



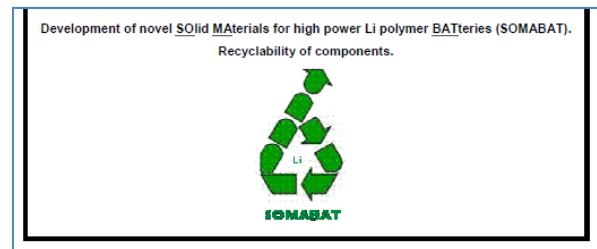
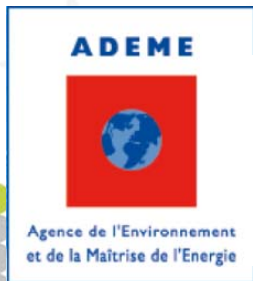
# Challenge for recycling advanced EV batteries



RECUPYL



Innovative Battery Recycling





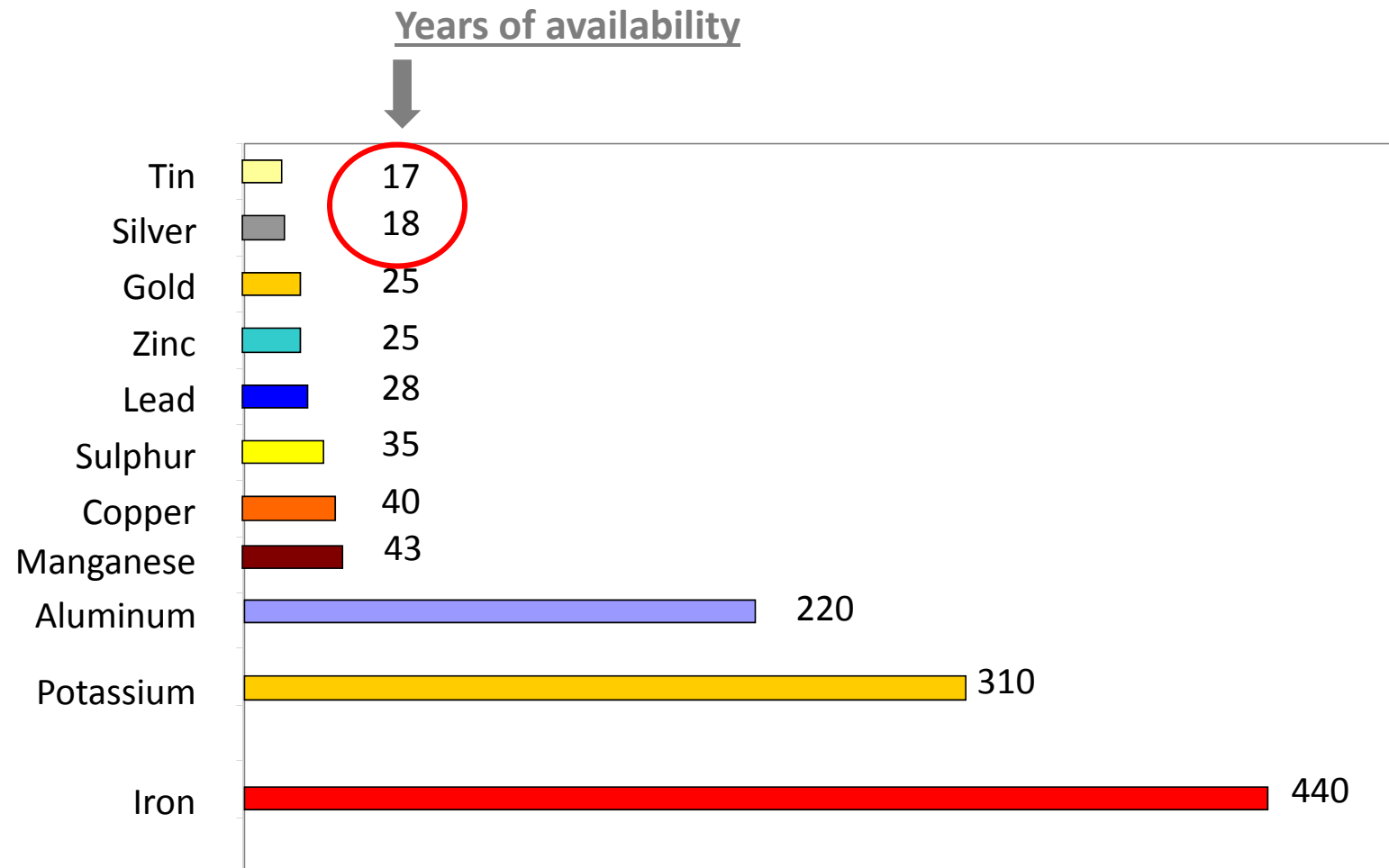
EV Segment addressed very well  
CO2 emission and low energy  
consumption,

**But..... What about resources???**

resources aspect must be integrated to  
access to a sustainable segment



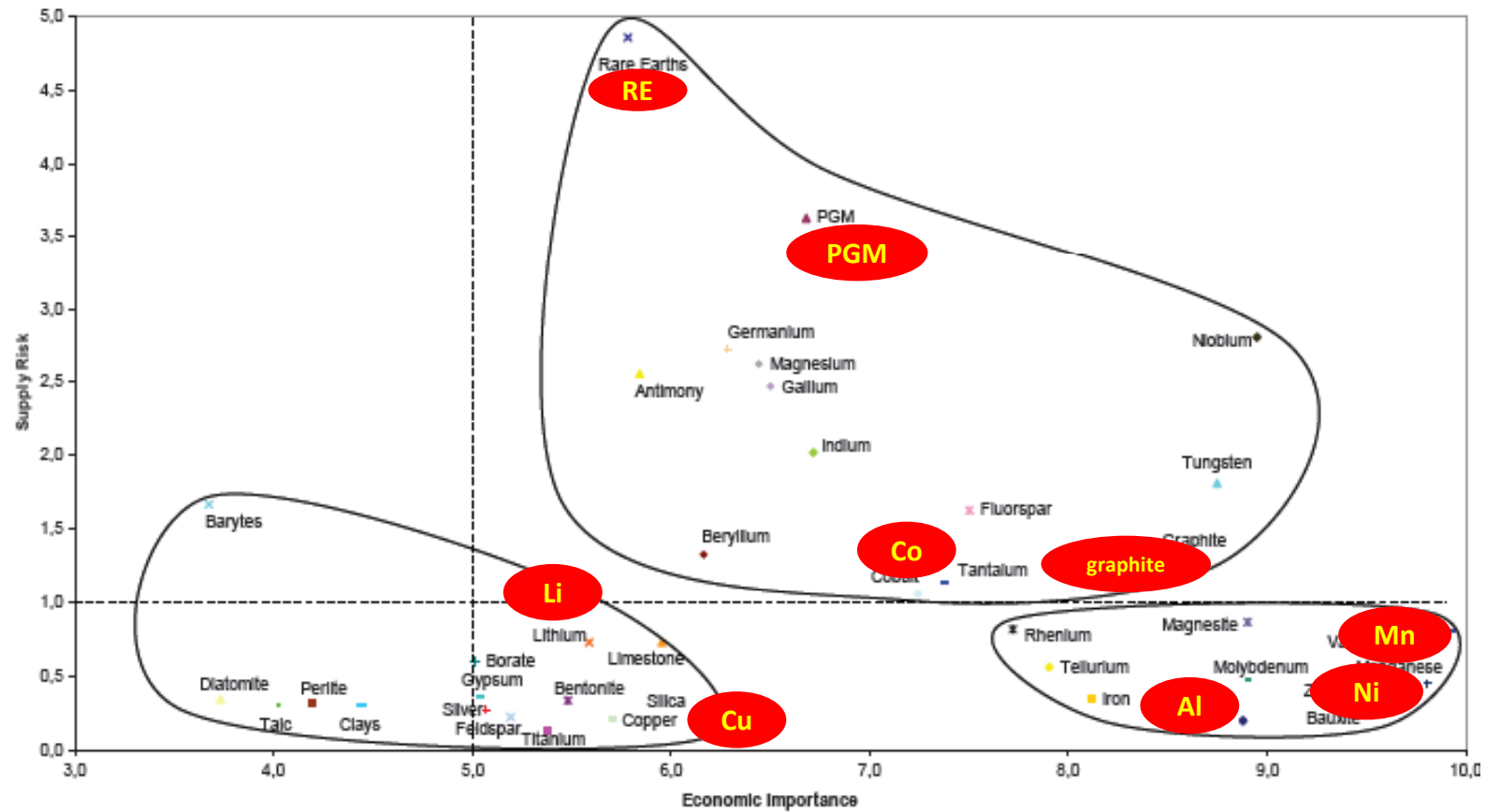
# Sustainability of natural resources



Sources USGS 2010 OMPM 2011



## Classification critical metals for EC (Madrid report July 2010) and EV Segment



The “Raw Materials Initiative”: a new challenge for the EU recycling industry: DG Industry and enterprise Madrid Report July 2010



The solution is around us!

