SECOND INTERNATIONAL
SLAG VALORISATION SYMPOSIUM
THE TRANSITION TO SUSTAINABLE MATERIALS MANAGEMENT

umicore
materials for a better life

Valorisation of battery recycling slags

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[1] Umicore Group Research & Development

[2] Umicore Battery Recycling

SMART-PRO²

Outline

- Introducing Umicore
- Rechargeable battery landscape
- Need for recycling
- Umicore's battery recycling flowsheet
- Slag valorisation
- Conclusions

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- **Introducing Umicore**
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- **Introducing Umicore in 3 slides...**
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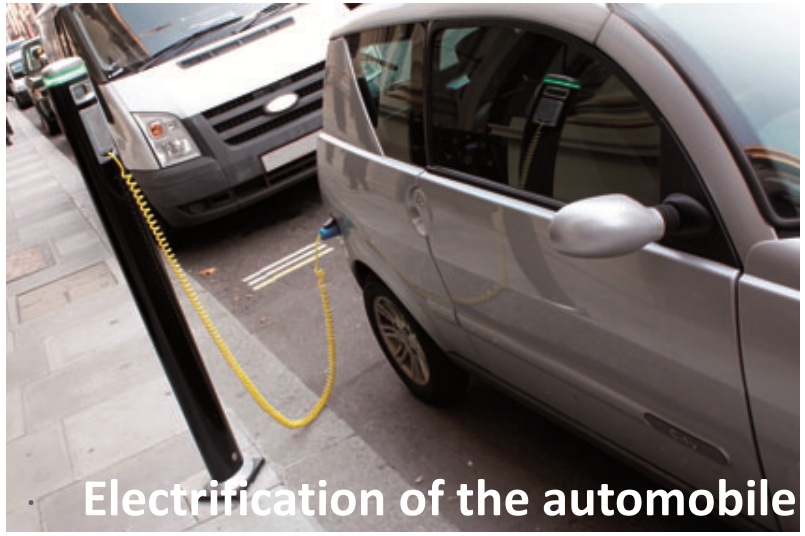
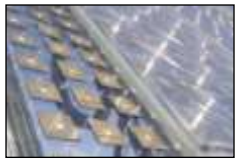
Key megatrends for Umicore



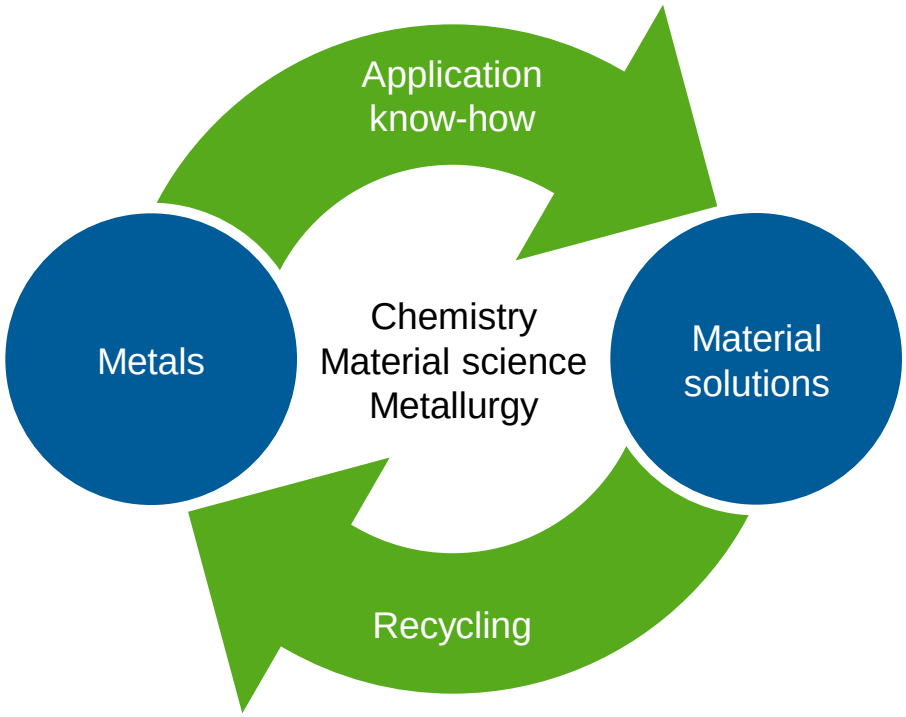
Umicore fit with megatrends

Electrification of the automobile	We are a leading producer of key materials for rechargeable batteries for laptops, mobile phones as well as electrified vehicles	
Resource scarcity	We are the largest recycler of precious metals; we are able to recycle more than 20 different metals	
More stringent emission control	We provide catalysts for 1 out of 3 cars in the world as well as for trucks & non-road vehicles	
Renewable energy	We supply key innovative materials for high-efficiency solar cells and other photovoltaic applications	

