The role of battery recycling in raw material supply for EV application

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Strasbourg FRANCE
Introduce Accurec

(PH)EV put on market analysis: past and prognosis

Corresponding batteries and critical raw materials

Lifetime study of (PH)EV batteries

Recycling technologies and the role of recycling
Accurec Recycling GmbH

Company key figures

- Headquarter: DE-Krefeld
- Plants: DE-Mülheim an der Ruhr, DE-Krefeld
- Employees: >60
- Turnover: 15 Million €

History

- Foundation of Accurec: 1995
- NiCd capacity 2500 t/a: 2003
- Capacity 4000 t/a incl. NiMH: 2006
- R&D Li-ion Project: 2012
- R&D Li-ion electromobility: 2015
- Start Li-ion recycling facility and move of headquarter to DE-Krefeld: 2016
- Expansion and completion of Li-ion recycling process: > 2019
### Business segments

**Service:** National collection service of EOL batteries

**Sorting:** Sorting and disassembly of used batteries

**Recycling:** Pretreatment and Recycling of used batteries

**Research & Development:** metallurgical process development
Plant Mülheim an der Ruhr

Capacity: 4,000 t/a

Battery recycling plant:
- NiCd
- NiMH
- Sorting of mixed household batteries

Key figures 2018:
- NiCd 1,500 tons
- NiMH 500 tons
- Mixed HH battery 2,000 tons
Plant Krefeld

Legal capacity: 60,000 t/a

Dedicated battery recycling plant for:
- Li-ion portable
- Li-ion automotive
- Li-Primary

Key figures 2018:
- Li-ion portable 1,500 tons
- Li-ion automotive 150 tons
- Lithium primary 1,000 tons
Industrial Modular Battery Pack concept for automotive applications

- development strategies and methodologies for maximizing the material recovery.
- maintaining highest safety standards during recycling.
- Develop design for recycling recommendations to cover the recycling demands in the development stage of an EV battery system.
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The global electric car stock surpassed 3 million in 2017 after crossing the 2 million threshold in 2016.

New registrations of electric cars hit a new record in 2017, with over 1 million sales worldwide.

Source: OECD/IEA
EU (PH)EV market

715 thousands (PH)EVs

- Norway: 25%
- UK: 19%
- Netherlands: 17%
- France: 17%
- Germany: 15%
- Sweden: 7%
- Finland: 1%
- Portugal: 0%

Source: OECD/IEA
Global (PH)EV market Prognosis

Figure 9 • Deployment scenarios for the stock of electric cars to 2030

Scenario 1: The Reference Technology Scenario (RTS): 56 million EVs by 2030. CAGR: 26.87%

Scenario 2: The Paris Declaration on COP21: 115 million EVs by 2030. CAGR: 33.56%

Scenario 3: The 2-Degree Scenario: 160 million EVs by 2030. CAGR: 36.75%

Source: OECD/IEA
Europe (PH)EV market Prognosis 2016 - 2030

- Scenario 1: CAGR: 26.87%
- Scenario 2: CAGR: 33.56%
- Scenario 3: CAGR: 36.75%

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2016</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>579,386</td>
<td>1,551,080</td>
<td>4,933,992</td>
<td>16,217,845</td>
</tr>
<tr>
<td>2</td>
<td>579,386</td>
<td>1,873,629</td>
<td>7,835,301</td>
<td>33,299,502</td>
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<tr>
<td>3</td>
<td>579,386</td>
<td>2,256,177</td>
<td>9,689,782</td>
<td>46,339,429</td>
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</tbody>
</table>
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Li-ion battery put on EU market

- Top 5 best seller of BEV and PHEV (2016) were selected

91,343 BEVs: 3.6 GWh

117,999 PHEVs: 1.2 GWh

Source: EAFO
Li-ion battery put on market

Estimated battery tonnage sold in EU

Scenario 1
Scenario 2
Scenario 3

 acc. to 2016
 acc. to 2020
 acc. to 2025
 acc. to 2030

Thousands Tons

 today
2020
2025
2030

240Wh/kg
300Wh/kg

55
148
407
1268

178
178
634
2579

215
215
729
3581

0
500
1000
1500
2000
2500
3000
3500
4000

GWh
Thousands Tons
Li-ion battery and critical raw materials

- 1.6% Lithium
- 15.5% Manganese
- 1.8% Cobalt
- 5.4% Nickel
- etc.
- 11.8% Copper
- 15.1% Carbon

Single (PH)EV cell from 4 different EU OEMs

Cathode

2030
NMC 811
2025
NMC 622
2020
LMO / NMC
Today
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<table>
<thead>
<tr>
<th>Reach end-of-life after..... years</th>
<th>percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>5%</td>
</tr>
<tr>
<td>8</td>
<td>25%</td>
</tr>
<tr>
<td>10</td>
<td>40%</td>
</tr>
<tr>
<td>12</td>
<td>25%</td>
</tr>
<tr>
<td>14</td>
<td>5%</td>
</tr>
</tbody>
</table>
Expected annual battery tonnage (tons) ready for recycling in EU