... To URBAN MINE(\*\*)

For old mine



Regsitred by Recupyl in 2004 N° 79083906 Int. TM Register

# Sustainability: the choice



**250 T** of ore  
(spodumène)

Or  
**750 T** of brines



To produce  
1 Ton of Lithium  
We need



**28 T** of Li ion batteries  
from mobiles/laptops



Or **256** batteries  
for EV





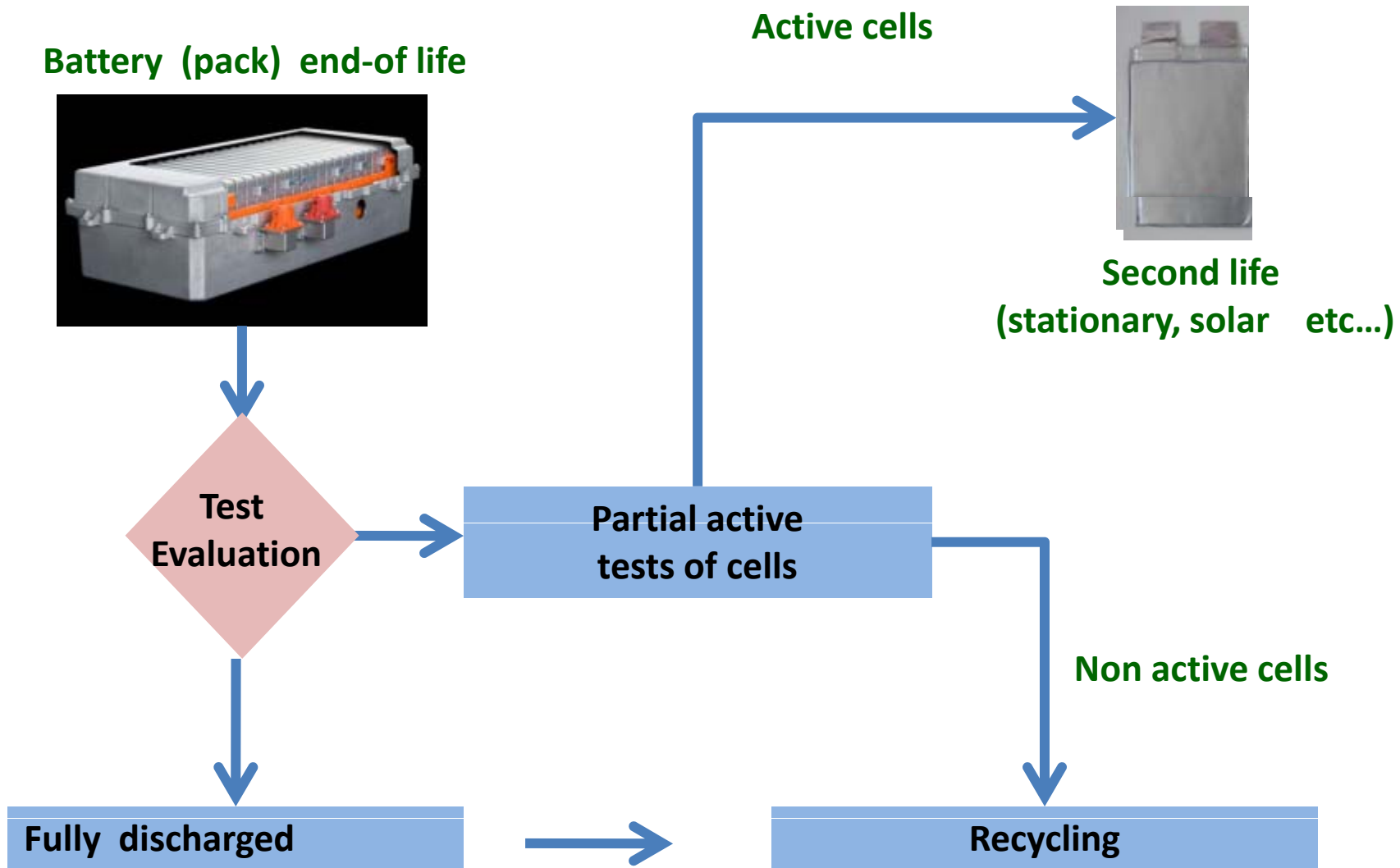
HISTORY OF RECUPYL  
IN RECYCLING OF LITHIUM BATTERIES  
**Up to 10 years experience**



- 2002 : First study on HydroQuebec Lithium metal/polymers Batteries (now out of NDA)
- 2003 : Continuation of study on new chemistry
- 2004 : Pilot project under European Support 5th FP VALIBT
- 2005 : World Patent granted including  $\text{LiFePO}_4$  (claims 6)
- 2006 : Pre-industrial facility in France 50 T/y
- 2007 : 1<sup>nd</sup> industrial facility in Singapore 450 T/y
- 2009 : 2<sup>nd</sup> industrial facility in England 450 T/y
- 2010 : 3<sup>rd</sup> industrial lines in USA (Michigan) 450 T/y
- 2011-2012 : Pilot plant for EV Batteries (patent pending) supported by 2 EU projects
- 2013 : Industrial Demonstration facility for EV batteries (600T/y) supported by French Program of “Investment for the Future”



# Value chain and second life of batteries



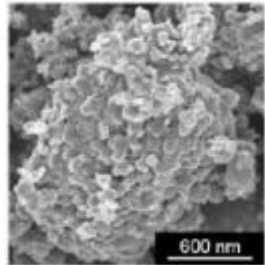




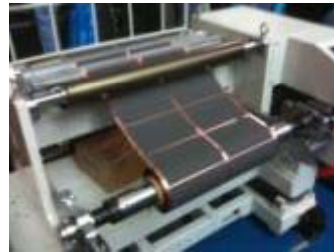
# THE EV BATTERY CHAIN

Battery production concept for construction Li-ion for EV

Materials



processing



cell



module



pack



RECUPYL concept for « de-construction » Li-ion battery for EV

Pack



module



cell



processing



materials





Dismantling of packs/ modules  
is mandatory for resource recovery?

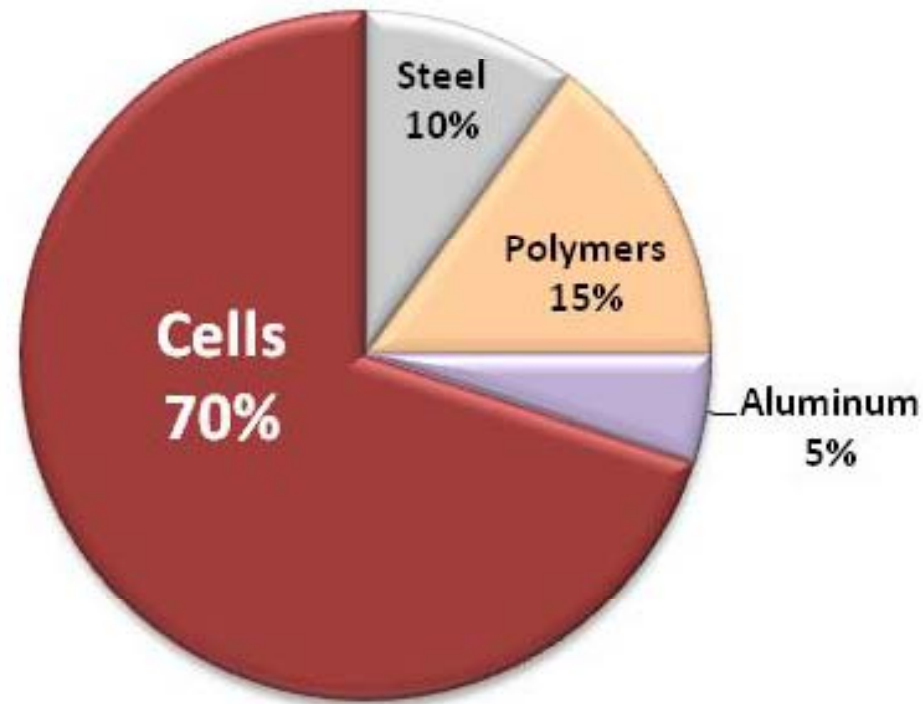
To dismantle, Eco-conception is the real challenge for:

- 1 safety of operator during dismantling
- 2 selective access to materials
- 3 allows a second life for cells



## Even the non active parts contributes to the sustainability of the end-of-life

### Average mass balance of NMC battery



Dismantling is mandatory for resource recovery

# Why to dismantle (1)?

## Safety aspect



Pack 120 à 400 V, > 30 kWh



Module 46 - 60 V, 1 -3 kWh



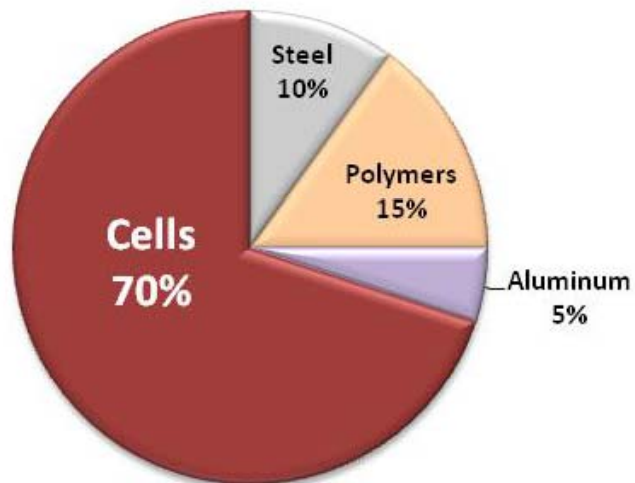
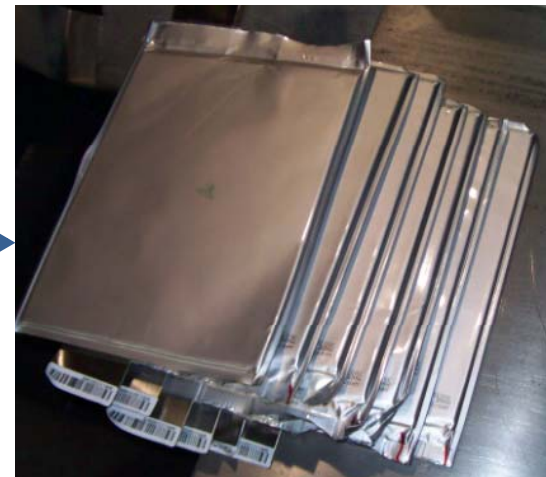
Cell 3.7 V, 0.1 kWh



