



# Saadaanko litium kierrätettyä litiumparistojätteestä?

*Mari Lundström  
Aalto University, Finland*

## 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

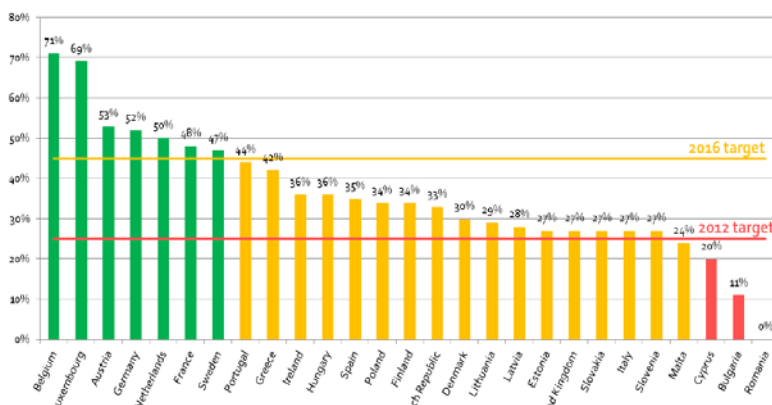


- Waste LIBs are rich in valuable metals
  - Co: 5-20%
  - Ni: 5-10%
  - Li: 2-7%
  - Cu: 6-12%

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

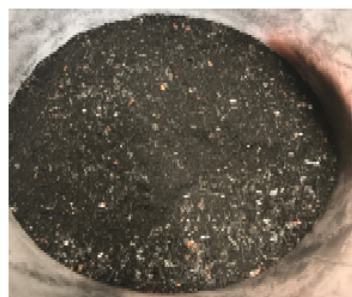


# → Keräysaste noussut

## 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	<b>2.3</b>	0.9	<b>0.2</b>	(Shin et al. 2005)
3	29.5	3.1	0.1	<b>16.5</b>	(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	<b>11.0</b>	1.9	(Vassura et al. 2009)
7	<b>19.3</b>	2.4	0.1	0.6	(Barik, et al. 2016)
8	36.0	5.0	<b>0.1</b>	13.0	(Mantuano et al. 2006)
9	23.6	3.7	2.7	6.2	(Aaltonen and Peng 2017)
10	<b>54.0</b>	<b>6.4</b>	-	-	(G. P. Nayaka, et al. 2015)

→ Mekaanisen  
esikäsittelyn optimoinnilla  
tärkeä rooli Li-rikkaan  
patterijätejakeen  
keräämisessä



## Pyrometallurgical processing



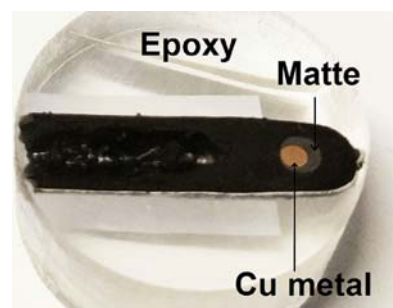
- Key processes in primary metallurgy
- Integration of battery processing into the existing infrastructure is beneficial

## Pyrometallurgical processing of Li Battery waste?



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

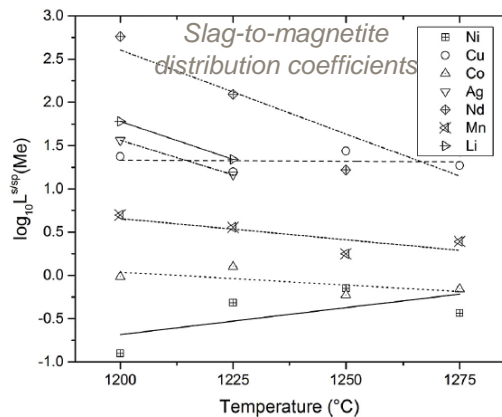
- Distributions of lithium-ion and nickel-metal hydride battery elements in copper converting
- Equilibrium/quenching method + direct phase analysis (EPMA and LA-ICP-MS)



