Industrial scale EOL (X)EV Battery Recycling – an existing solution in a global network
Umicore business approach

We transform metals into hi-tech materials
We use application know-how to create tailor-made solutions in close collaboration with our customers
We close the loop and secure supply by recycling production scrap and end-of-life materials
We aim to minimize the environmental impact and be the best employer and neighbour
Unique integration in the battery value chain
guaranteeing high speed to market, supply security and responsiveness to customer needs

Umicore offers a **closed materials loop for Li-ion batteries**: The innovative recycling process enables a **cost efficient and environmentally sound** battery recycling with **high recovery rates** and **minimal waste**.
Fundamentals of effective Recycling

Input
Flexibility for complex materials

Output
Maximize value creation

Pyrometallurgy
Hydrometallurgy
Mechanical processing

Recovery of > 20 metals

Base metals
Minor metals
Precious metals

Copyright © 2017 Umicore. All rights reserved
Treating all kinds of Li-ion batteries

Li-ion battery = complex mix of materials containing metals, organics, halogens:

- Strong variation in cathode chemistries with more variation to come
- Umicore has knowledge on battery chemistry evolution through its Rechargeable Battery Materials division

Umicore’s UHT-process is designed to handle this complexity and variability
Innovative technology for metal recovery

1887

Continuous innovation and investments for recycling efficiency and QEHS improvement.

More than € 600 million of investments over the past 20 years and ongoing …

2017
Experience in Industrial Scale Processing

Precious metal recycling
industrial scale
>1000 t / day
>350,000 t / year

Battery recycling
industrial pilot scale
7000 t / year

Delivers…

…experience and know how to grow from current to future high volume scale
Variable feed size

Flexible on Size
- Medium sizes → directly to furnace
- Larger sizes after (partial) dismantling

**No pre-treatment necessary**
= direct feed to the furnace

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Feed Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile phone battery</td>
<td>± 0,030 kg</td>
</tr>
<tr>
<td>Laptop battery</td>
<td>0,5 - 0,7 kg</td>
</tr>
<tr>
<td>Power tool battery</td>
<td>1 - 1,5 kg</td>
</tr>
<tr>
<td>E-bike battery</td>
<td>± 3 kg</td>
</tr>
<tr>
<td>XEV / Industry battery module</td>
<td>15 - 20 kg</td>
</tr>
<tr>
<td>HEV battery</td>
<td>30 - 60 kg</td>
</tr>
<tr>
<td>EV battery</td>
<td>150 - 500 kg</td>
</tr>
</tbody>
</table>

* Illustration from different sources
Drop-off points as customer oriented service network

Europe

<table>
<thead>
<tr>
<th>Hoboken (B)</th>
<th>Hanau (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• UHT plant (industrial scale)</td>
<td>• Dismantling Line</td>
</tr>
<tr>
<td>• € 25 million investment</td>
<td>• Drop off point</td>
</tr>
<tr>
<td>• 7,000 t capacity</td>
<td></td>
</tr>
</tbody>
</table>

N. America

USA
4 Drop off points

S. America

Brazil
Drop off point

Asia/Pacific

Japan-China-Taiwan-Korea
Umicore Representatives

Asia/Pacific

Thailand
Drop off point

Other countries: collaboration with local partners

Copyright © 2017 Umicore. All rights reserved
Growing with the market

**Figure 32: Deutsche Bank global EV sales estimates**

**Governments’ xEV targets by 2020:**

14 countries have announced quantitative EV stock objectives, aspiring to bring 13 million EVs on the road by 2020:

- Germany: 1 million cumulative sales
- UK: 1.5 million cumulative sales
- France: 2 million cumulative sales
- China: 5 million cumulative sales
- Etc…

Source: Global EV outlook 2016 - OECD/IEA 2016

---

several 100,000 metric tons in need for recycling in the years thereafter

When? Uncertain, depends on actual sales xEV, battery designs, lifetime batteries, potential 2\(^{nd}\) life,…

How? Efficiency and cost of recycling are driven by volume

Copyright © 2017 Umicore. All rights reserved
Recycling technology ➔ UHT

Capacity:
7,000 t/y installed
- ± 250 mio mobile phone batteries or
- ± 200,000 HEV’s or
- ± 35,000 EV’s

Recycling efficiency > 50%:
- Alloy: Cu – Co – Ni
- Slag: for Li-Ion: used in construction (potential recovery Li)
  for NiMH: rare earth concentrate (REE)
- Flue dust: controlled separation of F

Eco-efficient:
- Close-to-zero waste
- Advanced gas cleaning
- Energy of battery used to obtain high temperature
  (incl. the caloric energy (electrolyte, plastic, metal))

Umicore Battery Recycling Scheme

Copyright © 2017 Umicore. All rights reserved
For discussion: Aspects, Conclusions and Perspective

Battery recycling efficiency is specified as an EU standard and to ensure recycling quality to keep sustainability high and environmental impacts low:
- Battery recycling processes are only qualified if a recycling efficiency > 50% will be reached for all kind of batteries – Reference: EU Battery Directive

Effective Battery Recycling (economic and ecological) requesting technological flexibility because of…
- High dynamic of battery chemistry and high variety of composition
- High variety of battery pack and module design
- Different conditions of batteries (esp. damaged) require flexibility in handling and (pre)treatment to ensure safety → exchange of info / data along the waste & recycling chain is essential

Furthermore effective Battery Recycling (economic and ecological) in a circular economy needs:
- To be well understood as a final part of a (complex) chain with strong interfaces which has to be managed
- Strong cooperation between involved partners with an interdisciplinary approach
- Exchange of information as important part of a safety concept (e. g. BMS data → battery history)
- Well established collection schemes – well prepared for safe handling at high volume streams
- Well established logistic solutions – allowing management of high volume streams
- To bring back resource-critical and valuable material (metals)
- Reuse and 2\textsuperscript{nd} life solutions / concepts
- Clarification and aligning of waste classification / waste code on EU level → “individual” view doesn’t help
Thank you