Challenge for Recycling Strategic Metals From Renewable Energy Equipment

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IUMP Seville
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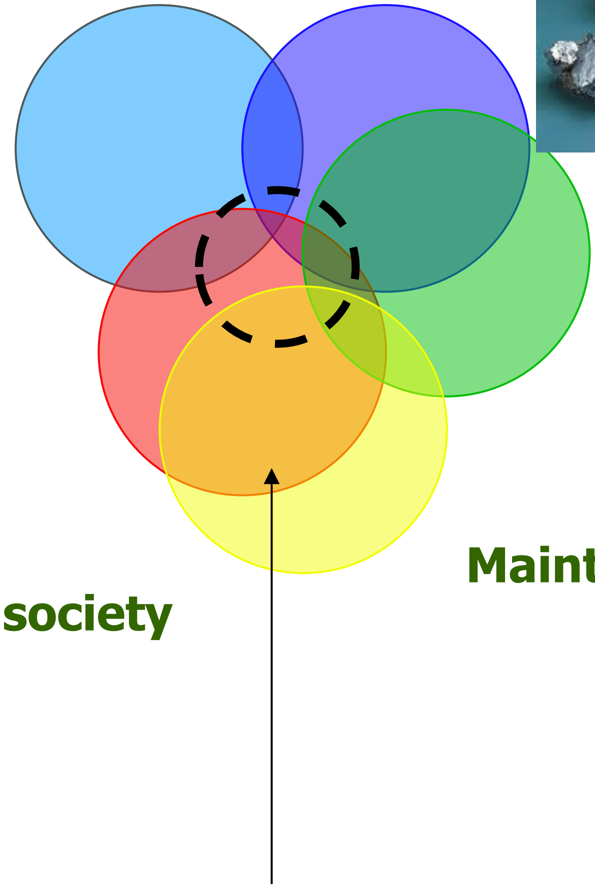
Renewable energy segment is a key for the sustainable growth in regards to energy and resources scarcity