Umicore's business approach

"Less is more"

Metal related materials can be efficiently and infinitely recycled, which makes them the basis for sustainable products and services



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Types of batteries

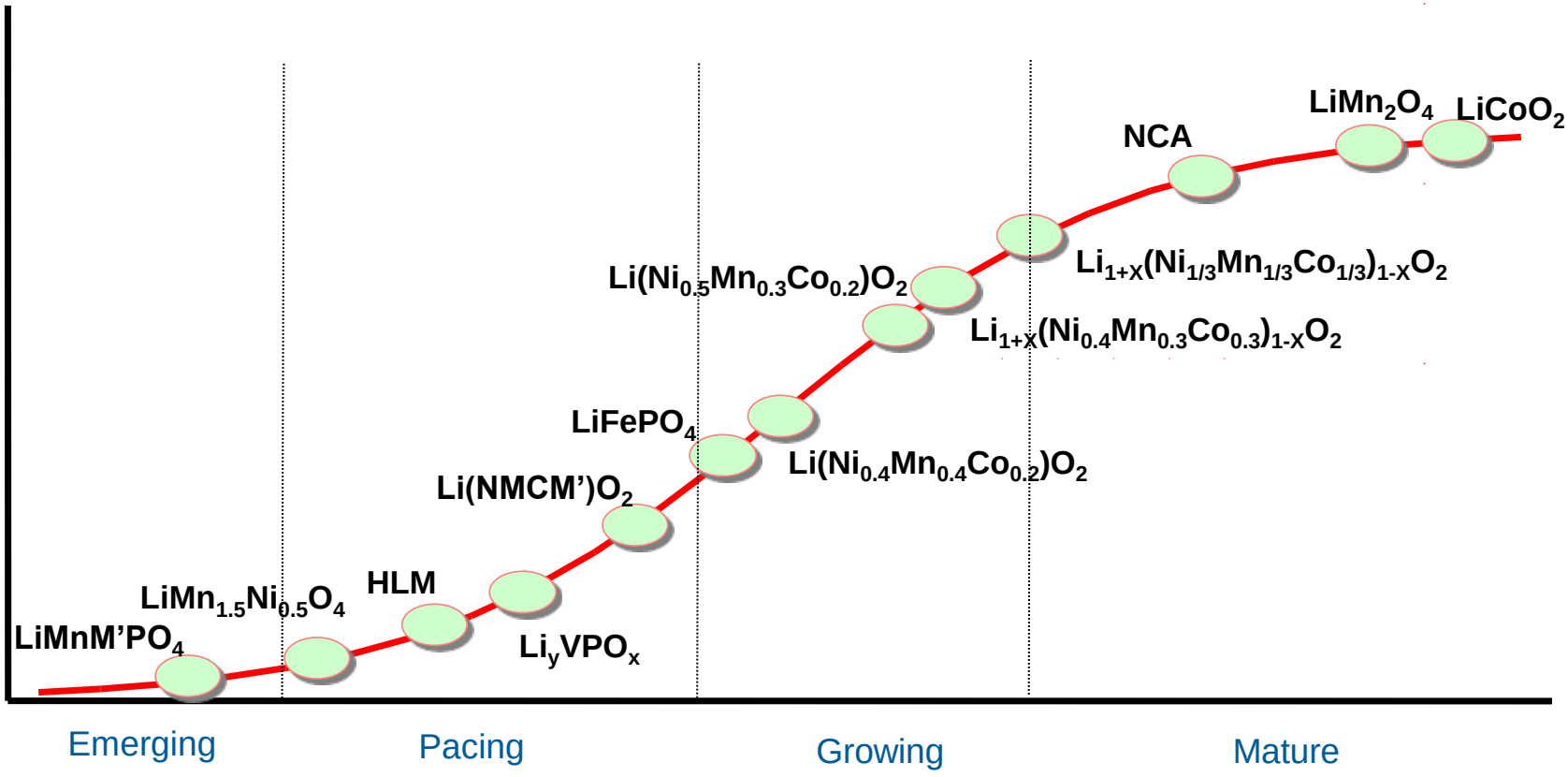
Mobile phone batteries

Laptop batteries

HEV-PHEV-EV batteries

Types of batteries

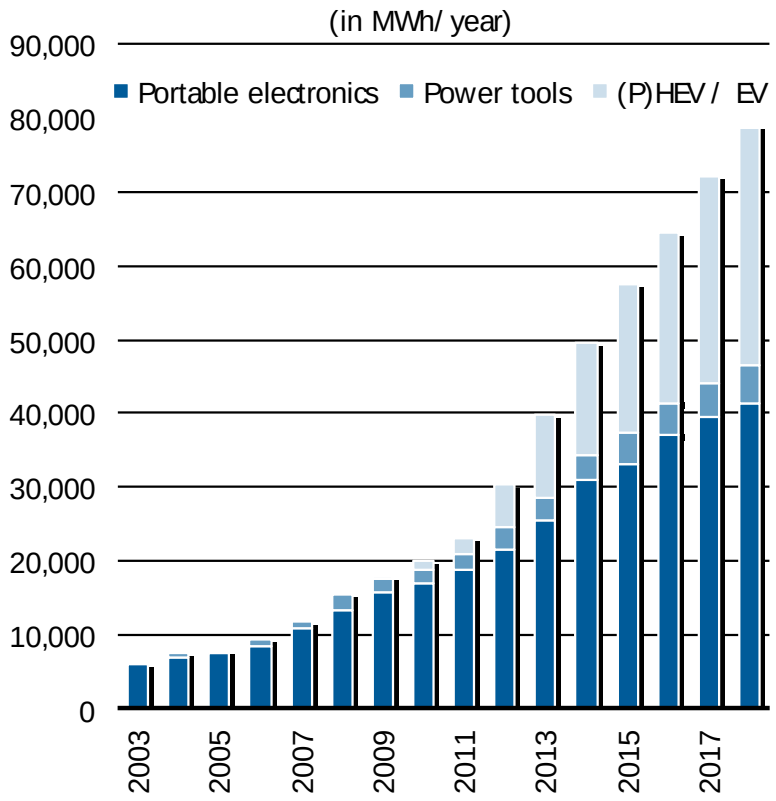
Evolution on battery chemistry



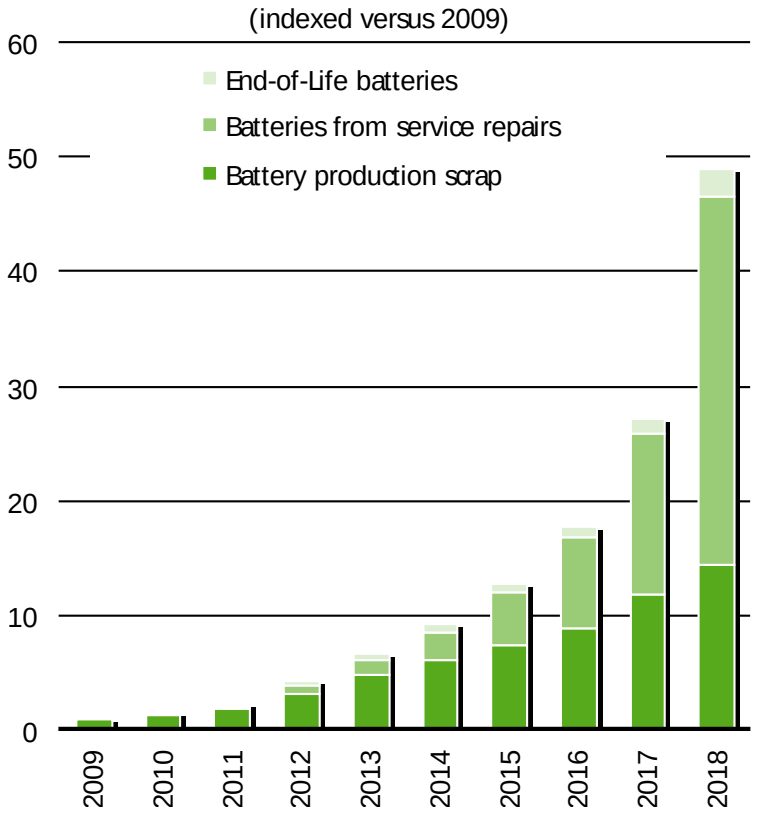
Types of batteries

Increasing volumes & demand

