Li-ion battery (LIB) Recycling

Arendal August 15 2019 - Christian Rosenkilde
Hydro - why batteries?

Hydro's value chain has several potential contact points with LIBs

- Bauxite
- Alumina
- Energy
- Primary
- Recycling
- Rolling
- Extrusion
- Casting
- Products

1. Mining operations with many vehicles (trucks etc.)

2. LIBs in our energy operations (grid services, balancing renewables, etc)

Hydro is a major Al recycler. Similar technologies are used in LIB recycling.

Aluminium cathode foil for LIB cells

AI sheets and profiles for battery packs
Aluminium in LIBs

An EV battery pack can contain more than 30% aluminium

Anode:
- Graphite powder
- Binder

Cathode:
- Metal oxide
- Binder
- Carbon

BMW i3 module and cell

Foil inside cell

Cathode powder particles

Anode powder particles

Cathode: Metal oxide + binder + carbon

Anode: Graphite powder + binder

BMW i3
LIBRES – Lithium Ion Battery Recycling project

Leverage Norway’s leading EV position to create a cost efficient recycling process

• Main goal
  • By 2022 develop technologies for a LIB recycling pilot plant in Norway large enough to handle commercial volumes in 2024

• Hydro is project owner

• NFR (EnergiX) support

• Budget
  • 22 millNOK over 4 years (2018-2022)

• Partners
  • Commercial: Hydro ASA, Batteriretur AS, Glencore Nikkelverk AS, Keliber OY
  • R&D: IME RWTH Aachen, Elkem Technology, NTNU, UiA Grimstad
  • Other: Eyde Cluster
Circular LIB value chain

- Recycling
- Nickel, cobalt, lithium, graphite
- Precursor material
- Use phase
- Spent batteries
- Battery
- Electrode material
- Cell
- Battery
Circular LIB value chain

There are several options for shortcuts in the value chain

Cells at end-of-life can be recycled to

- Raw materials, e.g. nickel, cobalt and lithium
  - Replacing virgin raw materials
- Precursor material
  - Replacing refined raw materials
- Electrode material (?)
  - Direct recycling of active anode and cathode material
- Second life cells
- Battery - used for another application
  - E.g. EV battery used for stationary storage
European LIB value chain is incomplete

Currently, Europe has limited electrode material and cell production

- Limited precursor material production
- No electrode material production
- Limited cell production

Today, full European circularity is not possible
Asia must be included

- Send recycled electrode materials to Asia
- Get cells from Asia
LIB cell production scrap

Access to production scrap is beneficial for a recycler

Cell production creates production scrap
Production scrap is relatively pure and of high value
• Off-spec precursor and electrode material
• Anode and cathode foil cut-off
• Failed cells

A recycler with access to production scrap will have a volume and cost advantage
…and a cell producer will need recycling to manage production scrap
Conclusions

- Hydro sees LIB recycling as a potential business opportunity

- LIB recycling is already being done

- The LIB value chain is suitable for circularity
  - but full internal circularity in Europe requires local large scale electrode material and cell production
We are aluminium
The global and complete aluminium company

“...create a more viable society by innovative and efficient use of natural resources and products”

More than 110 years of industrial development and responsibility

Aluminium – metal of the future

Hydropower – infinitely recyclable energy

Engaged in the entire value chain – R&D, innovation and tailormade solutions

Global reach, local presence

Involved and engaged

35,000 employees

150 locations

40 countries
The LIBRES project - partner structure

Partners are well distributed along the LIB recycling value chain

**Commercial partners**
- Collection from workshops and scrapyards, etc
- Deactivation and dismantling to module or cell level
- Physical separation, e.g. shredding/sorting
- Chemical processing
- Battery material production
- Alternative material production

**Libraries**
- AS Batteriretur
- Hydro
- Glencore (Co, Ni, Cu) Keliber (lithium)

**R&D partners**
- Mechatronics
- MIL/Uni Agder
- Process
- Elkem, IME Aachen
- NTNU
Important LIB materials

LIBs are changing raw material markets

<table>
<thead>
<tr>
<th>Element</th>
<th>Main producing country</th>
<th>Battery use</th>
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<tbody>
<tr>
<td>Lithium</td>
<td>South America 40%, Australia 40%, China, ++</td>
<td>50%</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Congo &gt; 60%, ++</td>
<td>50%</td>
</tr>
<tr>
<td>Nickel</td>
<td>Australia, Russia, Canada, Indonesia, China, Phillipines, ++</td>
<td>5%</td>
</tr>
<tr>
<td>Manganese</td>
<td>South Africa, Gabon, China, USA, ++</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Graphite</td>
<td>China &gt;60%, ++ (incl Norway)</td>
<td>10%</td>
</tr>
</tbody>
</table>

Recycled material will be important for new batteries

• For example, 10% of global cobalt production is already recycled from LIBs (14 000 tonnes out of 140 000 tonnes)
Example - VW's announced LIB recycling process

Cobalt, Nickel, Manganese and Lithium reused
How the recycling process works