Management of used electric vehicle batteries in Africa
Considerations on technical, organisational and economic aspects
Andreas Manhart & Fred Adjei | Nairobi, 25.04.2024
Agenda

1) Some battery basics
2) The economy of Li-ion battery recycling
3) Battery testing & reuse
4) Li-ion battery recycling
5) Will EPR be the solution?
6) Summary
Battery cells, modules & packs

- Battery cells
- Battery module
- Several battery modules
- Battery pack

Graphics & pictures: Oeko-Institut
End-of-life challenges of e-vehicle batteries

1. **Electrical shocks:** Battery repairs and dismantling are high voltage operations.

2. **Hazardous substances:** All types of Li-ion batteries contain various constituents that can have considerable negative impacts on human health and the environment if not managed properly.

3. **Embedded raw materials:** Li-ion batteries contain raw materials that are considered as critical for economic development and expansion of green-energy technologies (lithium, graphite, cobalt, nickel...).

4. **Fire risks:** Batteries with residual charge may overheat, catch fire and even explode after damages (‘thermal runaway’). This may occur days or weeks after a damage happened.
Ideal management pathway of vehicle batteries

First life
- Use in e-vehicles
- Regular maintenance
- Safe transport of aged batteries

Second life
- Dysfunctional batteries
- Battery reuse / repurposing in stationary applications
- Functional modules
- Dysfunctional modules
- Testing & dismantling of batteries

Recycling
- Dismantling & pre-processing
- Recycling & refining
- Recovered raw materials for industrial production
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Economics of battery recycling

Indicative material composition of a NMC electric vehicle battery

<table>
<thead>
<tr>
<th>Element</th>
<th>Content</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>25.2 %</td>
<td>Cell &amp; module case, cathode current collector</td>
</tr>
<tr>
<td>Graphite</td>
<td>12.5 %</td>
<td>Anode active material</td>
</tr>
<tr>
<td>Co, Mn, Ni</td>
<td>13.6 %</td>
<td>Cathode active material with Co (2.7%), Mn (2.7%), and Ni (8.2%)</td>
</tr>
<tr>
<td>Copper</td>
<td>14.0 %</td>
<td>Cables, anode current collector</td>
</tr>
<tr>
<td>Lithium</td>
<td>1.5 %</td>
<td>Cathode active material, conductive salt</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>Plastic, organic substances...</td>
</tr>
</tbody>
</table>


- A broad variety of sizes, designs and sub-chemistries
- No clearly dominating material
- The name giving Lithium is only contained in small traces
- Recyclers focus on recovering Cobalt, Nickel & Copper
**Economics of Li-ion battery recycling**

Main types of Li-ion battery chemistries used in electric vehicles

|                     | NMC                                | LFP 
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy density</td>
<td>150-260 Wh/kg</td>
<td>90-180 Wh/kg</td>
</tr>
<tr>
<td>Cathode materials</td>
<td>Li, Ni, Mn, Co</td>
<td>Li, Fe, P</td>
</tr>
<tr>
<td>Copper content</td>
<td>~7%</td>
<td>~7-8%</td>
</tr>
<tr>
<td>Cobalt content</td>
<td>~6%</td>
<td>0%</td>
</tr>
<tr>
<td>Nickel content</td>
<td>~4%</td>
<td>0%</td>
</tr>
<tr>
<td>Trends</td>
<td>Used in demanding applications (high required mileage)</td>
<td>Rapidly growing market shares (~5% in 2019, ~40% in 2022)</td>
</tr>
<tr>
<td>Indicative recycling costs (gate fees)</td>
<td><del>0 - 1650 €/t + additional charges for larger batteries (</del> 500 €/t)</td>
<td><del>1000 - 2000 €/t + additional charges for larger batteries (</del> 500 €/t)</td>
</tr>
</tbody>
</table>

Sources: Weyhe & Yang (Accurec); Battery University 2021, Wunderlich-Pfeifer 2022, electrive.net 2022
Economics of Li-ion battery recycling

Interim conclusion:
Sound end-of-life management of e-vehicle batteries may be associated with net costs!

But:
Some types of management are likely profitable (although partly sub-standard)
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Battery reuse

Battery reuse is a significantly higher economic potential than recycling (preservation of value)

Battery diagnostics is key to identify functional / dysfunctional models and cells and the assess the second (& third) life potential.

Two types of battery testing methods:

1. Physical testing through dismantling, charging, discharging → measurements of these charging cycles.

2. Using the sensor data that are installed in electric vehicle batteries → significantly less time intensive, may also done remotely, but requires (reading) access to the Battery Management System (BMS)
### Relevant battery diagnostic data

<table>
<thead>
<tr>
<th>Signal</th>
<th>Unit</th>
<th>Value resolution</th>
<th>Time resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery current over time</td>
<td>A</td>
<td>0.1 A</td>
<td>≤ 1 sec</td>
</tr>
<tr>
<td>Battery voltage over time</td>
<td>V</td>
<td>0.1 V</td>
<td>≤ 1 sec</td>
</tr>
<tr>
<td>Cell temperature (avg/min/max) over time</td>
<td>°C</td>
<td>0.1°C</td>
<td>≤ 10 sec</td>
</tr>
<tr>
<td>Cell voltage (avg/min/max) over time</td>
<td>V</td>
<td>0.001 V</td>
<td>≤ 1 sec</td>
</tr>
<tr>
<td>Battery state of charge (SoC) over time</td>
<td>%</td>
<td>0.1 %</td>
<td>≤ 10 sec</td>
</tr>
<tr>
<td>Accumulated charge throughput</td>
<td>As</td>
<td>0.1 As</td>
<td>≤ 60 sec</td>
</tr>
</tbody>
</table>