Power demand for Li-ion batteries



Potential recyclable (H)EV battery material



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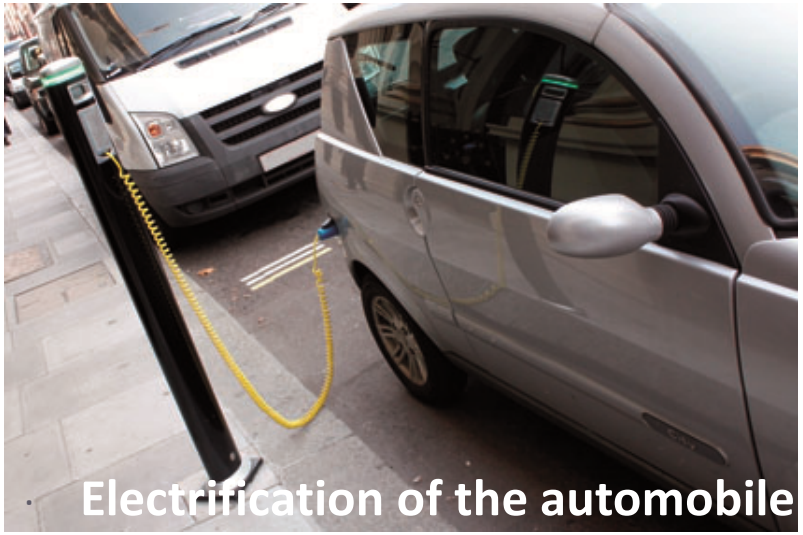
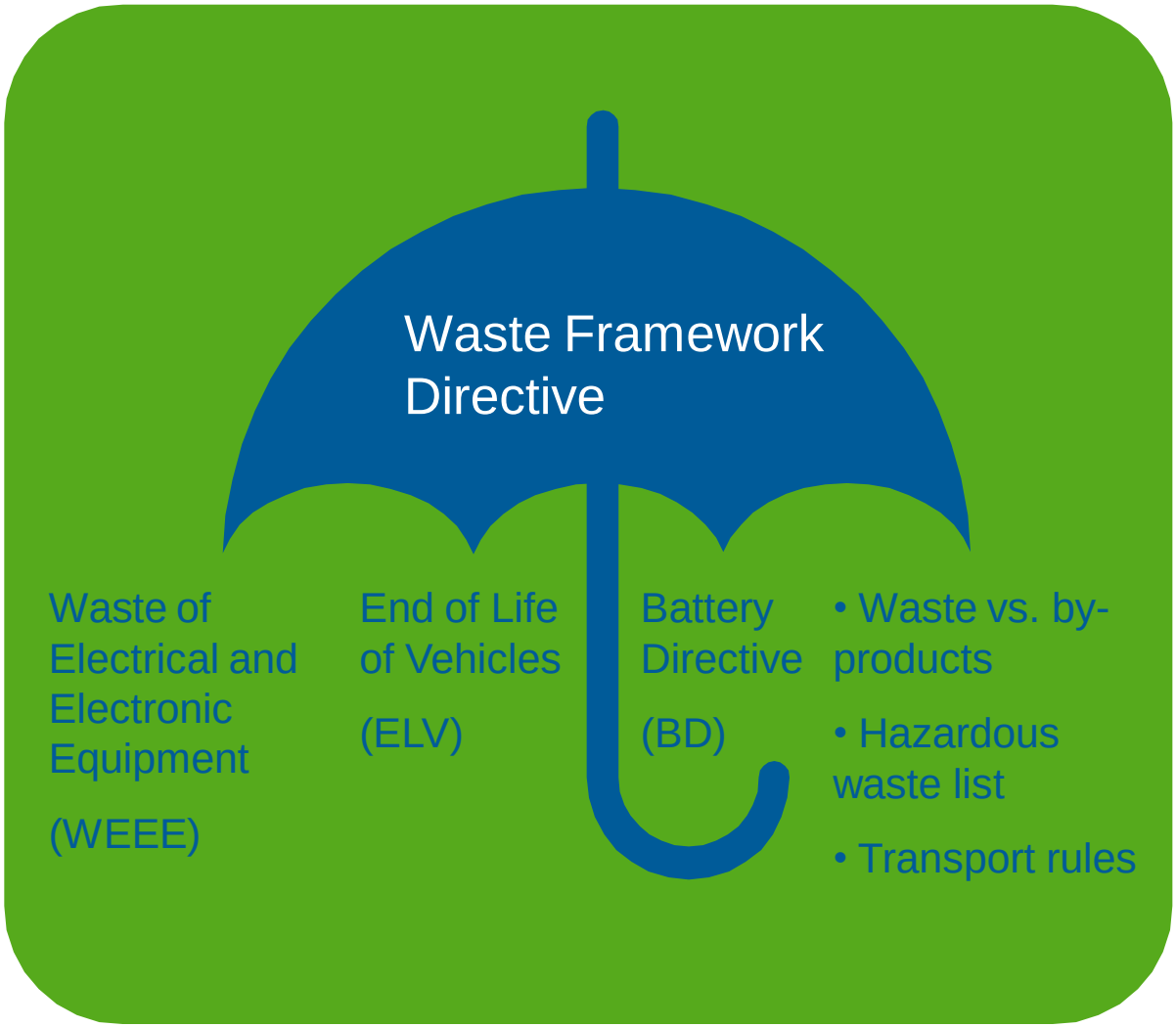
In the core of the megatrends



