THE SIGNIFICANCE OF BATTERY RECYCLING

Here, **Hans Eric Melin**, explains the significance of battery recycling in the supply chain and looks at the nuances of lithium ion recycling compared with other battery technologies

When will recycling significantly contribute to the lithium-ion battery supply chain? The question keeps popping up at conferences and in media. The answer is that recycling has been an integrated part of the value chain for more than ten years. Companies like Glencore and Umicore have for a long time been using waste batteries as part of their feedstock. In China and South Korea hundreds of companies are involved in the different steps required to take waste batteries and production scrap from its source and turn it into new battery material.

In many ways recycling of lithium-ion batteries is the perfect example on how we sometimes fail to see the wood for the trees. Recycling processes such as crushing and shredding of batteries are in Europe and North America viewed as insufficient recycling when they in fact represent the first step in an advanced process to produce chemical products such as nickel sulphate, cobalt sulphate and lithium carbonate although most of the refining and production is not located in the West but in countries where batteries are made. The focus on the lack of refining in Europe and the US has contributed to a perception that the challenges of a higher recycling efficiency are technological when it rather is about logistics and economics.

In China there are today around 30 large players that operate recycling processes which in most cases involve calcining of so-called black mass – the recovered active materials from shredded batteries – leaching, solvent extraction and precipitation of nickel, manganese, cobalt and lithium. The capacities range from 5,000 to 50,000 tonnes per year. Several of these companies are also involved in precursor and cathode production which means that they produce a more valuable product than if they only would produce sulphates or other intermediary products. In South Korea several companies currently scale up an already ambitious production using the same model.

In Europe and North America more processes are also coming online following the rapid increase in battery production. This makes perfect sense as production always generate waste which needs to be recycled and be fed back into the manufacturing. Even more important, with production of both cells and battery materials, there is now a real need for raw materials and intermediary products, something which hasn't really been

Credit: Hans Eric Melin

Nissan Leaf battery packs ready for disassembly. One of the most common battery types in second life applications

the case before.

With the rapid increase of electrified cars being placed on the market there is also a considerably larger need for recycling as the volume of end-of-life batteries is expected to grow in a similar pace. Although the lithium-ion battery market has grown with a compound annual growth rate of more than 20 per cent since the beginning of the new millennium it was from very small volumes, basically consisting of batteries for mobile phones, laptops and power tools. For collectors of waste batteries lithium-ion has historically been one of the smallest chemistries when they instead have been dealing with lead-acid and alkaline batteries which have been collected in much larger amounts. Now this is expected to change.

The question though is how fast batteries will become available for recyclers.

Compared with other batteries lithium-ion batteries are different in two aspects. First of all they are usually built into the devices they power, often without ability for users to easily remove them. The consequence is that the battery follows the device, for instance a mobile phone or a laptop computer, and is not collected separately the way we collect single-use batteries. Secondly, although many of us find that the battery in our phones degrade far too quickly, in particular larger packs last for a long time, in fact often longer than the device they power and can therefore be reused.

These aspects have made the lithium-ion battery one of the least collected battery for recycling, all over the world. The collection rate for alkaline batteries in northern Europe for the last 10 years has been between 50% and 60% while the rate for lithium-ion has been closer to 10% and rarely higher than 15%. The reason for this is that smartphones, tablets, and other electronic devices have high reuse values even when the devices are five to seven years old and sometimes even when they are broken. The refurbishment of the devices is, however, usually happening in China where most of the devices, and the batteries, were made in the beginning. This means that they are exported from Europe, North America and countries like Australia and Japan, and imported in China as devices for reuse. The batteries go with them.

For slightly larger packs like those in the scooters, which increasingly populate larger cities around the world, it is the actual cells that are reused. The 18650 cells which also used to be found inside laptops before they became as thin as envelopes are removed from the packs, refurbished and used in new

packs, in power banks, or sometimes even sold as new cells. This obviously generates much more value than what's possible to obtain from the extracted metals which enables traders to pay more for batteries which are intended for reuse than local recyclers can do.

For a long time this phenomena has driven batteries from Europe and North America particular to feed recyclers in China with batteries which haven't been fit for purpose. This has helped the Chinese and, indirectly, the South Korean recycling industry to scale as they have had access to more material than recyclers in other parts of the world.

With EV batteries this could be expected to be different. However, our research shows that it's not. While many feared that batteries in the electric cars should degrade far too fast, forcing the owners to buy expensive replacement packs, most EV batteries have proven to last far longer than the usual warrantied time of six to eight years. Many drivers of the Teslas Model S have after seven to eight years not experienced more degradation than 10% to 15%. This does not only keep the battery from recycling longer than what many recyclers expected. It also makes the car more attractive and valuable. That also means that they be traded.

