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Engineering

# Saadaanko litium kierrätettyä litiumparistojätteestä?

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## Lithium-Ion Batteries (LIBs)

- **Widely used in consumer electronics,**
  - By 2020, discarded LIBs will reach 25 billion units
- **Demand expected to grow:**
  - Hybrid and electric vehicles (HEVs, EVs)
  - Renewable energy related energy storage

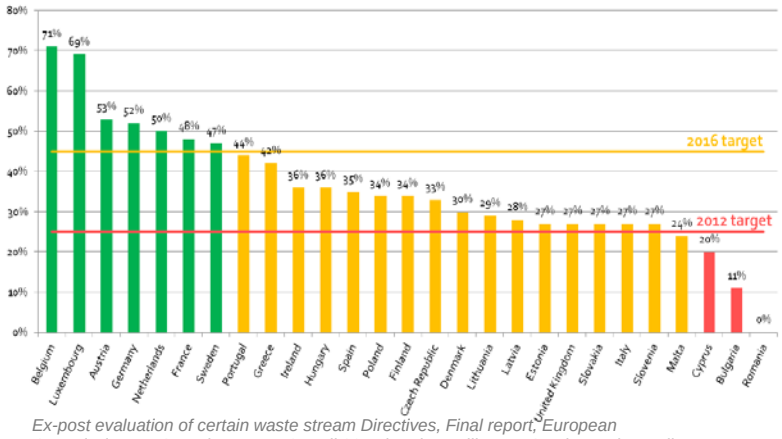
# Metals in LIBs

- Waste LIBs are rich in valuable metals
  - Co: 5-20%
  - Ni: 5-10%
  - Li: 2-7%
  - Cu: 6-12%

Economy&Environment




# EU - Portable battery collection rate 2014




*Ex-post evaluation of certain waste stream Directives, Final report, European Commission – DG Environment 18 April 2014 by Bio Intelligence Service and Arcadis*

# →Keräysaste noussut



## Recovery of Li from battery waste?

**According to UNEP report, less than 1% of Li was recycled from various applications (2011)**

# →Mekaaninen käsittely?



## Mechanical separation

- Based on physical differences between different components of a crushed lithium-ion battery
  - Particle size
  - Density
  - Magnetic properties

| Waste scraps | Li | Co | Cu | Ni |
|---|---|---|---|---|
| Overflow | 1.40 | 8.42 | 11.9 | 0.80 |
| Underflow | 3.65 | 23.6 | 6.24 | 2.72 |

## Metal content depends on mechanical separation

| No. | Co | Li | Ni | Cu | Ref. |
|---|---|---|---|---|---|
| 1 | 24.5 | 3.5 | - | 2.5 | (Zeng, Li, and Shen 2015) |
| 2 | 23.2 | **2.3** | 0.9 | **0.2** | (Shin et al. 2005) |
| 3 | 29.5 | 3.1 | 0.1 | **16.5** | (Dorella and Mansur 2007) |
| 4 | 26.8 | 3.3 | 0.3 | 1.3 | (Chen et al. 2011) |
| 5 | 23.3 | 2.7 | 1.4 | 12.2 | (Kang et al. 2010) |
| 6 | 26.0 | 3.2 | **11.0** | 1.9 | (Vassura et al. 2009) |
| 7 | **19.3** | 2.4 | 0.1 | 0.6 | (Barik, et al. 2016) |
| 8 | 36.0 | 5.0 | **0.1** | 13.0 | (Mantuano et al. 2006) |
| 9 | 23.6 | 3.7 | 2.7 | 6.2 | (Aaltonen and Peng 2017) |
| 10 | **54.0** | **6.4** | - | - | (G. P. Nayaka, et al. 2015) |

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# →Mekaanisen esikäsittelyn optimoinnilla tärkeä rooli Li-rikkaan patterijätejakeen keräämisessä

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Prof. Mari Lundström – Hydrometallurgy and Corrosion

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# Pyrometallurgical processing

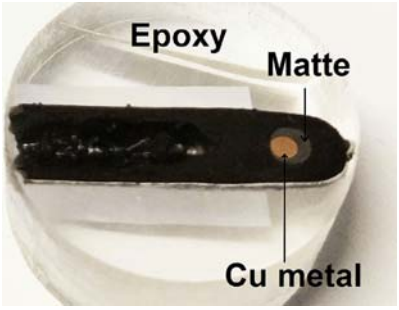
- **Key processes in primary metallurgy**
- **Integration of battery processing into the existing infrastructure is beneficial**



# Pyrometallurgical processing of Li Battery waste?

*T. Tirronen et.al. Journal of Cleaner Production 168 (2017) 399-409*

- Distributions of lithium-ion and nickel-metal hydride battery elements in copper converting
- Equilibrium/quenching method + direct phase analysis (EPMA and LA-ICP-MS)