**SAFETY**

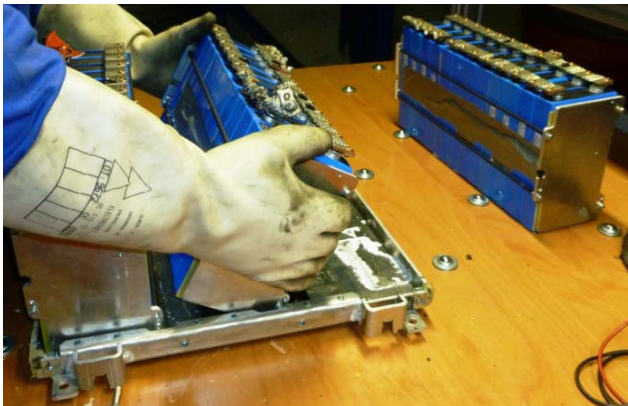
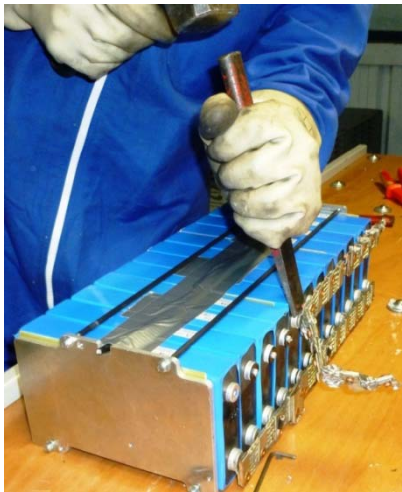
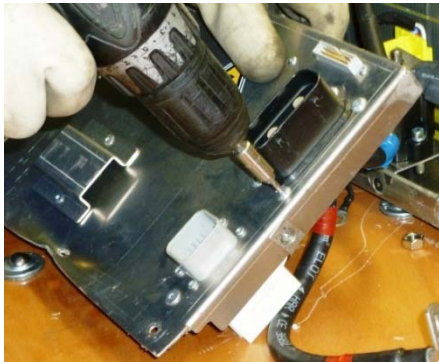
# Why to dismantle (2)?

