Battery sustainability

Amongst all the talk and promise of lithium ion batteries, we also need to consider the environmental and sustainability aspects of particular battery types. These issues will include the availability of materials, the mining and manufacturing process and the toxicity of the materials used in batteries, especially during the recycling and disposal period.

Although lithium is considered to be less toxic than lead it does have a lot of negative effects if we don't recycle or dispose of it correctly. Lithium is an element used in the treatment of psychological disorders and is a strong mind affecting substance.

Ultimately, one of the most concerning aspects of lithium ion batteries is the mining of lithium and the exploitation by the Western world of the countries that it is mined in, where we find the largest sources of lithium. One of the major concerns in particular, is for the exploitation of the local residents close to the mines who provide a source of low-cost labour.

A lot of work needs to be done to reduce the issues around lithium ion production in the major producing countries if it is to be considered truly ethical.

The Uyuni Salt Flats in Bolivia are home to over half the world's lithium deposits.

It is not unusual to read that lithium batteries contain no toxins and that mining the metal is "an environmentally benign process".

In reality, lithium affects the use of water by organisms, especially those with nervous systems. Obtaining it via underground reservoirs of dissolved salts known as salar brines is harsh on creatures in any desert-like environment where it is extracted.

In order for batteries to function, lithium must be used with chemicals that are even more toxic. Friends of the Earth (FOE), Europe states: "The release of such chemicals through leaching, spills or air emissions can harm communities, ecosystems and food production. Moreover, lithium extraction inevitably harms the soil and also causes air contamination."

Lithium ion batteries - bad for the environment

Lithium (Li-ion) batteries used for energy storage are showing a lot of great potential, but a report from the Environmental Protection Agency says there are still a lot of areas for improvement with their main concern being specifically the impact to the environment and on public health.

"While Li-ion batteries for electric vehicles are definitely a step in the right direction from traditional petrol and diesel fuelled vehicles, some of the materials and methods used to manufacture them could certainly be greatly improved," as quoted by Jay Smith, ABT Associates senior analyst and co-lead of a cradle-to-grave life-cycle assessment for the EPA and DOE.

One part of the study revealed that batteries using cathodes with nickel and cobalt, as well as solvent-based electrode processing, show the highest potential for certain environmental and health impacts, including resource depletion, global warming, and ecological toxicity.

Life Cycle Assessment of Lithium Ion Batteries

The information below was taken from the document of April 24, 2013. Application of Life- Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries. United States Environmental Protection Agency. (126 Page Document).

This EPA study looked at the impact of several kinds of lithium-ion batteries on resource depletion, global warming potential, acidification potential, eutrophication potential, ozone depletion potential, photochemical oxidation potential, ecological toxicity potential, human toxicity potential, occupation cancer hazard, occupational non-cancer hazard.

Battery recycling by location
(all battery types)

Country	Return percentage 2002[8]	2012
Switzerland	61 %	73 %
Belgium	59 %	-
Sweden	55 %	-
Germany	39 %	44 %
Austria	44 %	-
Netherlands	32 %	-
United Kingdom	-	32 %
France	16 %	-
Canada	3 %	5.6 %

Since the lifetime of a li-ion battery was assumed to be 10 years, about twice as long as reality, and it is assumed ways to recycle most of the materials will be found, various other parts of the LCA analysis were not emphasized. Also, "Because the market for recovered and recycled material from lithium-ion batteries is not well developed for large battery packs, we assumed an optimistic scenario for the reuse and recycling of materials, essentially modelling all recovered materials as being directly reinserted into the applicable commodity market and displacing virgin materials". The results are therefore optimistic, but the reader can decide how to modify the results to reflect current reality. Also, certain life-cycle stages were emphasized and characterized more than others.

A worst case scenario with a battery life of 5-years is presented in the paper and "Halving the lifetime of the battery has a significant adverse effect on impact categories, including occupational cancer and non-cancer, ecotoxicity, and ozone depletion."

The paper has many interesting sections not all covered here, i.e. how batteries are made, the energy used, the supply chains, and environmental impacts.

Why Advanced Lithium Ion Batteries Won't Be Recycled

In the world of the energy storage sector, one of the most pervasive and enduring myths is that a recycling infrastructure for our used lithium mine batteries, will be designed and built before these wonder batteries that are being designed reach the end of their useful lives. Unfortunately, in the worst case scenario, advocates suggest that the used lithium ion batteries will be stockpiled until there are enough used batteries to justify the building of a recycling infrastructure.