Legislative framework



Legislative framework

- WEEE directive
  - obligation to remove batteries
- ELV directive
  - End of Life concerns to be addressed in design phase
  - feasibility of reuse & recycling to be demonstrated
  - promotes use of recycled materials
  - target by 2015:
    - reuse + recycling = 85%
  - obligation to remove & collect batteries

Legislative framework

- Battery directive
  - **scope**: all batteries (incl. rechargeable) except military & space
    - includes (H)EV's
      - producers have to take battery back
      - landfill or incineration explicitly forbidden
    - debate on possible conflict with ELV
  - clear **collection** & **recycling** targets
    - collection: 25% by September 2012 – 45% by September 2016
    - ban on landfill
    - recycling efficiency target: > 50% by September 2011
    - debate on method of calculation

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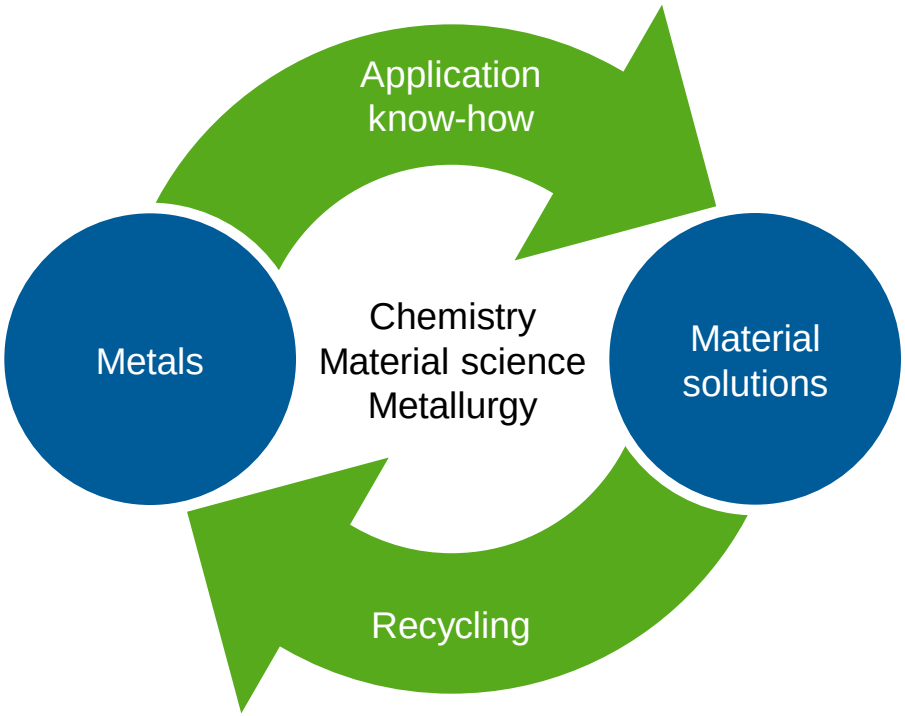
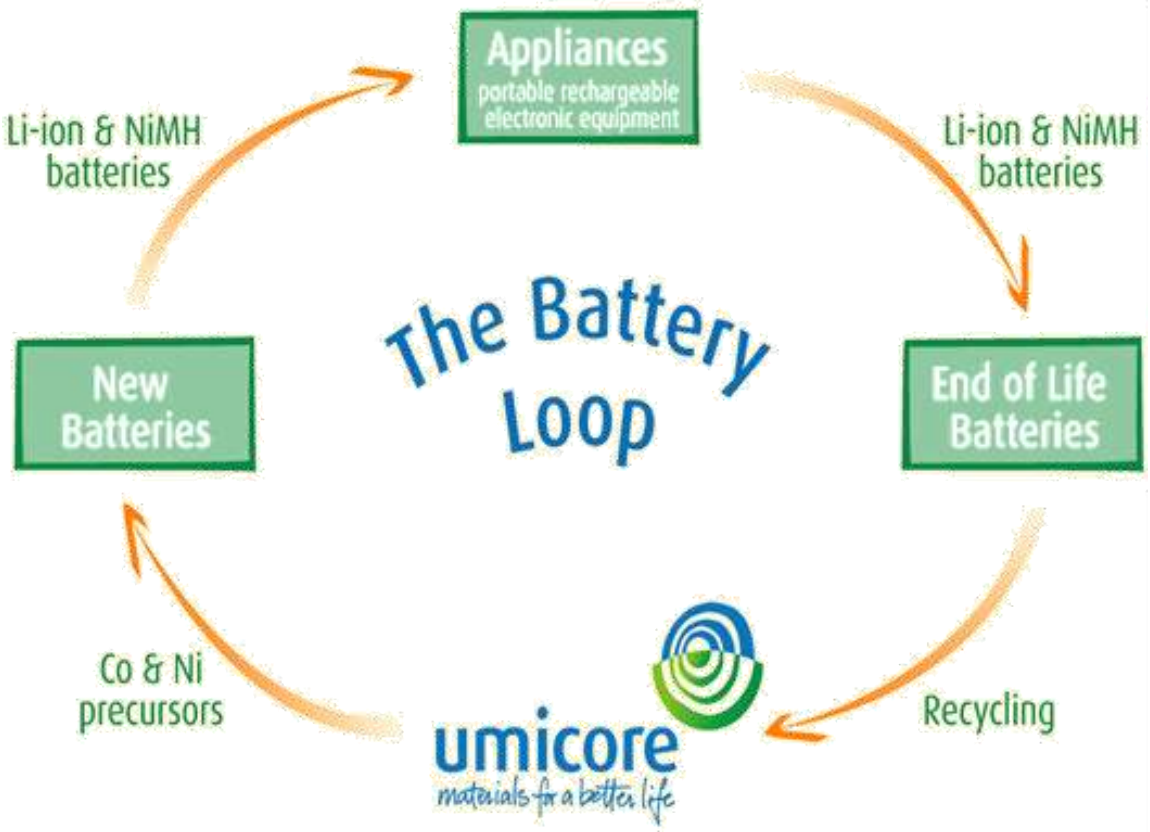
Closing the loop