Sustainable growth; it is intersection between

Resources conservation

Environment protection



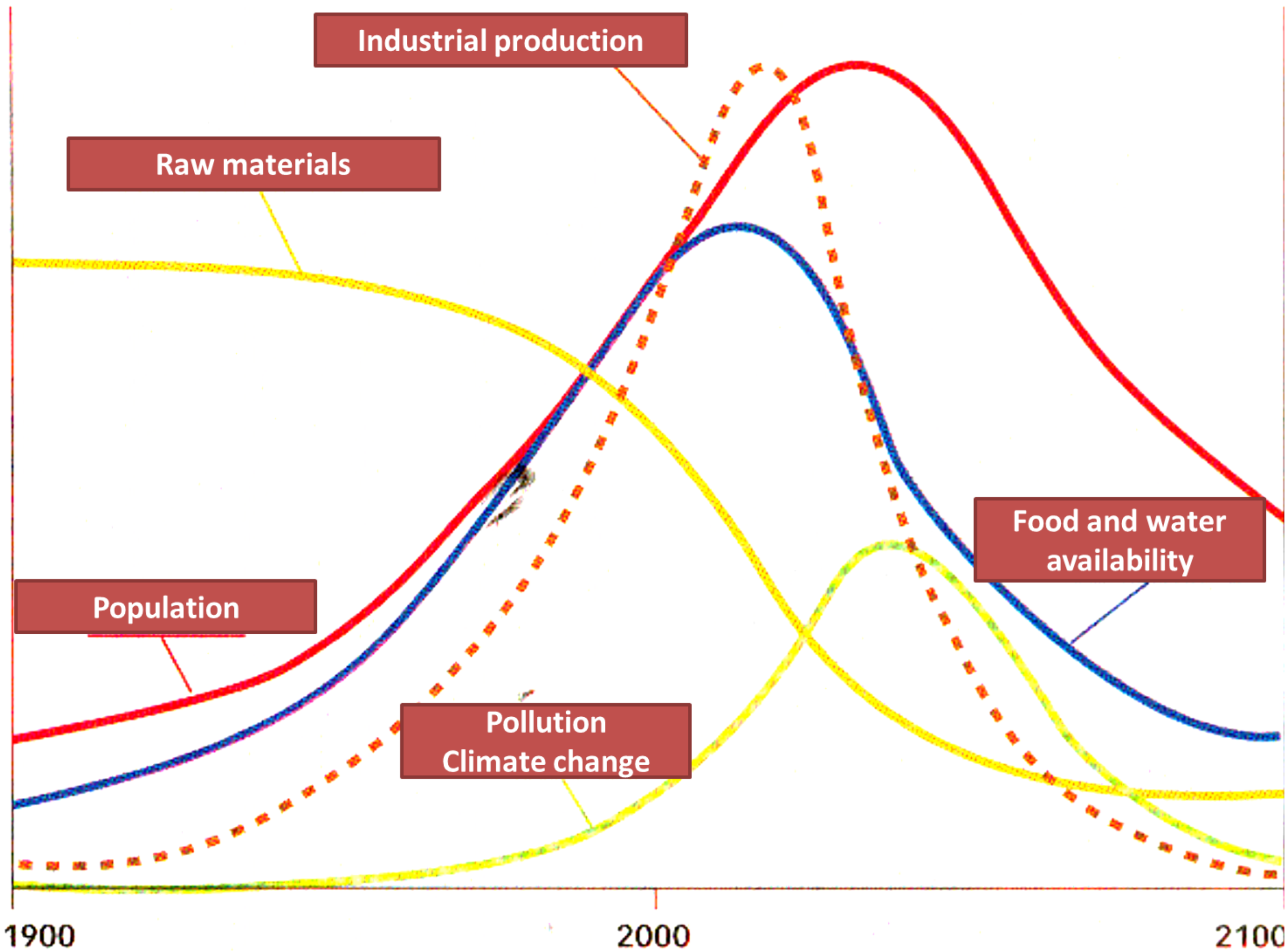
Social acceptance

Maintaining current growth

Acceptable cost for society

It is the challenge of 21^{e} century

Today the impac of the City Appetite has a very strong impact on eco-system *(Scenario of Meadows UN study)*



It is for this that it not anymore a concern of few countries but worldwide issue

Worldwide reaction under driving of UN from 30 years !!

- Rio Summit (1992)
- Kyoto Protocol (1998)
- Johannesburg Agreement (2002)
- Copenhagen convention (2009)
- COP21 Paris (December 2015)

Rio Earth Summit 1992
Local, national and international action

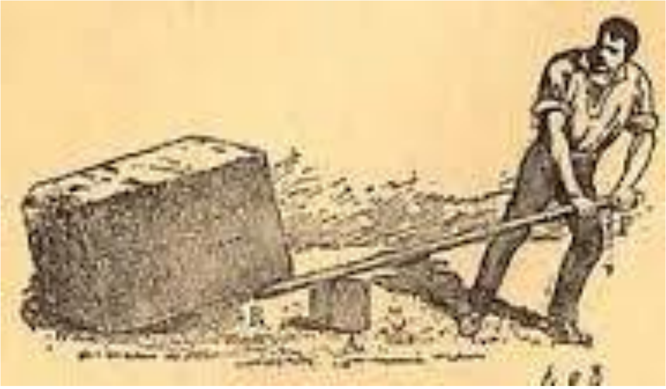
Kyoto Protocol

JOHANNESBURG SUMMIT 2002

COPENHAGEN
Climate Change Summit

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

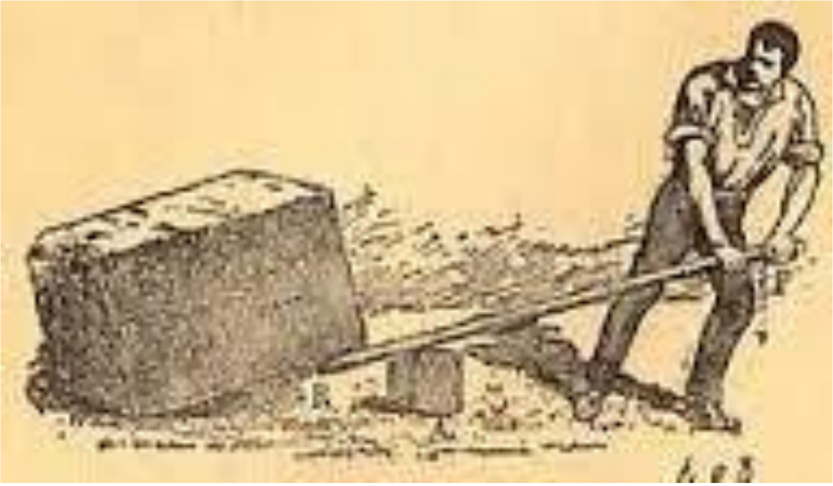
The 1st levier of sustainability :



