the US Department of Energy, the LIB industry and academicians.

[4] Although not currently in production, single-walled carbon nanotubes were assessed for their ability to improve the energy density and performance of EV batteries. However, significant resources are expended in the early stages of their production, which may outweigh the benefits of their energy efficiency.