THE RECYCLING EFFICIENCY OF
Li-ION EV-BATTERIES

Dr. Jan Tytgat – Umicore
jan.tytgat@umicore.com
# Why Battery Recycling?

Part of the clean mobility global picture

## clean mobility

- **Choice of transport mode**
- **Clean vehicles**
- **Clean energy**

## Exhaust control

- [Image of exhaust control]

## Electrification

- [Image of electric vehicles]

## Vehicle and battery recycling

- [Image of vehicle recycling]
- [Image of battery recycling]

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[Images of logos for AVERE, NEA, Fomento de las PYMES, EVAAP, and European Commission]
Why battery recycling?

- EHS concern: EV-Batteries = a complex mixture of chemical elements and compounds:
  - Li-ion: H, Li, C, O, F, Al, (Si), P, (Ti), Mn, Fe, Co, Ni, Cu, (Sn)
  - NiMH: H, C, O, K, Fe, Co, Ni, La, Ce, Pr, Nd
  - Electrolyte, solvent, plastics...

- Legislative context in EU
  - End of Life of Vehicles Directive (ELV): removal of batteries
  - Batteries Directive: ban on incineration and landfill of industrial batteries
    - To avoid dissemination of hazardous compounds
    - Resource efficiency
    - Quality target: recycling efficiency (RE) ≥ 50 %
      RE = (battery recycled materials)/(battery input materials on dry basis)
BD: Producers obligations regarding recycling

- Basic principle:
  - Extended Producer Responsibility (EPR) ↔ Polluter Pays Principle (PPP)
    - EPR stimulates to include End-of-Life concerns in design phase
  - Producer = *any person in a Member State that... places batteries or accumulators, including those incorporated into appliances or vehicles, on the market for the first time within the territory of that Member State on a professional basis* ➔ for same type of EV, sold in different countries, ‘battery Producer’ can be different

- (H)EV batteries are ‘industrial’ batteries, not automotive batteries (= limited to SLI-batteries).
  - no collection target, but take-back obligation (➔ reuse, recycling)

- Recycling Efficiency target (RE)
  - 50% of battery weight has to be transformed into an *output fraction that has ceased to be waste or that will be used for their original purpose or for another purpose (without undergoing further treatment).*
Calculation of the Recycling Efficiency

- the Battery Directive’s RE is a process efficiency indicator
  - Calculated per calendar year
  - On process/operator level:
    - 2 operators with ‘same’ process = different processes
    - 1 operator with 2 processes = different processes
    - 1 operator processing different battery chemistries together = same process
  - Refers to ‘recycling’ only, not including other recovery (energy).
  - Including all steps until the ‘end of recycling’ (output fractions with a ‘purpose’ without further treatment)

⇒ All batteries processed during the same year in the same process generate 1 RE!

- the Battery Directive’s RE is calculated on ‘battery level’
  - Non-battery materials, e.g. casing of battery packs, are excluded
  - EV-battery assemblies are not considered as ‘packs’ but as ‘batteries’
  - Battery cells are also considered as batteries

- Reporting: responsibility of first recycler (= operator that ‘breaks’ the battery)
  - ⇒ consolidation of all subsequent recycling operations
Calculation of the Recycling Efficiency

Non-active battery parts recycled according to existing schemes: partial RE (calculated according to BD) to be reported to ‘1st recycler’

Considered as ‘battery’: breakdown of battery = 1st recycling step; agglomerated RE includes partial RE of all subsequent process steps

Active battery parts recycled according to dedicated battery recycling schemes: partial RE to be reported to ‘1st recycler’
Impact of material choices of non-active parts

- Based on interviews, Recharge\(^1\) concluded that relative % (w/w) of cells varies between 40-70% of (H)EV battery assembly weight; metals: 15-40%; plastics: 10-15%. Main difference is OEM's choice for protective casing material (metal or synthetic fibres).
- For same partial RE for each material flow, resulting agglomerated RE can vary significantly.

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\(^1\)Recharge is the European sector association for the advanced rechargeable batteries industry (http://www.rechargebatteries.org/)

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**Calculation of the Recycling Efficiency**

<table>
<thead>
<tr>
<th></th>
<th>Cells</th>
<th>Metals</th>
<th>Plastics</th>
<th>Agglomerated RE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partial RE (%)</strong></td>
<td>50</td>
<td>95</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Composition (%)</strong></td>
<td>50</td>
<td>40</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Partial RE</strong></td>
<td>25</td>
<td>35</td>
<td>1</td>
<td>61</td>
</tr>
<tr>
<td><strong>Composition (%)</strong></td>
<td>70</td>
<td>15</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td><strong>Partial RE</strong></td>
<td>35</td>
<td>14.25</td>
<td>0.15</td>
<td>49.40</td>
</tr>
</tbody>
</table>
1) Battery to recycling

- Battery recycling; recycling target = 50%
- Car recycling target = 85%; reuse&recovery target = 95%
- Rejected cells/modules subject to recycling target 50%
- Battery considered as 100% reused for ELV reporting

2) Battery to refurbishment for reuse

- To battery refurbishment
- Battery considered as 100% reused for ELV reporting
- Car recycling target = 85%; reuse&recovery target = 95%

Consolidation of batteries RE in ELV reporting

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Consolidation of batteries RE in ELV reporting

- BD RE and ELV recycling rates are other concepts

<table>
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<tr>
<th>BD</th>
<th>ELV</th>
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<tbody>
<tr>
<td>Process focus</td>
<td>Product focus</td>
</tr>
<tr>
<td>• Including process steps until end of recycling of all fractions</td>
<td>• Materials flow reporting (weight fractions to recycling or landfill)</td>
</tr>
<tr>
<td>• Possible to treat also non-vehicle batteries in same process</td>
<td>• Does not include recycling steps until the ‘end of recycling’ as defined for batteries</td>
</tr>
<tr>
<td>• Recycling only</td>
<td>• Also reporting reuse and energy recovery</td>
</tr>
</tbody>
</table>

Suggestion: to consider batteries as 100 % recycled if delivered to compliant battery recycler
Umicore battery recycling technology
• Dismantling/discharging facility for (H)EV in Germany since January 2011.

• Another dismantling/discharging facility in US is operational since mid 2012.

• Industrial-scale UHT smelter in Hoboken, Belgium. Operational since mid 2011.
Umicore Process description - metallurgy
Conclusions

• Huge diversity of Li-ion battery chemistries requires a robust recycling process
• The Batteries Directive is the first EPR-directive that includes recycling efficiency targets until the final stage of recycling
• The Umicore recycling process complies with the BD’s RE target

Contact: jan.tytgat@umicore.com