Closing the battery loop



Battery recycling flowsheet

UMI
LISTED
NYSE
EURONEXT

umicore

Press release
CP-2009-31-R

Regulated Information

16 November 2009
08:00 CET

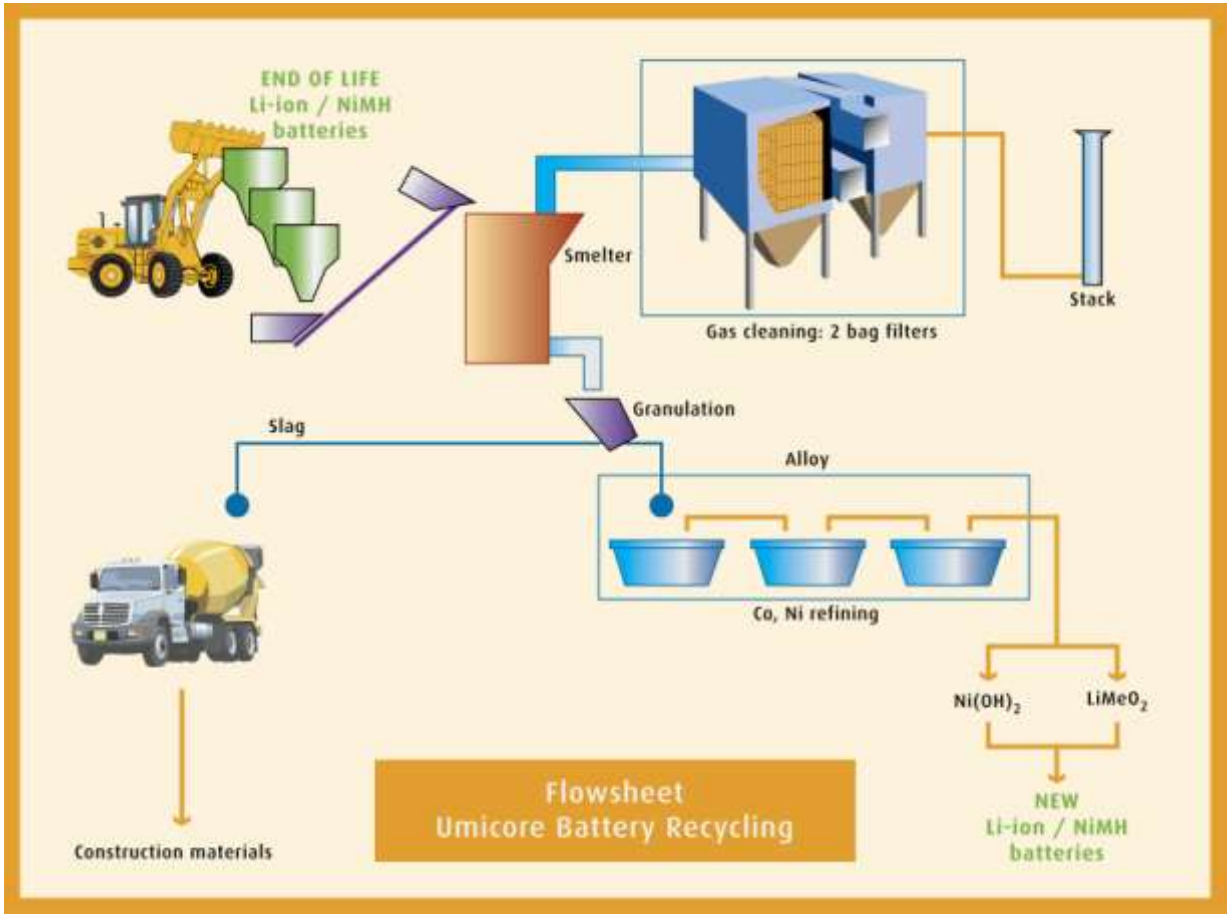
Umicore invests in recycling of rechargeable batteries

Umicore has decided to build an industrial scale recycling facility for end-of-life rechargeable batteries in Hoboken, Belgium. The investment will enable Umicore to deal with the expected growth in the availability of end-of-life Lithium-ion, Lithium-Polymer and Nickel Metal Hydride rechargeable batteries. The use of such batteries is set to grow substantially, particularly as a result of the increasing numbers of (hybrid) electric vehicles ((H)EVs) on the world's roads.

Increasingly stringent legislation is also placing a heavy premium on the efficient and eco-friendly recycling of end-of-life materials, such as used batteries[1].

Umicore currently operates a small scale facility which treats spent batteries that come primarily from portable electronic equipment such as mobile phones and laptop computers. The new facility will have an initial annual capacity of 7,000 tonnes. This is the equivalent of some 150,000 (H)EV batteries or 250 million mobile phone batteries. The plant, which involves an investment of € 25 million, is expected to start operating in the first half of 2011.