Access to expensive specific spare parts  
and second life of cells





But strong need of eco-conception « *designed for recycling* »  
pack N°1





# pack N°2





pack N°3



Cells 5000 V

# Example of pack « *designed for recycling* » pack N°4



**Pack**



**BMS**



**Packaging**



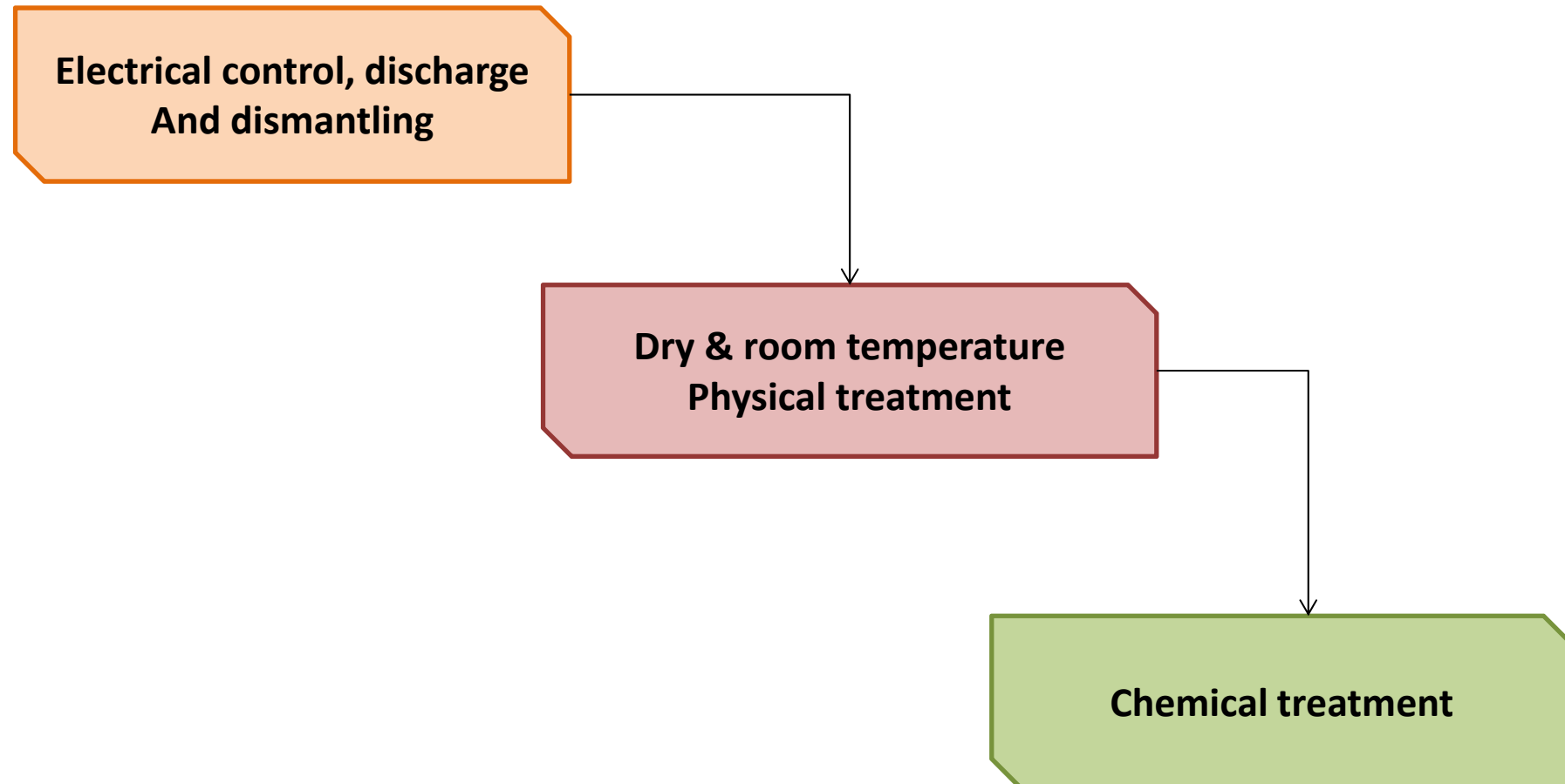
**Cells**



**Steel and non ferrous**



## Flows sheet of the non thermal developed process





**Dry & Room  
Temperature  
Physical Treatment**



# Equipment for Treatment of complete prototype cells

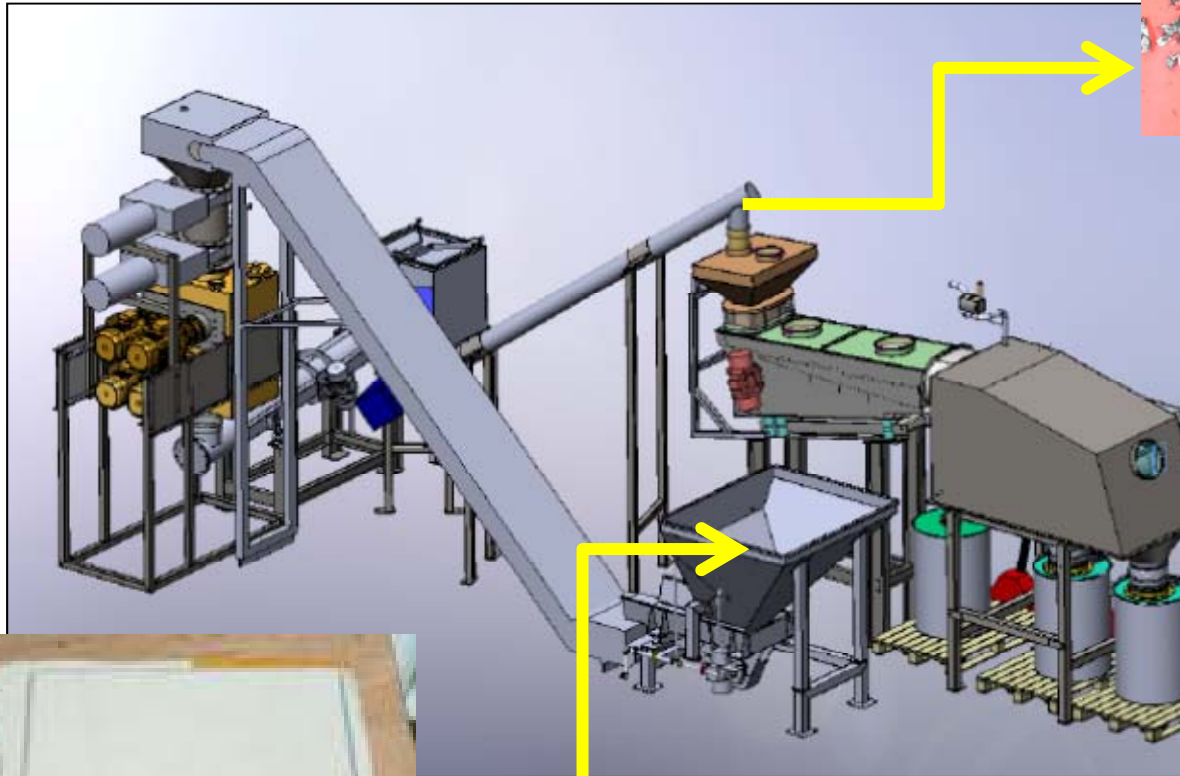


Safe and  
efficient  
mechanical treatment





## Safe and Clean mechanical treatment: First step



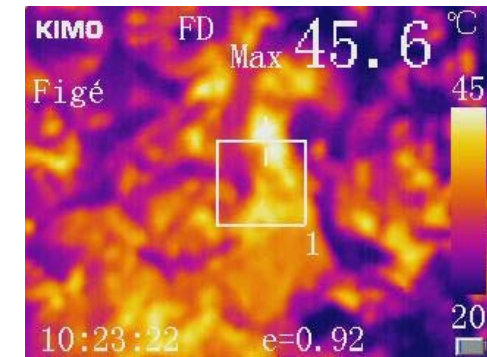
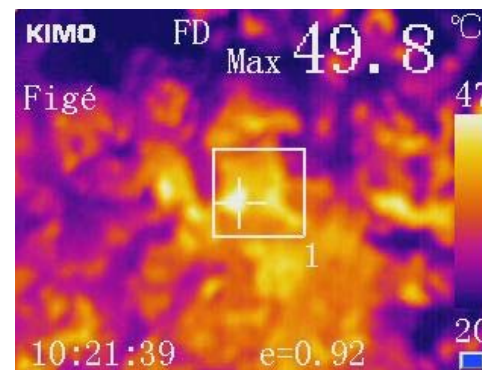
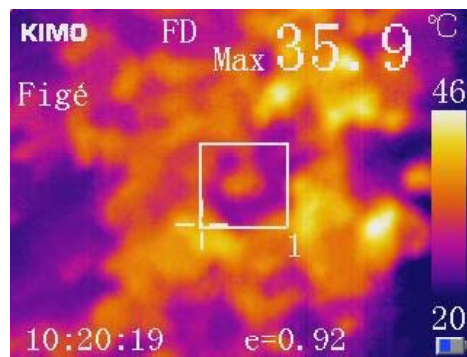
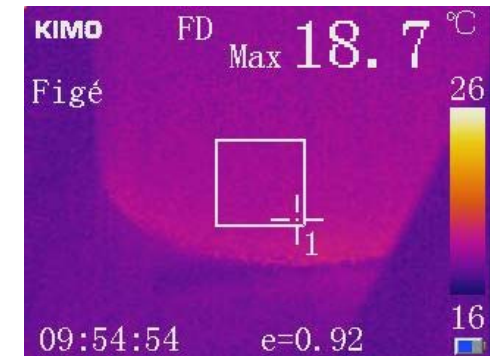
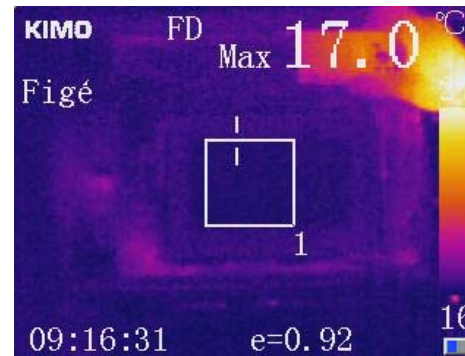
Recovered product  
after shredding :

Mix of (NMC) oxides  
and  
Cu/Al/polymers





# Temperature control during mechanical treatment

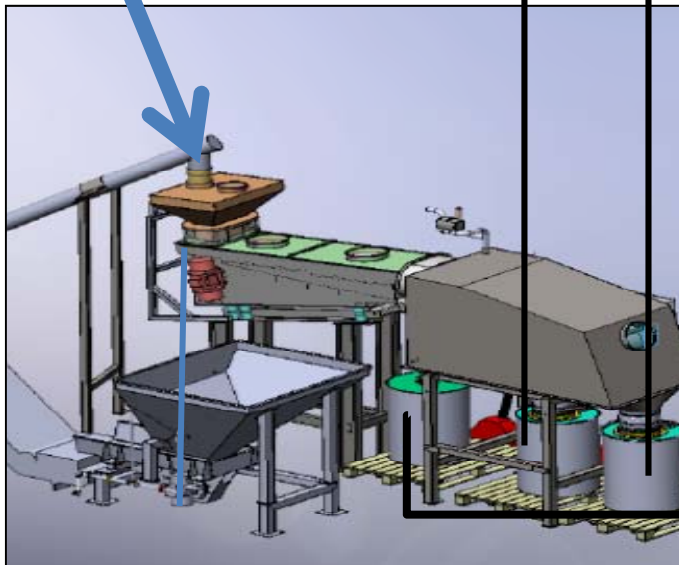






# Mechanical treatment

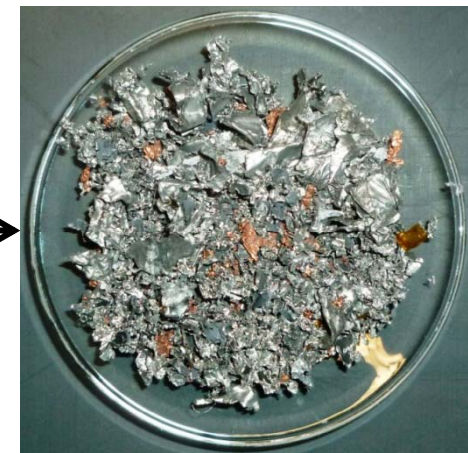
## Step 2



Mix of plastics



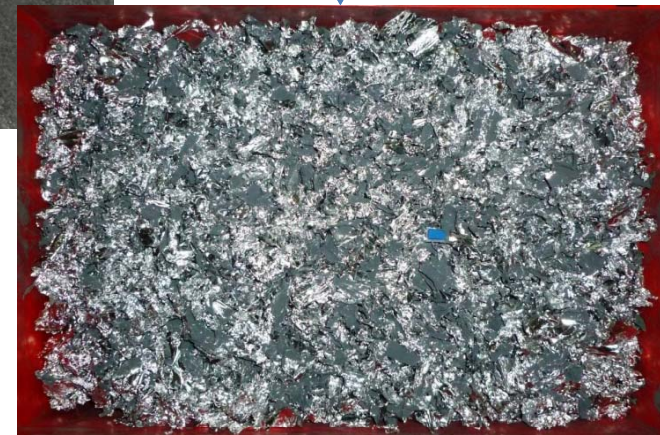
metals



Mix Cathode, anode



# Treatment of scrap production







## Industrial pilot treatment on mechanical steps



Recupyl Michigan site  
(recycling of EV packs and cells )