Thousands tons

<table>
<thead>
<tr>
<th>Year</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>1</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>2025</td>
<td>18</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>2030</td>
<td>29</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>2035</td>
<td>87</td>
<td>171</td>
<td>232</td>
</tr>
<tr>
<td>2040</td>
<td>726</td>
<td>284</td>
<td>1,109</td>
</tr>
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</table>
Expected annual materials ready for recycling in EU

- **Estimation of lithium (Li) tonnages**
  - 2020: Scenario 1 (0.04), Scenario 2 (<1), Scenario 3 (1)
  - 2025: Scenario 1 (1), Scenario 2 (2), Scenario 3 (2)
  - 2030: Scenario 1 (2), Scenario 2 (6), Scenario 3 (6)
  - 2035: Scenario 1 (8), Scenario 2 (3), Scenario 3 (10)
  - 2040: Scenario 1 (38), Scenario 2 (25), Scenario 3 (25)

- **Estimation of cobalt (Co) tonnages**
  - 2020: Scenario 1 (0.02), Scenario 2 (<1), Scenario 3 (1)
  - 2025: Scenario 1 (1), Scenario 2 (2), Scenario 3 (2)
  - 2030: Scenario 1 (2), Scenario 2 (6), Scenario 3 (6)
  - 2035: Scenario 1 (8), Scenario 2 (3), Scenario 3 (6)
  - 2040: Scenario 1 (25), Scenario 2 (17), Scenario 3 (17)

- **Estimation of nickel (Ni) tonnages**
  - 2020: Scenario 1 (<1), Scenario 2 (1), Scenario 3 (1)
  - 2025: Scenario 1 (1), Scenario 2 (6), Scenario 3 (7)
  - 2030: Scenario 1 (7), Scenario 2 (37), Scenario 3 (37)
  - 2035: Scenario 1 (14), Scenario 2 (8), Scenario 3 (8)
  - 2040: Scenario 1 (202), Scenario 2 (133), Scenario 3 (133)

- **Estimation of copper (Cu) tonnages**
  - 2020: Scenario 1 (<1), Scenario 2 (2), Scenario 3 (2)
  - 2025: Scenario 1 (2), Scenario 2 (2), Scenario 3 (2)
  - 2030: Scenario 1 (3), Scenario 2 (5), Scenario 3 (6)
  - 2035: Scenario 1 (20), Scenario 2 (27), Scenario 3 (27)
  - 2040: Scenario 1 (130), Scenario 2 (85), Scenario 3 (85)
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Lithium-ion battery recycling facilities in EU

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Scale</th>
<th>Process applied</th>
<th>Estimated capacity tons/a</th>
<th>Announced capacity tons/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>UMICORE</td>
<td>Belgium</td>
<td>industrial</td>
<td>P + H</td>
<td>4000</td>
<td>7000</td>
</tr>
<tr>
<td>Accurec</td>
<td>Germany</td>
<td>industrial</td>
<td>T + M</td>
<td>2000</td>
<td>3000</td>
</tr>
<tr>
<td>Nickelhütte Aue</td>
<td>Germany</td>
<td>industrial</td>
<td>P + H</td>
<td>800*</td>
<td>N/A</td>
</tr>
<tr>
<td>EDI</td>
<td>France</td>
<td>pilot</td>
<td>M</td>
<td>500*</td>
<td>N/A</td>
</tr>
<tr>
<td>SNAM</td>
<td>France</td>
<td>pilot</td>
<td>T</td>
<td>300*</td>
<td>N/A</td>
</tr>
<tr>
<td>AkkuSer</td>
<td>Finland</td>
<td>pilot</td>
<td>M</td>
<td>100*</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*: insufficient information, capacity estimated. N/A: information not available.
Recycling supply for raw materials **Global**

**Estimated cobalt demand and supply from recycling**

<table>
<thead>
<tr>
<th>Year</th>
<th>Cobalt Demand for Other Application</th>
<th>Cobalt Demand of Lithium-Ion Battery for EV Application (2DS)</th>
<th>Cobalt Supply from Recycling (2DS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>~9,000</td>
<td>~260,000</td>
<td>~101,000</td>
</tr>
<tr>
<td>2030</td>
<td>3.5%</td>
<td>~260,000</td>
<td>~19%</td>
</tr>
<tr>
<td>2040</td>
<td></td>
<td>~530,000</td>
<td>~19%</td>
</tr>
<tr>
<td>2050</td>
<td></td>
<td>~800,000</td>
<td>~19%</td>
</tr>
</tbody>
</table>

Source: Öko-Institut e.V.
Recycling supply for raw materials Global

Estimated lithium demand and supply from recycling

Source: Öko-Institut e.V.
Accurec Recycling GmbH

We manage battery resources

Thank you for your attention!