From the end of 2015 to this day New Zealand, a laggard in vehicle electrification, went from a few hundred electric vehicles to over 20,000. The interesting thing is that more than 11,000 of these vehicles, right-hand-side-drive cars, are used EVs imported from Japan and the United Kingdom, primarily Nissan Leaf but also BMW i3 and Tesla. This is not new. Both Japan and the US are big exporters of used cars with most of the vehicles going to Russia, Middle East, Africa and Latin America. The European Union is experiencing a significant trade of cars first of all within the union where cars go from west to east but then large volumes of cars are sold to Turkey, UAE and countries in Africa. While the official volume of cars leaving the EU is around a million per year there are more than five million cars every year which simply are not accounted for, neither as end-of-life vehicles or re-registered as road vehicles. Most likely a significant amount of these vehicles are exported as well.

The situation is very similar in the US. A difference though is that in the US vehicles

Credit: Hans Eric Melin

Black mass awaiting recycling at recycler in China

that have reached end of life are exported, with about 25% of cars which were written off by insurance companies after accidents are going overseas.

However, in recent years the international trade of vehicles has contracted as developing countries increasingly are banning the import of used cars, in particular older models. While one reason is to protect domestic manufacturing of cars another reason is to limit the import of cars with too high emissions. Interestingly this might be very different for EVs.

Today there is almost no Sub-Saharan African country without some kind of electrification program for the transportation sector. An abundance of sun which allows use of photovoltaics which have become too inefficient in a not-so-sunny Europe goes well together with both energy storage and electric cars. The same is true for South America. Over the next ten years there will be huge demand for low cost electric vehicles which makes it highly likely that we will see an increased export of used vehicles to countries on both continents and potentially in South Asia as well.

With this development recyclers might be left with batteries which have been replaced by OEMs when cars have been under warranty and batteries which come out of cars which have been damaged and deemed as write-offs by the insurance companies. Today the second category is significantly larger. According to the current battery directive in the European Union the collection of these batteries should be financed and arranged for by the OEMs. However, there is nothing that forces an owner of the batteries to hand it over and in fact there are usually few reasons to do so. Battery modules from Tesla Model S are today traded for more than 200 USD per kWh and 500 Wh Nissan Leaf modules go for 40-100 USD each. The batteries are used in everything from DIY projects to the conversion of classic cars to electric vehicles. Batteries taken back by the OEMs are by most makers assessed for remanufacturing which means that new batteries are assembled from old ones, where perhaps only a module or a few connectors were bad, and are then stored before they are used as replacement packs.

Batteries are also used in energy storage systems usually in different commercial and industrial applications but also for backup power. In China more than 4 GWh of used EV batteries have been re-deployed in backup for telecom towers and in Europe more than 300 MWh of EV batteries are used both

Credit: Hans Eric Melin

EV charging powered by photovoltaics and supported by second life batteries in Port Elizabeth, South Africa

behind and in front of the meter to support the grid and help to shave of the daily price peaks.

While the Chinese batteries have come from both end-of-life vehicles and from off spec series the batteries in Europe are predominately collected by the OEMs through replacement programs in which the packs have been upgraded to packs with higher capacities. This model is something we expect to see more of. Several car makers realise that the battery, which is both the most expensive and valuable component in the car, can be monetised much more efficiently if they take control of it. Over time we also expect to see more startups taking control over batteries which haven't been consolidated by the OEMs although this might be a market with limited growth when the OEMs become more active.

Usually recyclers which are not involved in reuse activities are not particularly enthusiastic about the batteries getting a second life. After all it may cause a delay of between five and ten years for the battery to finally reach recycling. However, for recyclers in Europe and North America, batteries which are left to reach their final end of life in an energy storage facility might be the best bet for making the batteries stay in the local market at all. On top of that the batteries are now much better consolidated and in some cases even disassembled which makes both transportation and handling much less costly.

However, inevitably the volumes of secondary materials will for the next 10-15 years not be as high as many expect and it is very important for recyclers to not only focus on the EV market but to penetrate all application areas for lithium-ion batteries, many of which contain batteries which reach end of life much faster than those from cars.

So, the real answer to the question if recycling soon will significantly contribute to the lithium-ion battery supply chain is simply "no". We will be far beyond 2030 before that happens. Not only because of a slow take-up in materials to recycle but of course also due to the enormous growth we expect in battery production which will dwarf the recycled volumes more than ten times. Then it's hard to be significant.

Recycling will be important though and, again, it already is. In an industry where the balance between supply and demand is repeatedly impacted both on a macro level and for individual companies the ability to add recycled volumes to the virgin supply gives very important advantages. However, to succeed, in particular outside of China, a global approach is key. Because batteries will travel and there will always be someone else out there welcoming them with open arms.

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Data and analysis of the global end-of-life market for lithium-ion batteries is available in the new report "The lithium-ion battery life cycle report" which can be accessed by subscribers to CES Online, Circular Energy Storage's data and analysis service.