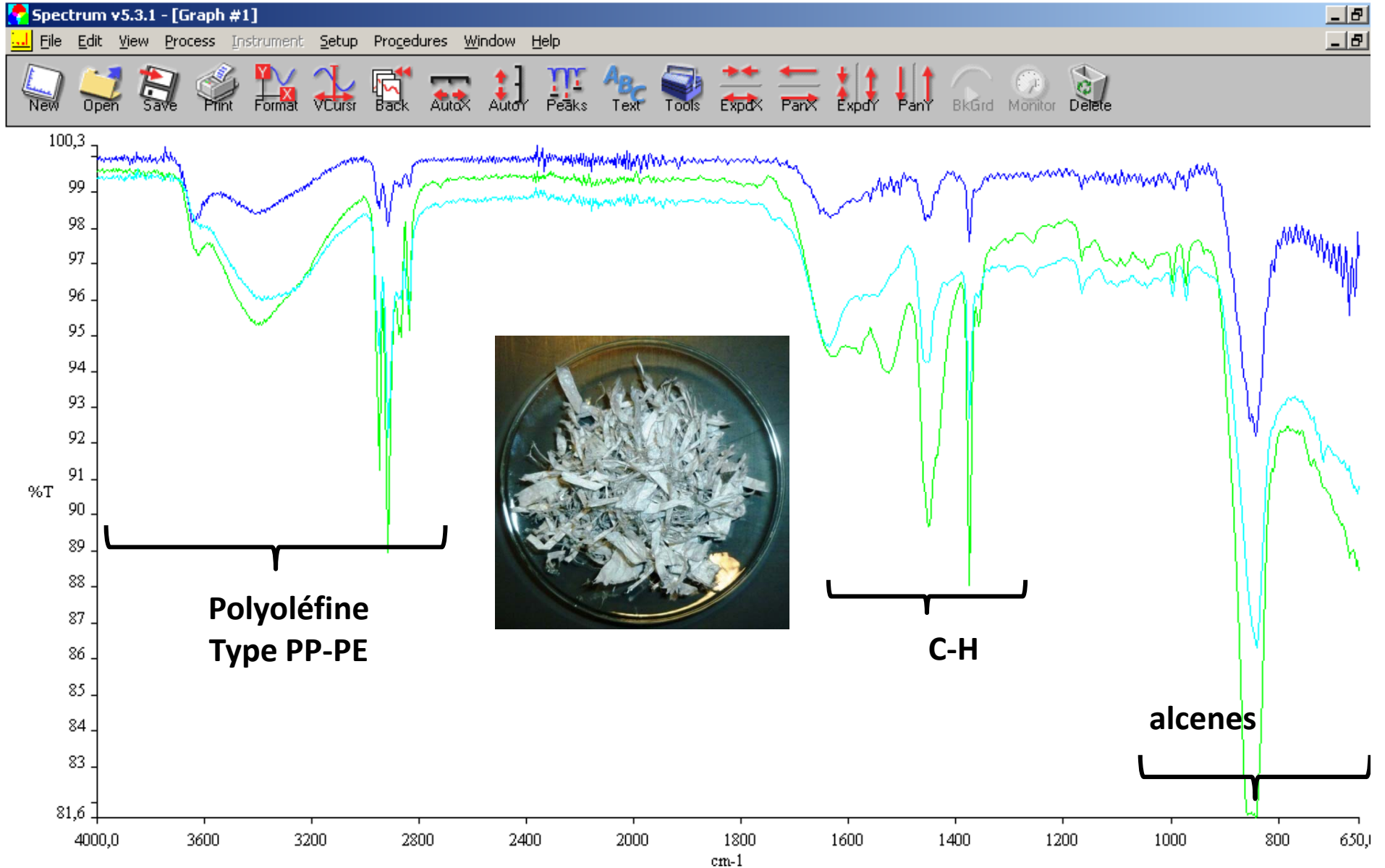
Recupyl France site  
Recycling of modules and cells



# **Separator and solvent recovery**



# Separator form Battery EV1, 2 and 3

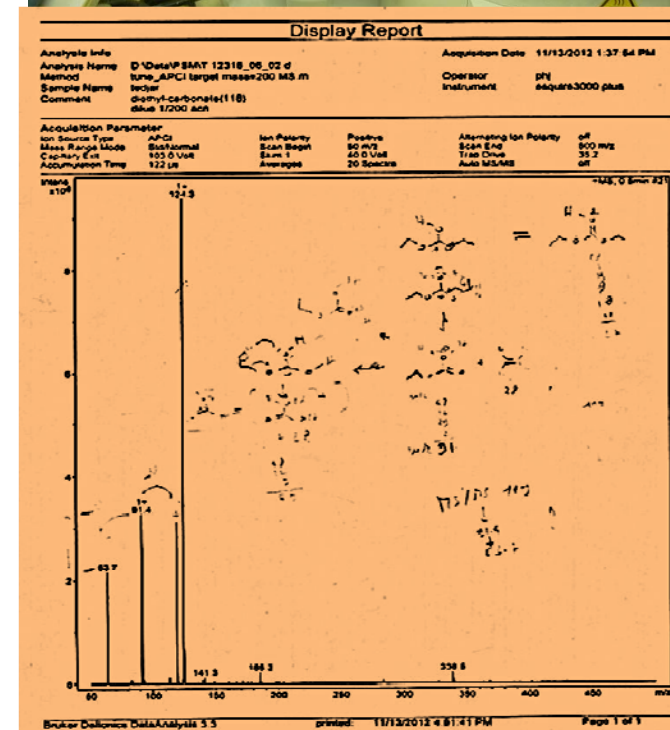
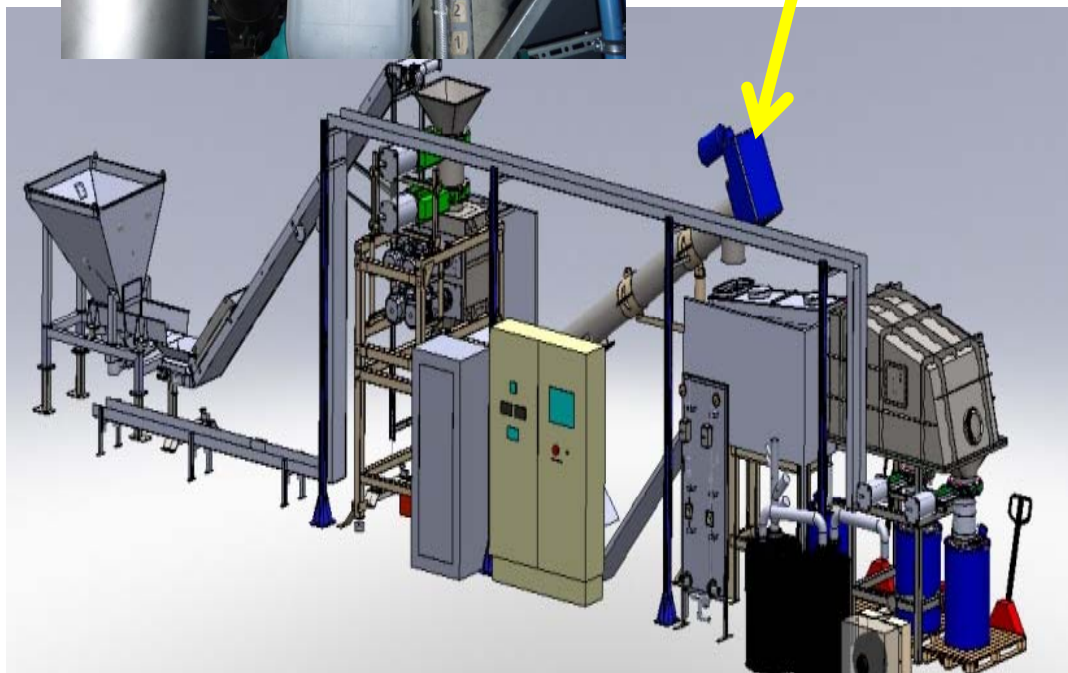