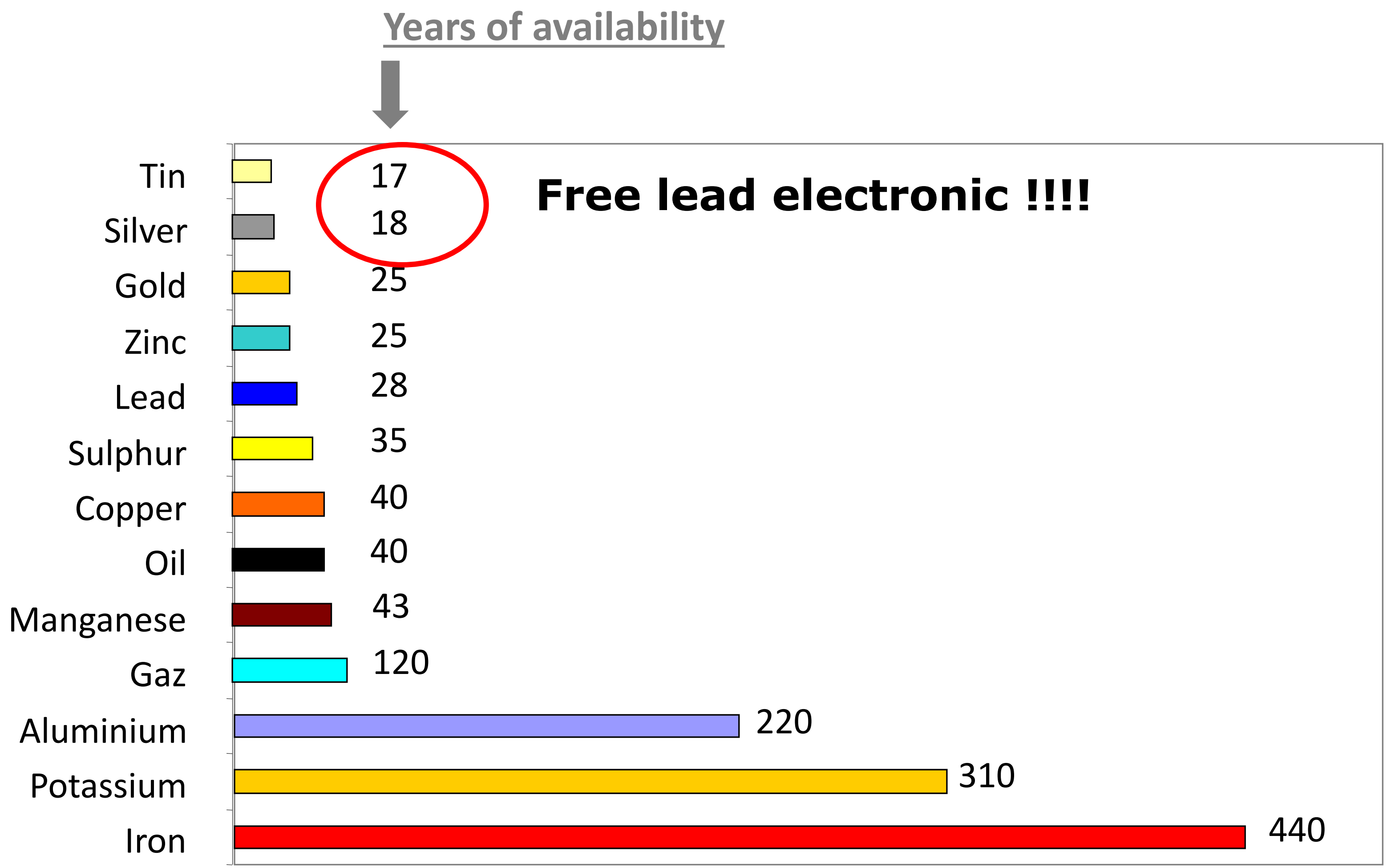
The drak side of large consumption products