Battery recycling flowsheet



Battery recycling flowsheet

- Step 1: smelting & energy valorisation
  - process
    - no pre-treatment (except for HEV)
    - evaporate electrolyte
    - melt metals
    - recover calorific capacity
    - reduction oxides to metal using graphite electrode material
  - production
    - alloy (Co-Cu-Ni-Fe)
    - slag (Li)
    - gas

Battery recycling flowsheet

- Step 2: refining & purification of metals
  - process
    - leaching in sulphuric acid
    - several purification steps
    - solvent extraction for $NiSO_4$
  - production
    - $CoCl_2$
    - $NiSO_4 \rightarrow Ni(OH)_2$**: closing NiMH loop**
- Step 3 & 4: oxidation to Co_3O_4 + production of $LiCoO_2$
  - oxidation of pure $CoCl_2$ to Co_3O_4
  - $Co_3O_4 + Li_2CO_3 \rightarrow LiCoO_2$**: closing Li-ion loop**

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Slag valorisation

- Slag properties
  - main components: CaO – Al2O3 – SiO2
  - minor components: FeOx – Li2O – MnO
  - particle size: 0-4mm and 4-32mm
- Regulation
  - VLAREA standards of OVAM
  - compliant with REACH – CE marking – waste & construction directives
  - leaching properties

Slag valorisation

- Construction applications
  - aggregate – cement raw material – filling material in concrete
  - used as filling in construction of industrial facility in Sweden

Tests	EN Standard	Slag (Fine & Coarse aggregate)
Free CaO (%)	1744-1 § 18 (1998)	0.22
Free MgO (%)	1744-1 § 18 (1998)	<1%
Los Angeles Coefficient (La)	1097-2 (1998)	24
Micro Deval Coefficient (MD)	1097-1 (1996)	10

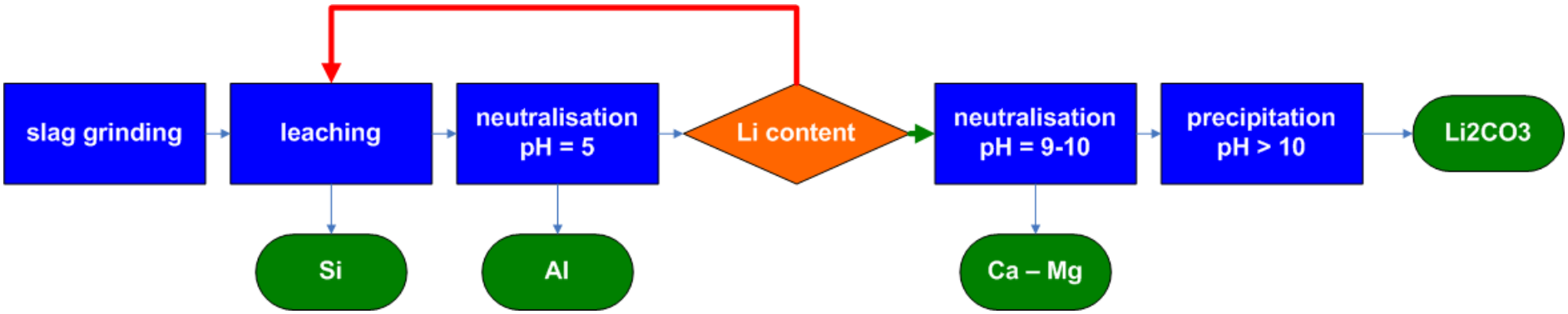
  - LA-test: resistance to fragmentation
    - LA < 30: suitable for coating & road surface treatments
  - MD-test: resistance to wear
    - MD < 20: suitable in concrete

Slag valorisation

- CO_2 neutrality
  - nearly 5% of man-made CO2 emissions from cement
  - secondary materials avoid CO2 emission
    - transition limestone ⟶ CaO already made
- Li-source in glass/ceramics
  - vitro-ceramic glass: Li for heat resistance

Slag valorisation

- Li-valorisation



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Conclusions

- Rechargeable batteries are everywhere
- Megatrends
  - resource scarcity
  - electrification of cars
- Legislative drivers towards recycling
- Umicore closes battery loop
- Slag valorisation
  - application in construction
  - Li-valorisation

Thank you for your attention!