# Solvent separation strategy

## Recovery first solvent online



Recovery point





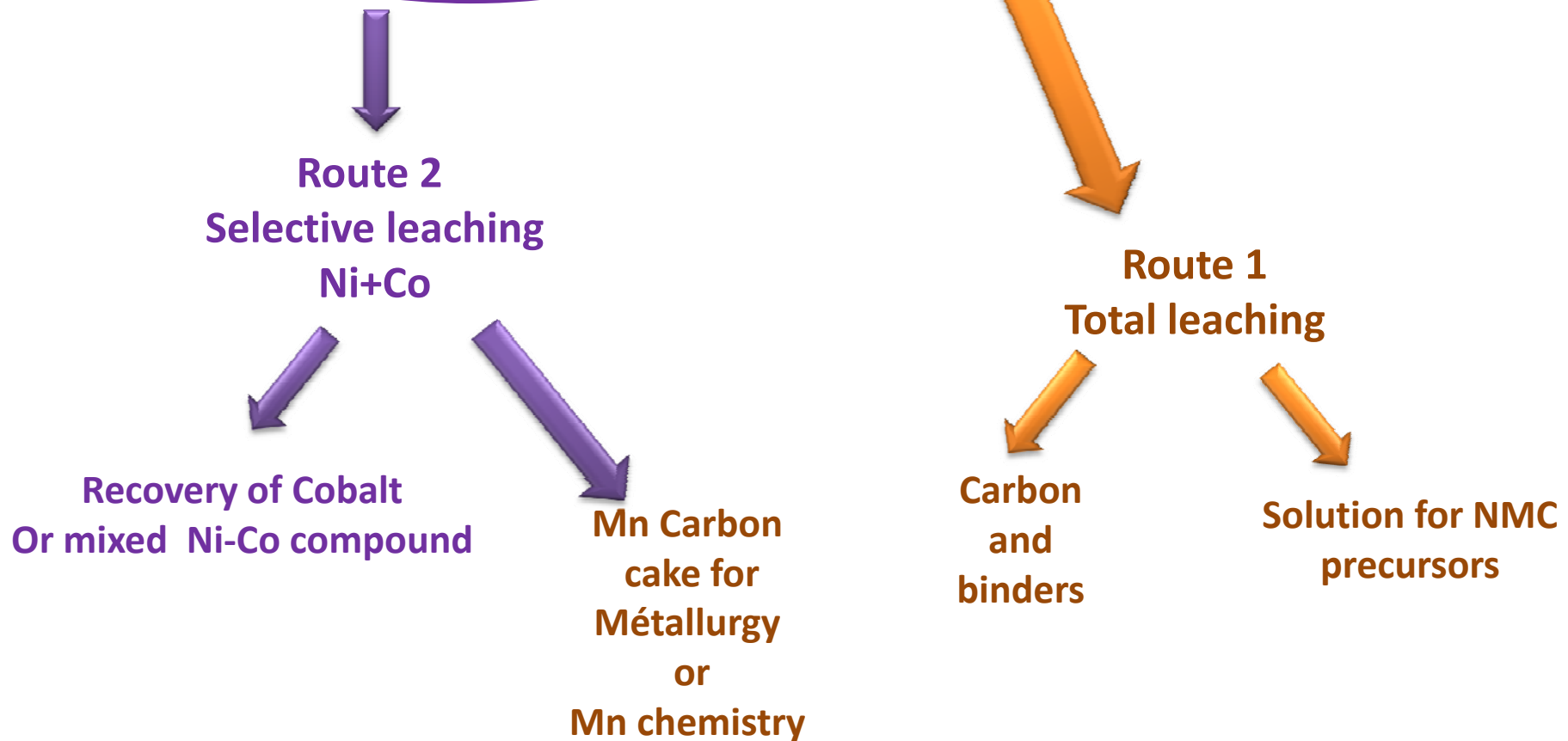
# **Chemical Treatment NMC Chemistry**



# NMC: Strategy of treatment



Co	Ni	Li	Mn
2,1%	8,6%	2,4%	23,2%



# Cobalt recovery from NMC

Using a strong difference of kinetic oxidation between Co and Ni&Mn



Seed



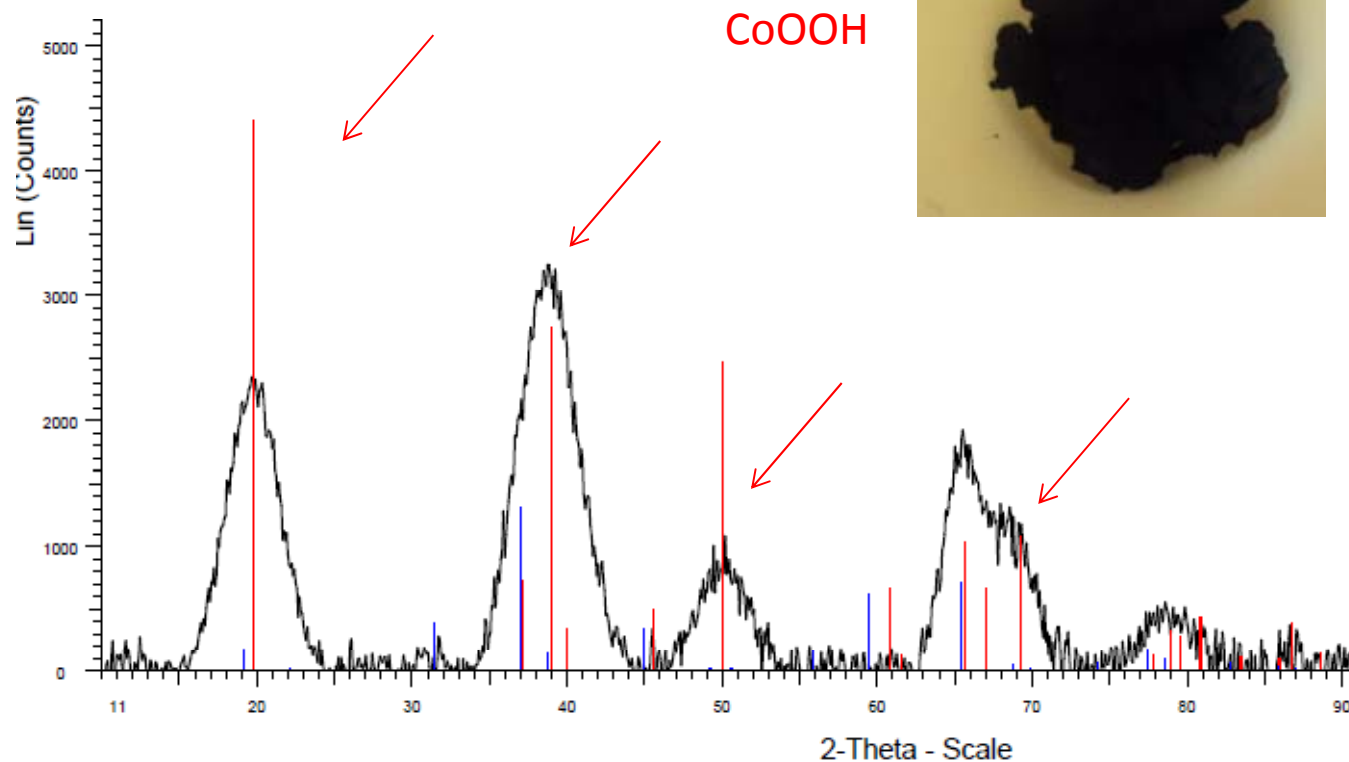
oxidation



Co(III) oxide

# Selective recovery of Cobalt (III) Oxide

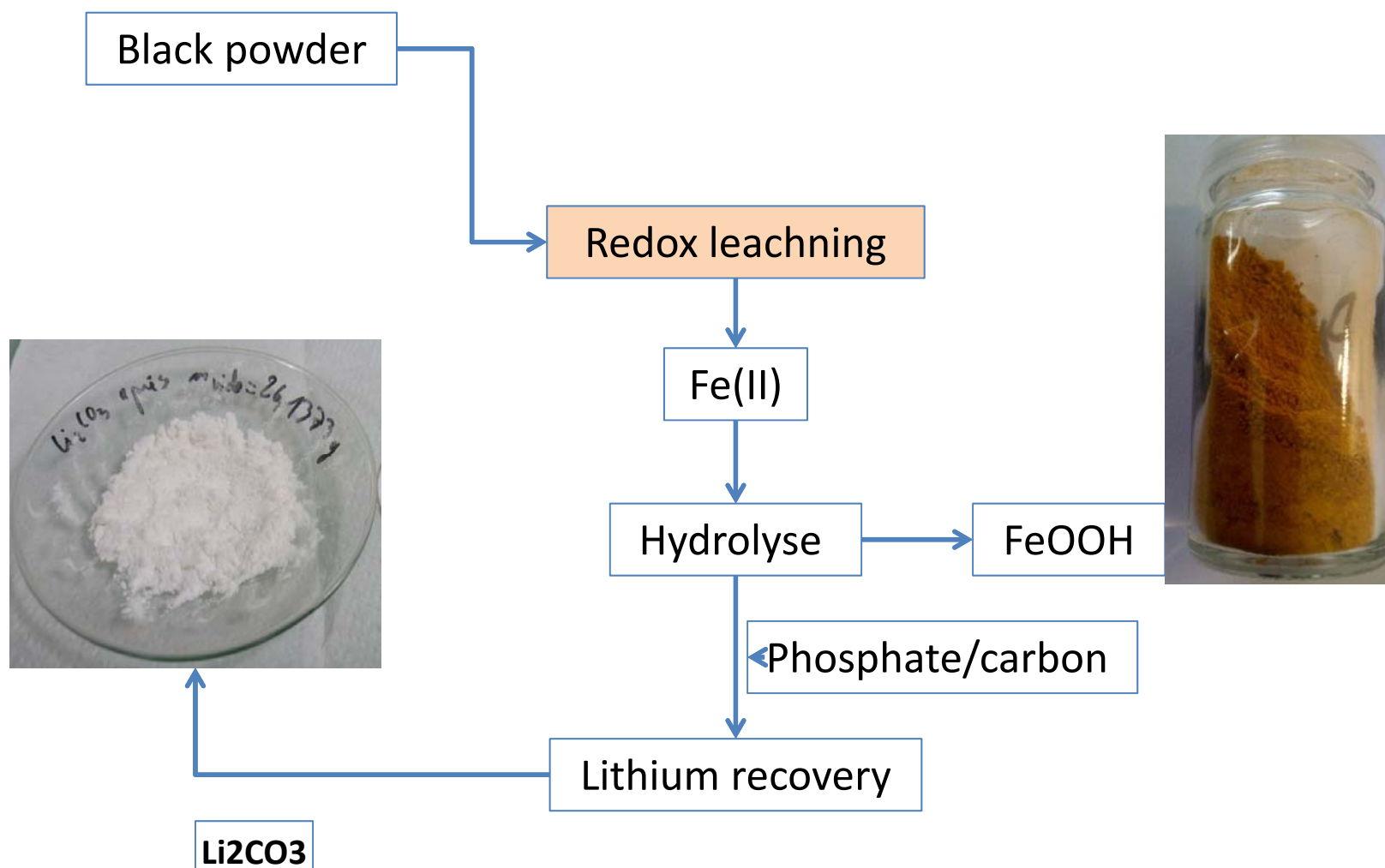
Cobalt oxide	
élément	content
<b>Co</b>	<b>52.50%</b>
Cu	0.75%
Al	0.59%
Ni	0.49%
Fe	0.02%
Mn	0.17%