Ex: Heavy metals around us

The 2nd levier :
Availability and geopolitical aspect of strategic metals

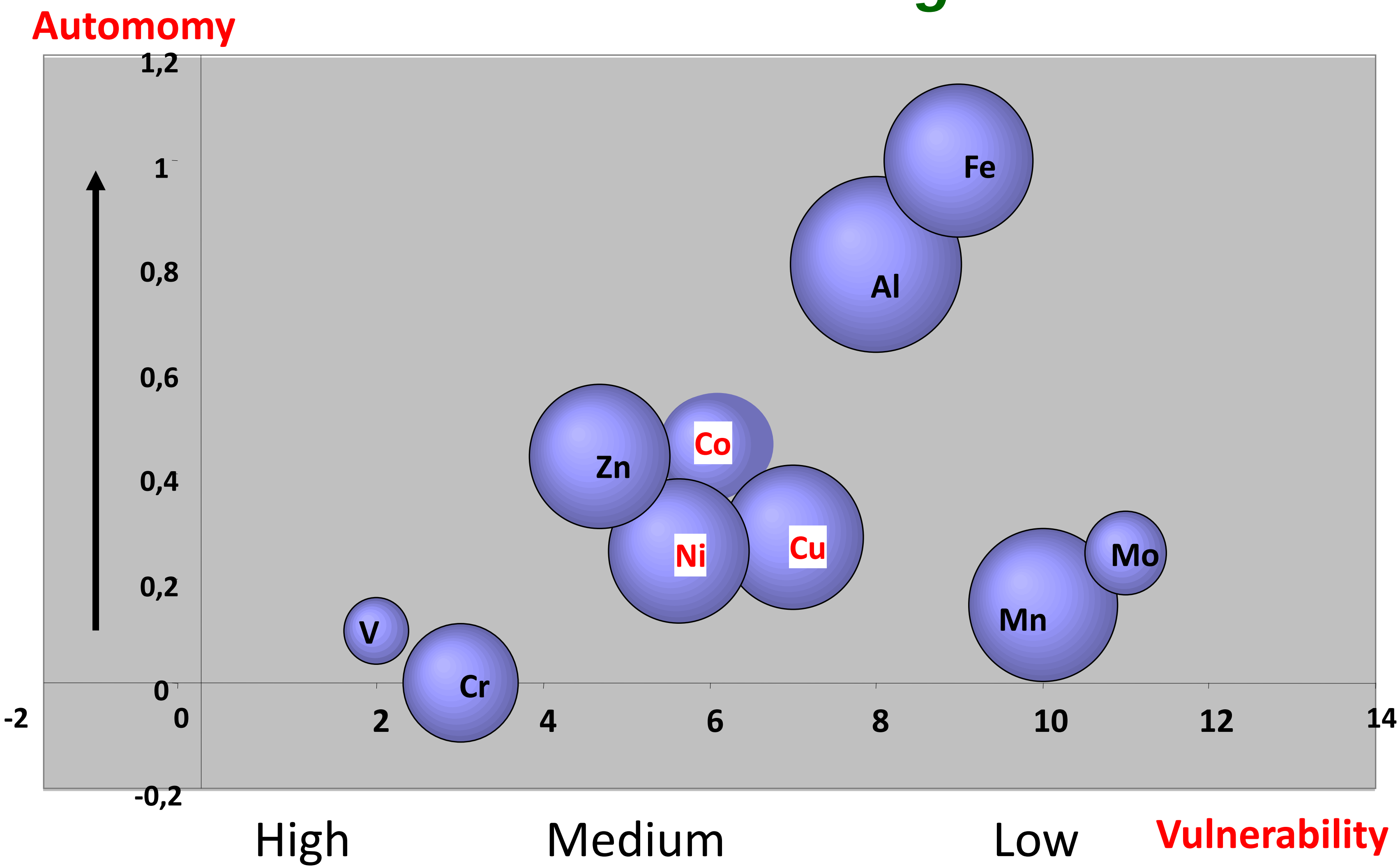


"sustainability " of strategic ressources



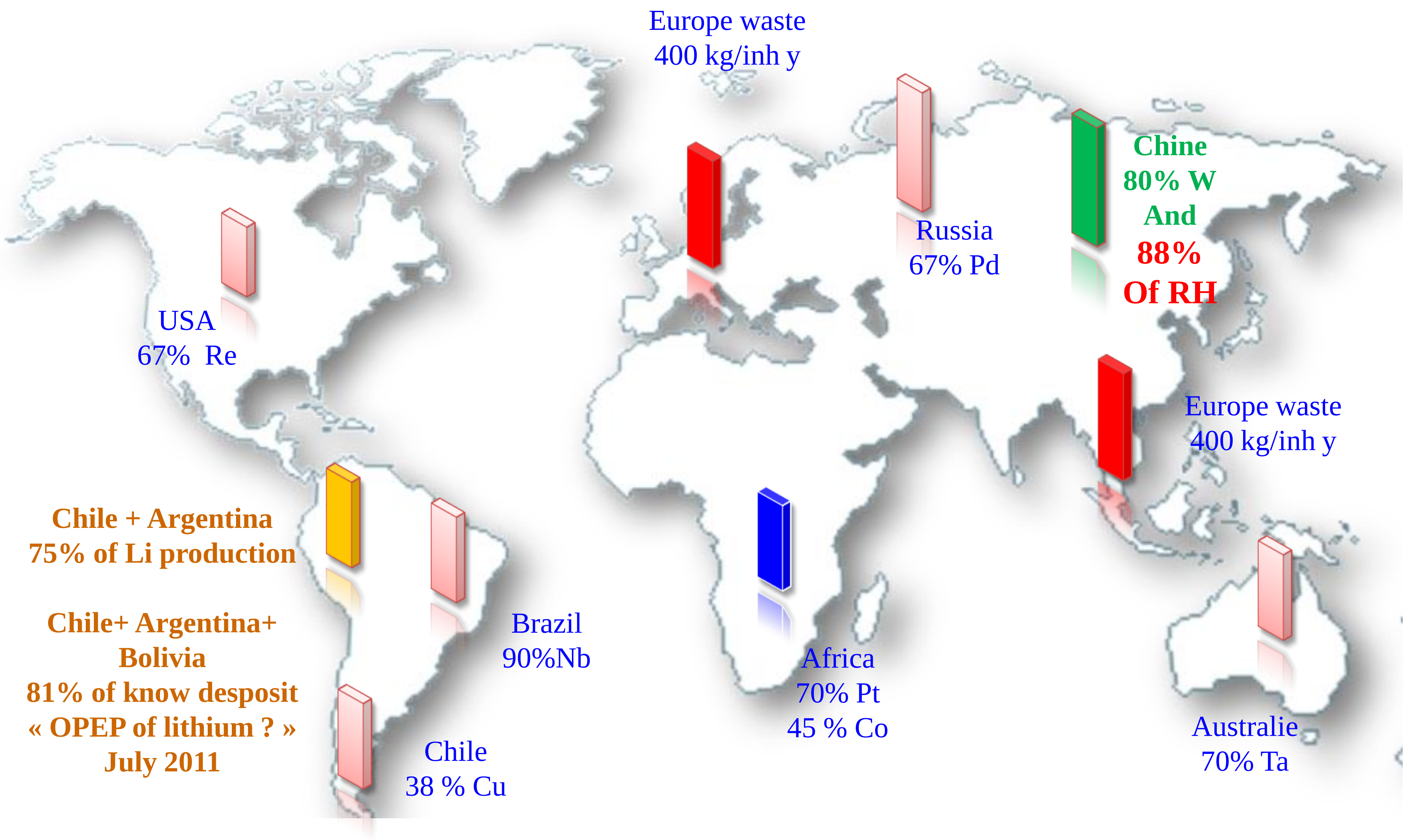
Sources USGS 2010

situation of main strategic metals



F. Tedjar invited course Collège de France, French Academy of Science, Sustainability Chair ,Mars 2012

Geopolitical Aspect
Concentration of strategic resources



Impressive increase of end-of-life product