To be continuously sampled, time-synchronous, provided through a standard output interface, in a digital format compatible with publicly available software.
Battery reuse already practiced in Africa

There are already Li-ion battery reuse activities in most countries:

- Testing of cylindrical cells for reuse (not from electric vehicles)
- Battery from reused cells (sub-standard → unsafe products)
- Rechargeable lanterns with second life battery cells
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Graphic: Oeko-Institut
Pyrometallurgy

Battery cells & modules smelted in a furnace

Off-gas treatment to remove dust, fume and acidic emissions

Smelter output: Copper alloy with trace elements (cobalt, nickel…) → hydrometallurgical treatment
Mechanical treatment

- Battery cells or modules are shredded and copper, aluminium, plastics and black mass separated
- Process requires due care and is difficult to be conducted in a controlled and safe manner:
  - Fires & explosions during shredding are common (not all cells can be fully discharged before shredding)
  - Li-ion batteries contain substances that are highly corrosive. High wear and tear of shredding equipment.
  - The electrolyte and binders must be removed. Otherwise, the generated black mass is chemically still active and prone to accidents during shipment (bursting of drums…)
  - Embedded chemicals and elements partly hazardous (process must be well contained to protect workers and neighbouring communities)

Black mass output destined for shipment & further treatment to recover cobalt and nickel

Open question: what about black mass for LFP batteries that do not contain nickel and cobalt?
Li-ion battery recycling already practiced in Africa

Export of Li-ion batteries for recycling
(costly, requires notification according to Basel Convention procedures)

Copper foils and black mass from manual (!) Li-ion battery dismantling
Focus is on cobalt rich batteries from mobile phones and laptops

Some recyclers aim at installing battery shredders in their facilities → no information on an operational facility so far

Smelter for copper scrap
(limited further information)
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About EPR

“Traditional” Producer Responsibility:
• Sound production
• Functionality
• Product safety
• …

Extended Producer Responsibility:
• Sound end-of-life management

Producers shall take over logistical & financial responsibility to pick-up and soundly manage obsolete batteries

Either individually, or through a Producer Responsibility Organisation (PRO)
About EPR

Various African countries have passed EPR legislation requiring producers & importers to collect and adequately manage end-of-life e-waste and batteries:

- Ghana: Act 917 from 2016
- Ethiopia: E-waste Regulation 425 from 2018
- Nigeria: Battery policy
- Rwanda: …
- …
Is EPR the solution?

• EPR systems require a legal framework and are complex to be implemented. They require constant attention by governments and authorities (a law is not enough…).

• EPR systems can strengthen flows towards certain treatment options. The treatment options (facilities) must be monitored by authorities.

• Discussions around “international EPR systems” are ongoing but will not yield tangible results anytime soon.

• There are further (partly still unexploited) levers:
  • Batteries owned by government bodies (schools, offices, car fleets) should be given to best performing recyclers.
  • Large corporates controlling battery volumes (e.g. telecoms, transport companies) can be directly required to give end-of-life batteries to best performing recyclers.
  • Large vehicle producers/importers can be required to collect and manage their (and other) batteries → “EPR light”
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Summary (I/II)

• The question whether used and end-of-life electric vehicle batteries will be collected and soundly managed at their end-of-life will strongly depend on the possibility to make economic gains with such processes.

• Material compositions and complexity of handling points towards a situation in which some batteries might be collected, partly reused and recycled, while others are left behind (dumped). In case the African markets continue to be effectively unregulated, there is a high likelihood that such management will be mostly sub-standard.

• Current trends in battery sub-chemistry lead to lower raw material values, putting a question mark behind some forms of currently promoted recycling approaches (battery shredding to recover black mass).

• Reuse of batteries, module and cells has a high potential but will also rely on the question if battery diagnostic data will be accessible to vehicle owners and third parties (currently uncommon).
Summary (II/II)

• EPR is extensively discussed and partly already required by law in various African countries.
• Despite such legal requirements, EPR systems did not yet have larger tangible impacts on end-of-life battery markets in most African countries.
• Discussions around “international EPR systems” are ongoing but will not lead to tangible systems anytime soon.
• While EPR is an important tool to make producers and importers co-responsible for sound management, it is not a silver bullet to resolve end-of-life challenges.
• Further aspects to be considered:
  • Requirements for management from government owned / controlled batteries
  • Requirements for big battery using sector (telecom, transport agencies, banks…)
  • Requirements for big producers and importers of electric vehicles (“EPR light”)
• EPR does not replace the need to monitor, regulate and (if necessary) sanction business activities around battery reuse and recycling.
Thank you for your attention

Andreas Manhart (a.manhart@oeko.de)
Fred Adjei (f.adjei@oeko.de)