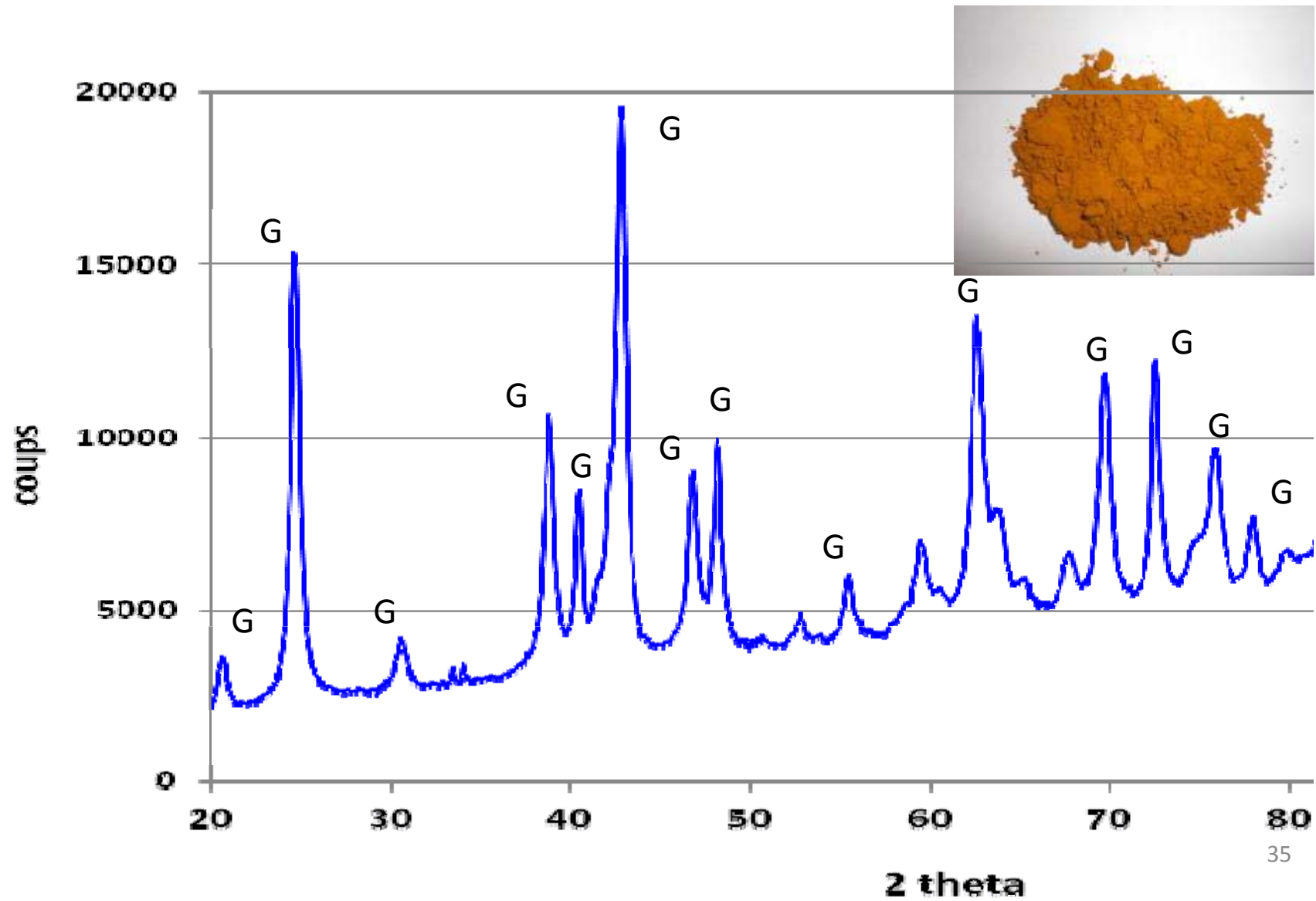


# **Chemical Treatment LFP Chemistry**

## Chemical treatment of LPF based cathodes



## Recovered iron oxide





# Recupyl already familiar with iron oxides production extracted from steel dust

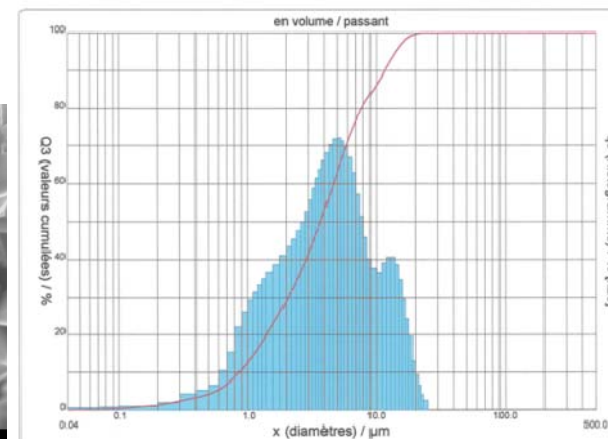
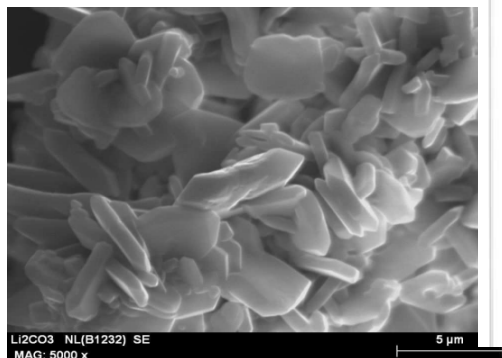
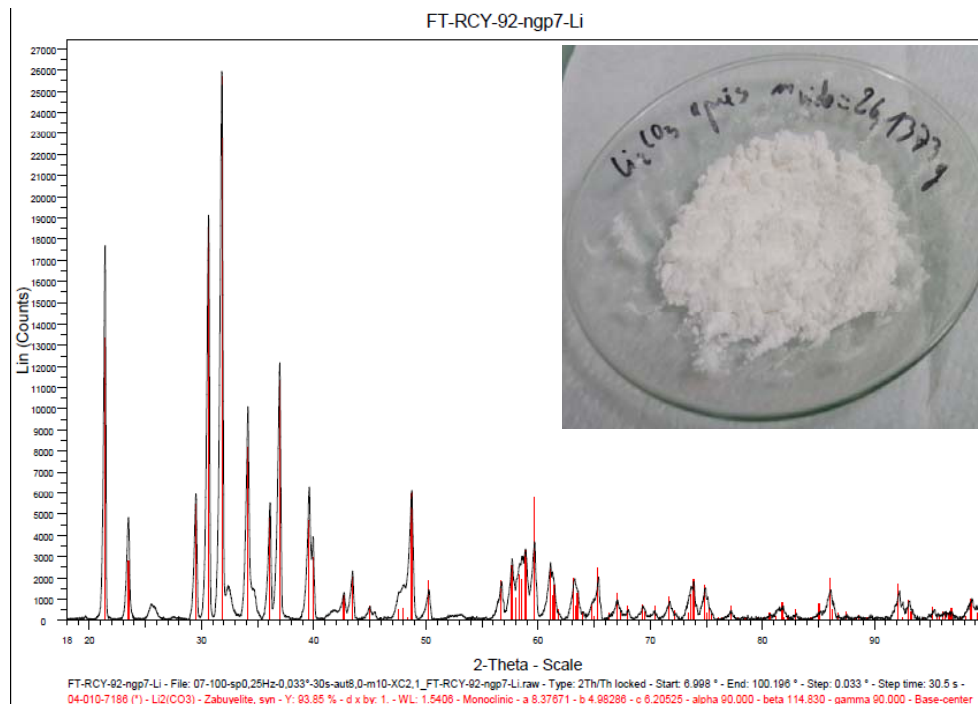






# The last challenge: Lithium salt suitable for the market

Compound	Average composition	Request from technical market
Li <sub>2</sub> CO <sub>3</sub>	99,5%	99,00%
Fe	6 ppm	10 ppm
Cu	5 ppm	10 ppm
Ni	< below LoD	10 ppm
K	83 ppm	100 ppm
Ca	133 ppm	150 ppm
Na	55 ppm	800 ppm