Is needing more and more dedicated processes

Only ONE solution !!!!

From old mine……………….

... To URBAN MINE®

Regsitred by Prof. Tedjar (Recupyl -2004) N° 79083906   Int. TM Register

The first surface « urban » mine !!!

But need the adhesion of the citizen (volontary action)

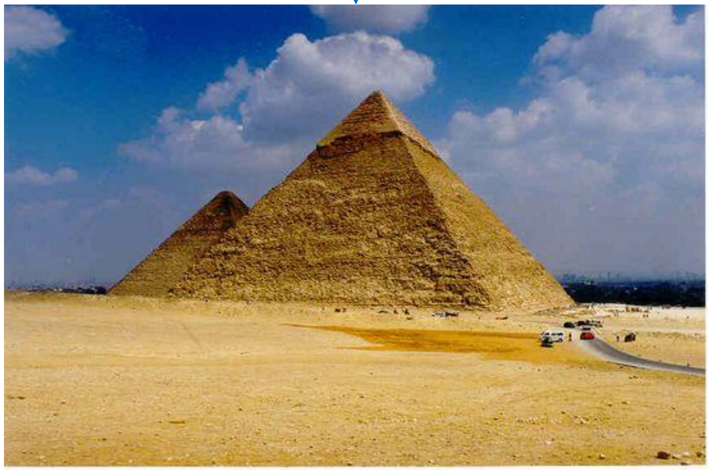
RECUPYL

How to construct Urban Mine for Sustainable City ?

Life cycle of products

From cradle to….

…….To grave



Which sustainable technology to exploit Urban Mine?