Unfortunately, the numbers tell a very different story.

What has been happening for several years now, with the obsession of all lithium-ion battery developers has been reducing costs to a point where using batteries as a substitute in electric vehicles for a fuel tank makes economic sense. But the progress that has been made has mainly come from substituting cheap raw materials like iron, manganese and titanium for the more costly cobalt and nickel that were used in first generation lithium-ion batteries. This unfortunately means, when you slash the cost of the materials that go into a battery you also slash the value of the materials that can be recovered from that battery at the end of its useful life.

Battery Chemistry	**Metal Value Per Ton**
Lithium cobalt oxide	$25,000
Lead acid	$1,400
Lithium iron phosphate	$400
Lithium manganese	$300

Figures derived from the Material Data Safety Sheets of Powerizer and current LME Prices from MetalPrices.com, in the table below shows the calculated value of the metals that can be recovered from recycling a ton of used batteries and is summarized in the following table.

Considering the extremely high metal value of used cobalt in lithium based batteries it seems strange that only one company in the world, Umicore of Belgium, has bothered to develop a recycling process. If you take the time to read and digest Umicore's process description, however, the reason soon becomes obvious. Recycling lithium-ion batteries is an incredibly complex and expensive undertaking that includes:

- Collection and reception of batteries;
- Burning of flammable electrolytes;
- Neutralization of hazardous internal chemistry;
- Smelting of metallic components;
- Refining & purification of recovered high value metals; and
- Disposal of non-recoverable waste metals like lithium and aluminium.

Chemetall Foote Lithium Operation showing the chlorine polluted water.

The process only becomes economic when a ton of batteries contains up to 600 pounds of recoverable cobalt that's worth $40 a pound. The instant you take the cobalt out of the equation, the process becomes hopelessly uneconomic. Products that cannot be economically recycled can only end up in one place, your friendly neighbourhood landfill.

This means that despite their extremely high metal value, cobalt-based lithium batteries are rarely recycled because process is so difficult and expensive.

When we take into consideration their appallingly low metal values, lithium iron phosphate batteries from A123 Systems (AONE) and Valence Technologies (VLNC), lithium manganese batteries from Ener1 (HEV) and lithium titanate batteries from Altair Nanotechnologies (ALTI) will never be reasonable candidates for recycling, which effectively guarantees that eventually buyers will ultimately be required to pay huge disposal fees.

Currently freelance miners work to break up the surface salt and sell the lithium salt to passing trucks for just a few dollars

Comparatively, Lead-acid batteries are the most widely recycled product in the world and this is because they contain 70% lead by weight, the recycling process is simple and a robust global recycling infrastructure already exists. Many leading lead-acid battery manufacturers including Johnson Controls (JCI) and Exide Technologies (XIDE) view their recycling operations as major profit centres that also insures continuity of raw materials supply.

What is the life span we can expect from a Lithium-ion Battery?

A lithium-ion's battery life is defined in studies as beyond its useful life when its capacity falls by 20 percent or more.
Lithium-ion batteries start to degrade as soon as they're made, even when you aren't using them.

Temperature. This can change a batteries life by 5 years or more. Ideally a lithium-ion battery should be kept between -10 to 30 degrees Celsius. When a lithium ion battery is operating in a temperature above 30°C the battery can be permanently degraded, that is why cooling technology is used in Tesla's batteries for protection. Below -10°C the battery can't provide full power.

Depth of discharge. If you discharge a lithium-ion battery too much before recharging, you may shorten the lifetime to just 300-500 cycles and the battery capacity will drop to 70%. A lithium-ion battery will last much longer if you use half or less than the maximum depth of discharge and then recharge, extending the cycle life as high as 1,200-1,500 cycles.

At the same time fully charging isn't good either, that's why for example the Tesla Roadster and other EV don't allow you to recharge more than 95% of the original power or drain the power to less than 2%.

It is important that we also sometimes we need to be sceptical of "breakthroughs" such as the Oak Ridge National Laboratory battery that retains 90% of capacity after 10,000 cycles but doesn't mention energy density, in "Solid electrolyte: the key for high-voltage lithium batteries," Advanced

Energy Materials (2014). All too often any advancement in one area almost always results in a loss in other area(s).

Li-ion Batteries deteriorate. The more deeply you discharge a battery, the more often you charge/recharge it (cycles), or the battery is exposed to below freezing or above 25°C degree temperatures, the shorter the life of the battery will be. Even doing nothing, shortens battery life: Li-ion batteries lose charge when idle, so an old, unused battery will last only as long as continuously used one. Tesla engineers expect the power of their batteries to degrade by as much as 30% in five years.