# Hydrometallurgy treatment at pilot level





# Hydrometallurgy treatment at pilot level





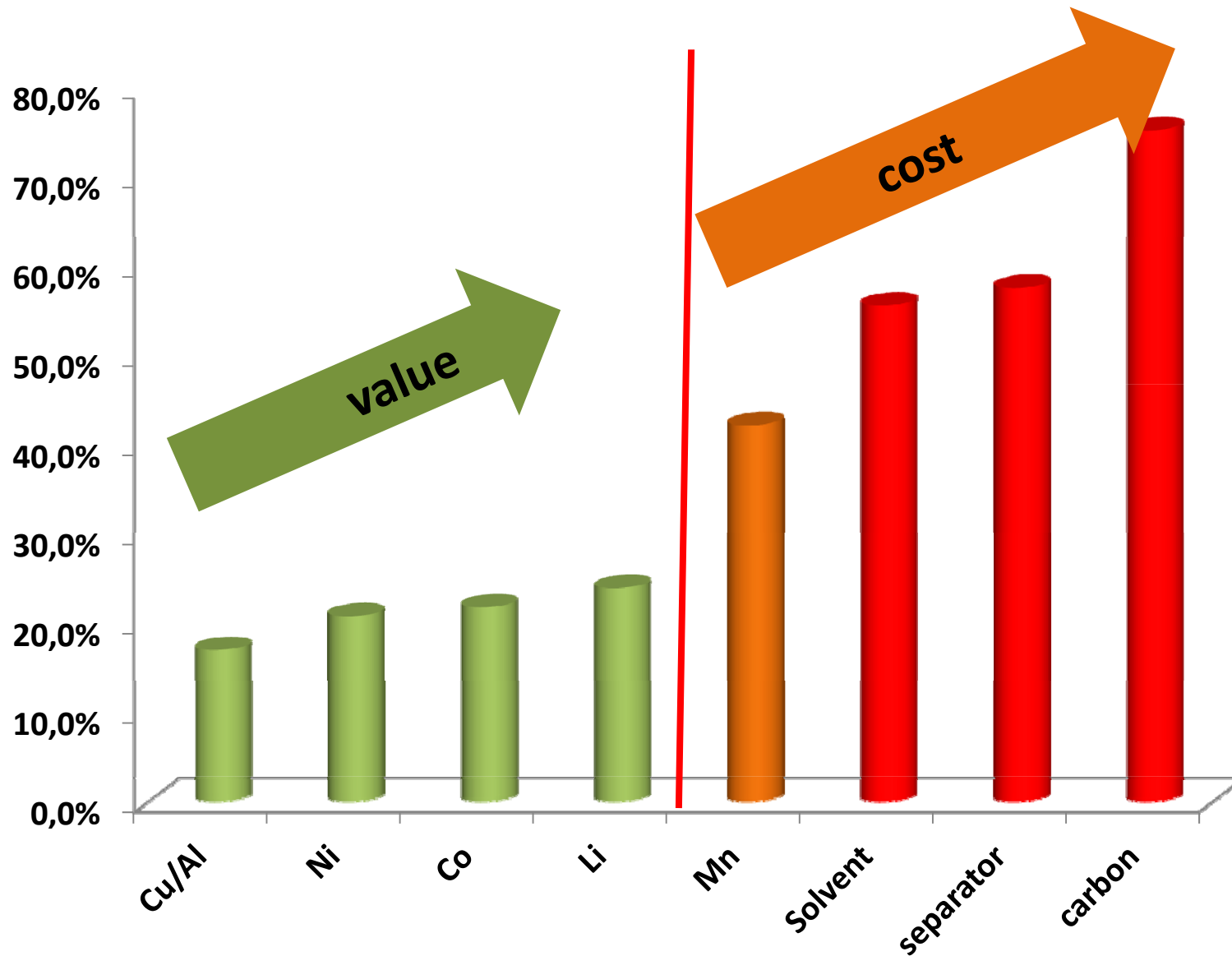
## Approach on Recycling Rate

in regards to EU Directive 066-06

Lithium ion batteries must recycled at minimum of 50% explained as metals



# Recycling of NMC chemistry (hydro process)





**Sustainability also in the  
model of implementation**

# UN Class 9

But....

UNITED NATIONS

ST



Secretariat

Distr.  
GENERAL

ST/SG/AC.10/C.3/2006/97  
10 September 2006

Original: ENGLISH

## Proximity?

COMMITTEE OF EXPERTS ON THE TRANSPORT OF DANGEROUS GOODS AND ON THE GLOBALLY HARMONIZED SYSTEM OF CLASSIFICATION AND LABELLING OF CHEMICALS

Sub-Committee of Experts on the Transport of Dangerous Goods

Thirtieth session  
Geneva, 4-12 (a.m.) December 2006  
Item 2(a) of the provisional agenda

PROPOSALS OF AMENDMENTS TO THE RECOMMENDATIONS ON THE TRANSPORT OF DANGEROUS GOODS

Model Regulations on the Transport of Dangerous Goods

Special provision 188 concerning lithium batteries

Transmitted by the expert from the United States of America

### Background

Special Provision 188 provides an exception from the provisions of the UN Model Regulations for lithium cells and batteries provided certain conditions are met. Currently, except when installed in equipment, packages containing more than 24 lithium cells or 12 lithium batteries must also meet the following additional requirements:



# Avoiding the "Tourism of waste" and heavy management of far shipment?

## To be close to collection

model already implemented for portable batteries by RECUPYL

### USA

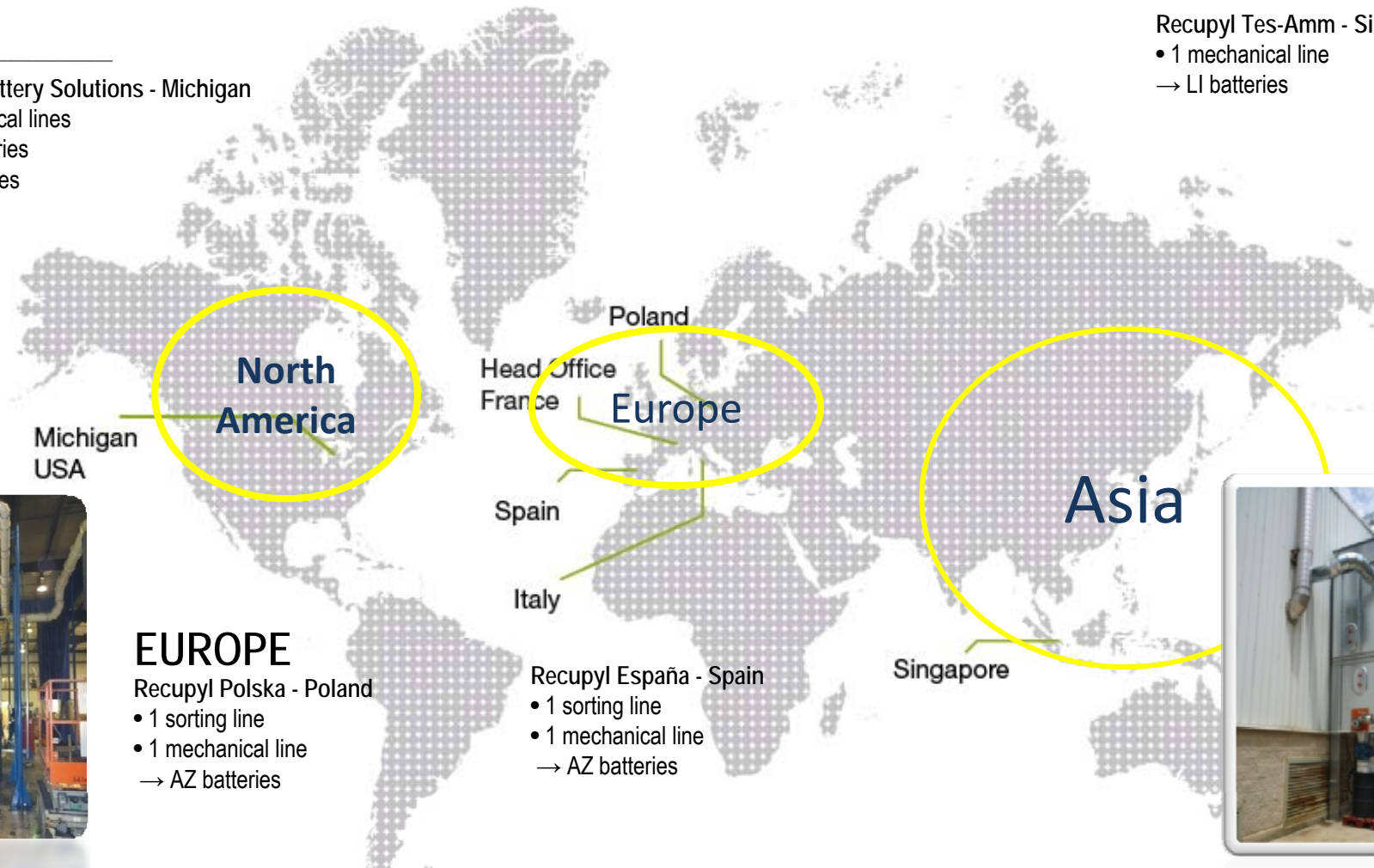
Recupyl Battery Solutions - Michigan

- 2 mechanical lines
- AZ batteries
- LI batteries

### ASIA

Recupyl Tes-Amm - Singapore

- 1 mechanical line
- LI batteries



North America

Europe

Asia



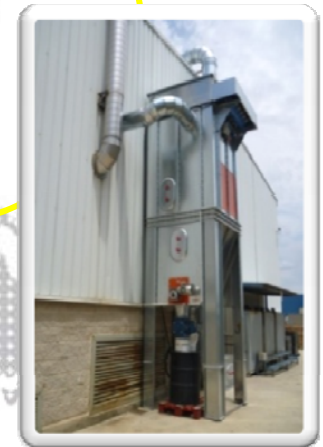
### EUROPE

Recupyl Polska - Poland

- 1 sorting line
- 1 mechanical line
- AZ batteries

Recupyl España - Spain

- 1 sorting line
- 1 mechanical line
- AZ batteries



CO2 credit can also be claimed with the good choice of implementation



# Conclusion

- Some metal are becoming more and more **strategic** due to limitation resources
- Better environmental technologies are needed with lower **energy** consumption, lower **CO2** emissions and better efficiency
- **Shipment** of waste is more and more difficult ( Basel Convention, UNEP etc..)
- **New approach** of waste recycling is needed, close to collection, close to market and **close the loop!!!**

And .....If Resources are finite  
Innovation is infinite !!!!!!!

A also great thanks to  
the Team of RECUPYL

Thank you for  
your attention