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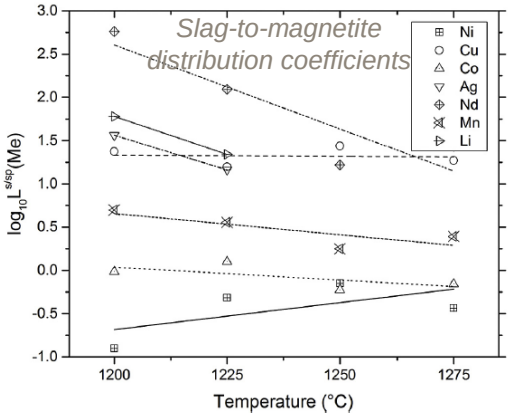




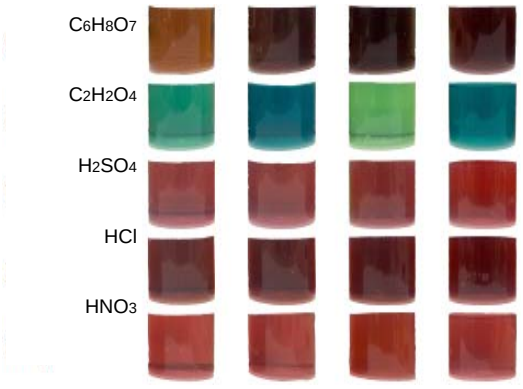

# →Pyrometallurgiset prosessit hyviä perusmetallien talteenottoon, Li menetetään kuonaan

# →Hydrometallurgia?

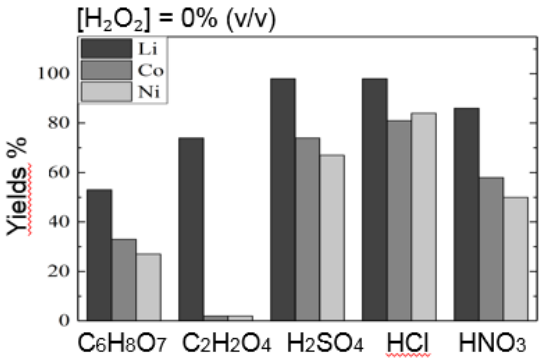


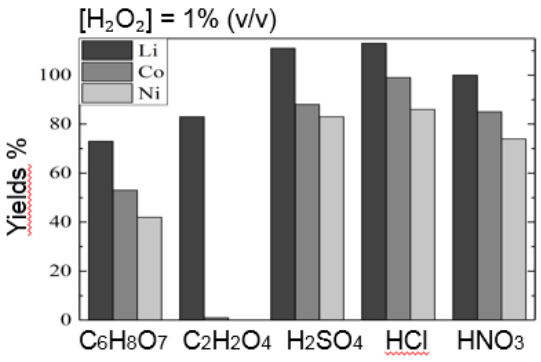
## Leaching Tests

- **Various leaching media**
  - *2 M citric ($C_6H_8O_7$)*
  - *1 M oxalic ($C_2H_2O_4$)*
  - *Sulfuric acid ($H_2SO_4$)*
  - *4 M hydrochloric (HCl)*
  - *1 M nitric ($HNO_3$)*
- Comparison of reducing agents



# Leaching Tests



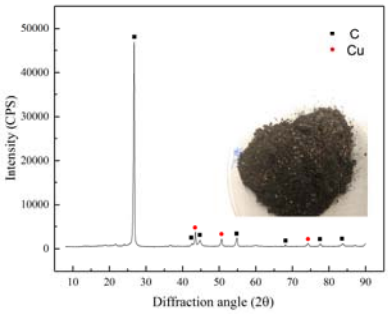




Leaching of Metals from Spent Lithium-Ion Batteries
Aaltonen, M., Peng, C., Wilson, B. & Lundström, M.
31 Oct 2017 In : Recycling. 2, 20, 9 p., 2040020



# Optimized sulfuric acid leaching produces:

- **Co rich PLS:**
  - Co 44 g/L, Li 7 g/L
  - Co/Cu = 401
- **Cu rich residue**
  - Co 0.5%, Li 0.06%, Cu 12%

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# HCl leaching

- **2 step-precipitation process**
- **$Li_2CO_3$ precipitation**
- **Purity of 96%**

Lithium Recovery by Leaching and Precipitation from Lithium Accumulator WAstes
Porvali, A., Han, B., Eronen, E., Lundström, M., Louhi-Kultanen, M., 24th International Workshop on Industrial Crystallization, August 29th – 31th, 2017, Dortmund, Germany



# Litiumia EI nykyään juurikaan kierrätetä akkujätteestä

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