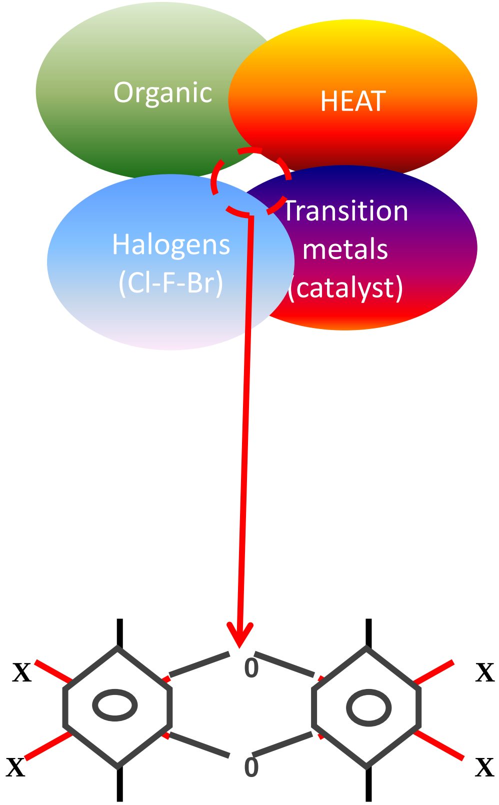
Metallurgy approach

But today negative sides > to benefits

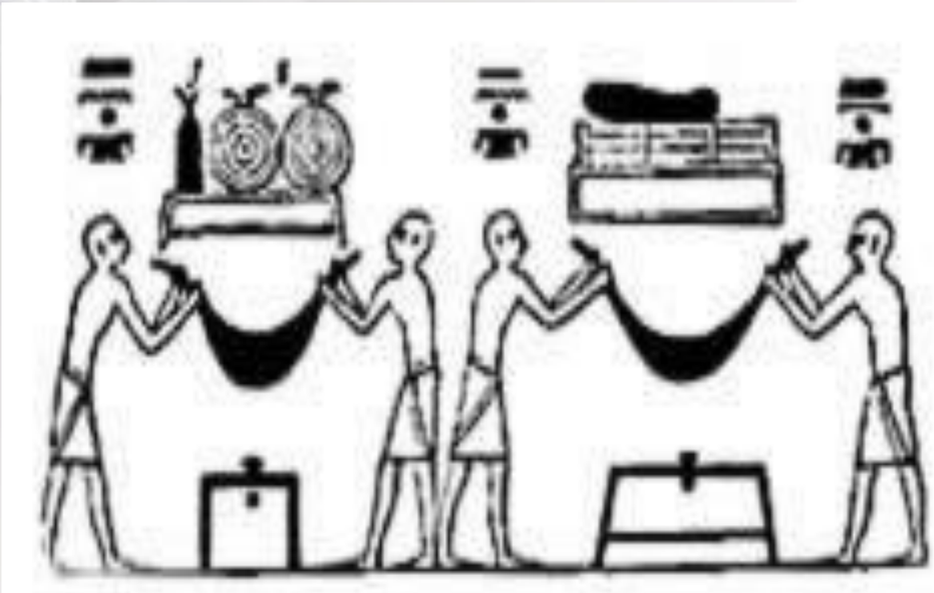
It is known that metallurgy is millenary old !!

The issue of Dioxins in thermal processes

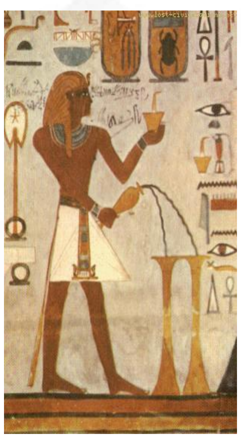
1- High energy used
2- High CO2 emission
3-high risk with other Toxic emissions
4- some metals lost in slag



But Hydrometallurgy is also millenary !!!!



Filtration of sulfur/oxides/k'hol



Preparation of Leaching solution

The new segment of Hydro

Battery segment

battery segment

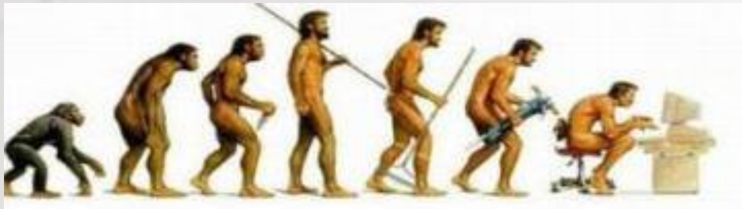
A huge progress !!!!!

1960

1990= 1960 +

2015= 1990 +

Challenges in battery recycling
Metals in batteries : 130 years evolution
More and more elements have to be recycled



3 metals

1880

- Zn-MnO2
- Pb-PbO2

1940

- Zn-MnO2
- Pb-PbO2
- Ni-Cd
- Zn-HgO
- Zn-air

1980

- Zn-MnO2
- Pb-PbO2
- Ni-Cd
- Zn-HgO
- Zn-air
- Ni-MHx
- Ni-Fe
- Zn-Ag2O
- Li-MnO2
- Li-SOCl2
- Li-CFx
- Li-FeS2

2000

- Zn-MnO2
- Pb-PbO2
- Ni-Cd
- Zn-HgO
- Zn-air
- Ni-MHx
- Zn-Ag2O
- Li-MnO2
- Li-$SOCl_2$
- Li-CF_x
- Li-FeS_2
- Ni-Fe
- Li-CoO_x