## Pyrometallurgical processing of Li Battery waste?



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



→ Pyrometallurgiset prosessit  
hyviä perusmetallien  
talteenottoon, Li menetetään  
kuonaan



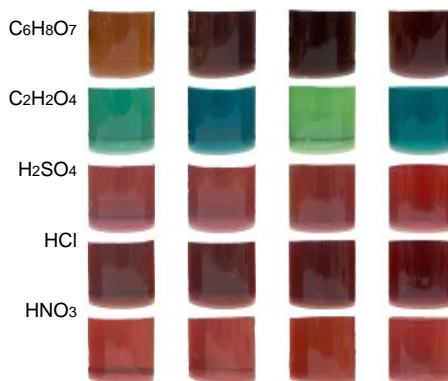
# → Hydrometallurgia?

## Leaching Tests

- **Various leaching media**

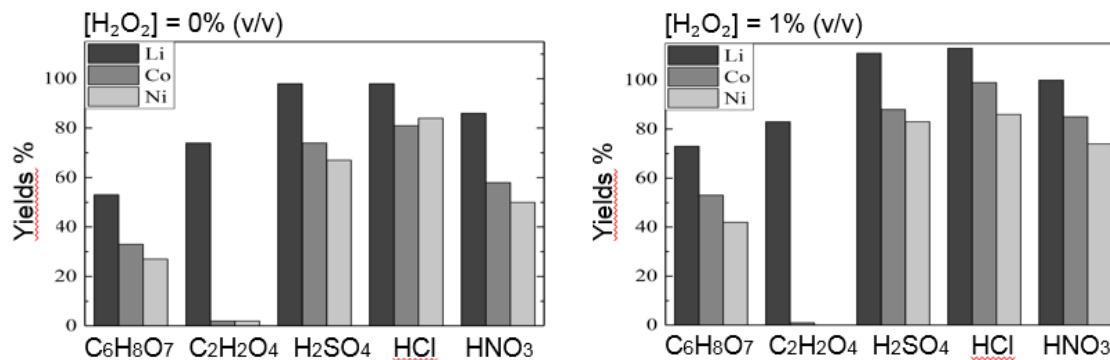
- 2 M citric ( $C_6H_8O_7$ )
- 1 M oxalic ( $C_2H_2O_4$ )
- Sulfuric acid ( $H_2SO_4$ )
- 4 M hydrochloric (HCl)
- 1 M nitric ( $HNO_3$ )

- **Comparison of reducing agents**





## Leaching Tests



### Leaching of Metals from Spent Lithium-Ion Batteries

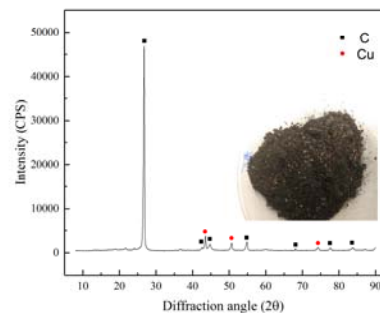
Aaltonen, M., Peng, C., Wilson, B. & Lundström, M.

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%



### 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

## HCl leaching



- 2 step-precipitation process
- $\text{Li}_2\text{CO}_3$  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 kierrätetään  
 akkujätteestä



Kierrätys on teknisesti mahdollista,  
 kannattavuuden määrittää  
 taloudelliset ja  
 ympäristölainsäädännölliset tekijät

# Acknowledgements



Mari Lundström  
 mari.lundstrom@aalto.fi



**A!** Aalto University  
 School of Chemical  
 Engineering

Chao Peng, Antti Porvali, Miamari Aaltonen, Benjamin Wilson, Severi  
 Ojanen, Rodrigo Serna, Pekka Taskinen, Topi Tirronen,  
 Mari Lundström