According to Popp et. al. in their 2014 "Lifetime analysis of four different lithium ion batteries for plug-in electric vehicle" for Transport Research Arena, Paris, the commercial Nickel-cobalt oxide version is superior to all other experimental cells in their capacity, energy content, energy density, and series resistance, but have the worst environmental impacts.

Lithium Ion battery – information collation

Most of this information is taken from data that has been collected from lithium ion batteries currently used in electric vehicles as there is not enough data yet available for lithium ion batteries designed to be used to store electricity. However, information currently available suggests that the larger scale lithium ion batteries will actually be a lower quality battery than the ones currently used in electric vehicles.

Polluted water, blue with chlorine, at a lithium mine in the Atacama Desert, Chile

Battery sustainability – Lead Acid Batteries

Although there is a lot of talk and promise of lithium ion batteries, many people are still considering using lead acid batteries. The health and environmental effects of lead acid batteries also needs to be taken into account before making this decision.

The poisonous nature of lead has long been known, including its poisonous effects on both animals and humans. Lead effects and damages the nervous system and can cause muscle pain, nausea and reduces IQ levels along with many other symptoms.

And whilst we almost entirely recycle lead acid batteries here in Australia and in most other developed countries, there is a proportion of the batteries that aren't recycled and end up being dumped or going to landfill. These batteries can then contaminate waterways and groundwater over time. We need to move further towards using non-toxic materials in batteries to begin with.

Sections from the Environmental Protection Agency USA paper:

The study showed that the batteries that use cathodes with nickel and cobalt, as well as solvent-based electrode processing, have the highest potential for environmental impacts. These impacts include resource depletion, global warming, ecological toxicity, and human health impacts. The largest contributing processes include those associated with the production, processing, and use of cobalt and nickel metal compounds, which may cause adverse respiratory, pulmonary, and neurological effects in those exposed.

As of 2007, batteries accounted for 25% of lithium resource consumption; this amount is projected to increase significantly.

Water is the main material input at 500-5400 kg/kWh (24-67% of total) and second is the lithium brine taken from saline lakes in Chile at 540-750 kg/kWh (9-28% of total). Most of which comes from the materials extraction stage in the life cycle.

Lifetime of the battery is a significant determinant of impact results; halving the lifetime of the battery results effectively doubles the non-use stage impacts, resulting in substantial increases in global warming potential, acidification potential, ozone depletion potential, and photochemical oxidation potential (e.g., smog).

Life-Cycle Stages

Though the use stage of the battery dominates in most impact categories, upstream and production is non-negligible in all categories, and relatively important with regard to eutrophication potential, ozone depletion potential, ecological toxicity potential, and the occupational cancer and non-cancer hazard impact categories. The extraction and processing of metals, specifically aluminium used in the cathode and passive cooling system and steel used in the battery pack housing and battery management system (BMS), are key drivers of impacts.

Recovery of materials in the EOL stage significantly reduces overall life-cycle impacts, as the extraction and processing of virgin materials is a key contributor to impacts across battery chemistries. This is particularly the case for the cathode and battery components using metals (e.g., passive cooling system, BMS, pack housing and casing). Therefore, the analysis underscores the importance of curtailing the extraction of virgin lithium to preserve valuable resources and reduce environmental impacts.

Battery recycling issues

Although metals are recovered from Li-ion batteries, they are currently not fed back into the battery cell manufacturing process. To do so, the recovered battery materials (including lithium) would need to be processed so they are "battery grade" which means they can be used as secondary material in the battery cell manufacturing process. However, there are a few key obstacles to achieving this goal, including:

1. *The battery manufacturers frequently modify their battery chemistries, which makes it difficult to incorporate recovered materials. This is especially a concern for EV batteries, which may be recovered 10 to 15 years after the battery is manufactured. The battery companies continually modify their chemistries to try to obtain market distinction and to improve charge capacity and energy density, which generate benefits in the use stage of the battery.*

2. *The battery manufacturers are hesitant to use secondary materials, as they fear it will not be of high enough quality to meet the battery specifications required by the original equipment manufacturers (OEMs) that purchase the batteries and manufacture the vehicles.*

3. *Batteries may be capable of having a –second life or use as part of another product, such as to provide energy storage for an electricity grid; however, there is limited information on characterizing spent batteries in a secondary application, so the potential second life was not included in this study.*