2013

- Zn-MnO2
- Pb-PbO2
- Ni-Cd
- Zn-HgO
- Zn-air
- Ni-MHx
- Zn-Ag2O
- Ni-Fe
- Li-MnO2
- Li-air
- Li-SOCl2
- Li-CFx
- Li-FeS2
- Li-Li CoO_x
- Li-$LiNiO_2$
- Li-Li Mn2O4
- Li-(V_6O_{13})
- Li-Li FePO4
- Li-M-N-C
- Li(Si)- Sx

25 metals,60% Li based

Why to collect and recycle household batteries

1- batteries are Sources of valuable metals

2- Batteries are source of environnent Impact

Steel, Cu, Al

Zinc, lithium, cadmium, Tin , Antimony

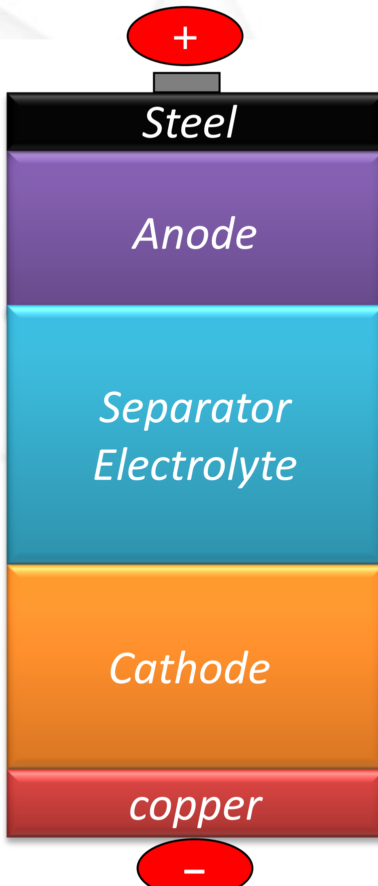
Manganese, Nickel, Cobalt

Mercure

KOH

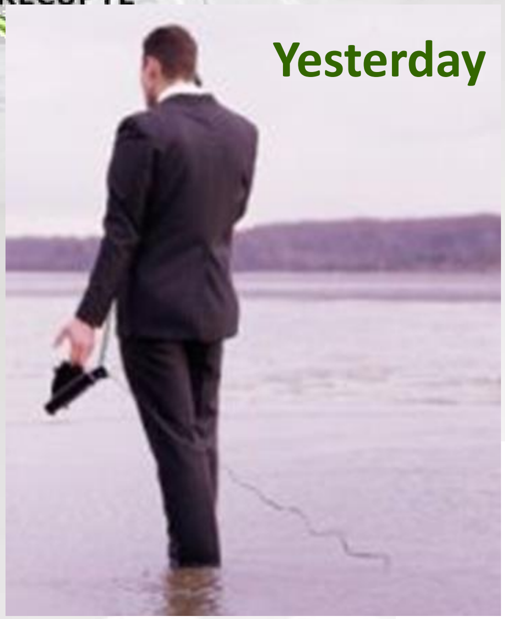
Zinc, ammonium chlorides

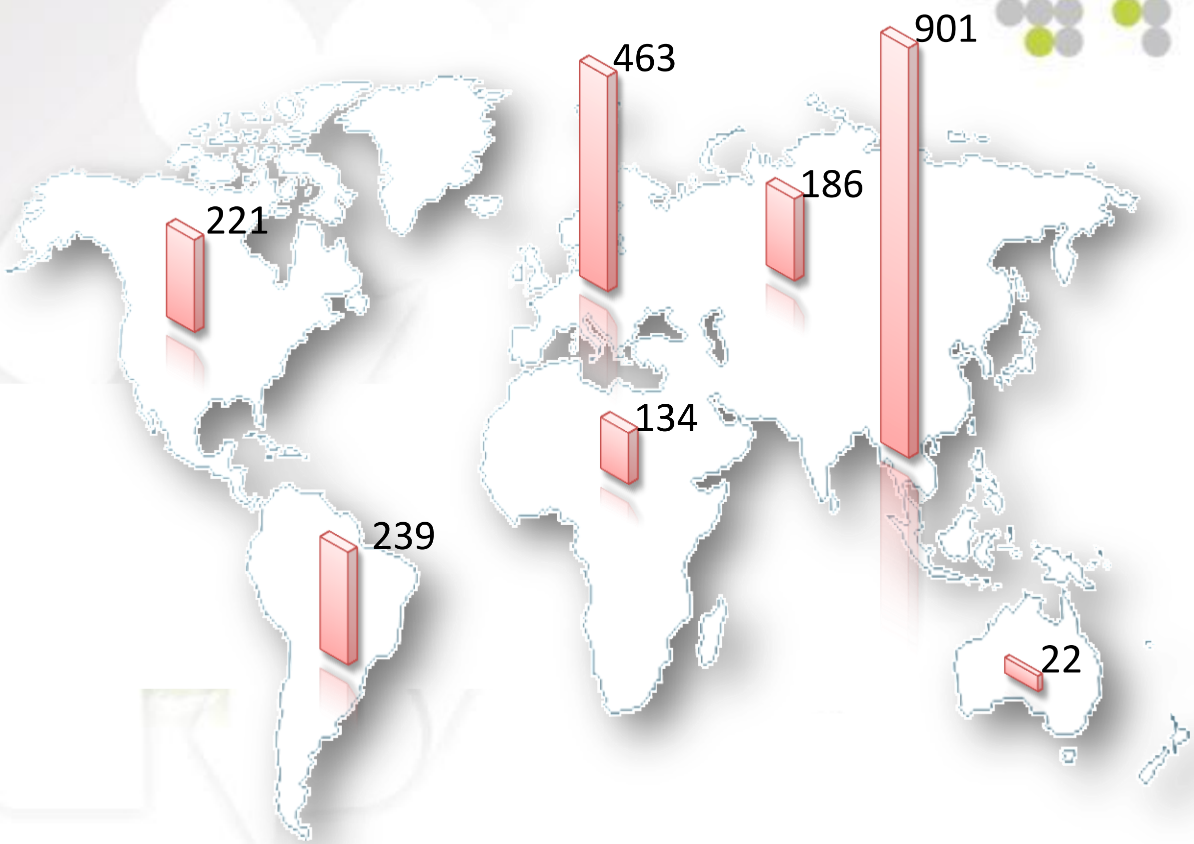
Solvents, fluor



Red products
are harmfull and some are toxics

Mobiles phones



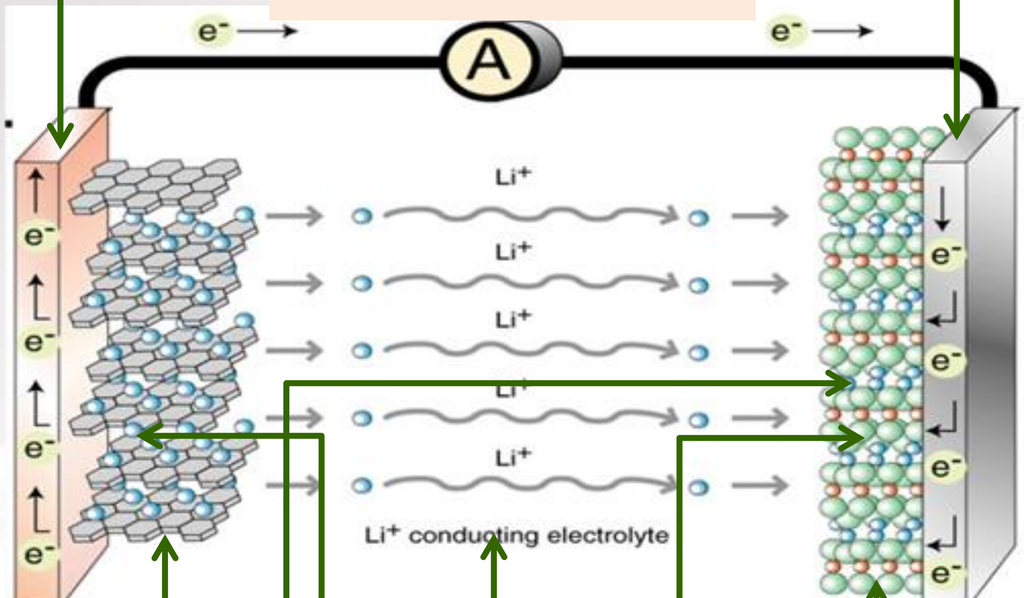


Market world (in millions of unit, 2014)

Around 2.2 Billions mobiles phones In the world → = around 100 000 T of batteries

Li-ion recycling :
materials object of the recovery

Copper and aluminium
for contact



Carbon
as conductive material
or anode

Solvent for electrolyte
And Li salts

Precursors Mn, Ni, Co and Fe
for related cathode

Flows sheet of the non thermal developed process

Electrical control, discharge
And dismantling
(if EV)

↓

Dry & room temperature
Physical treatment

↓

Chemical treatment

STEP A : mechanical treatment (first prototype)

Safe and efficient mechanical treatment

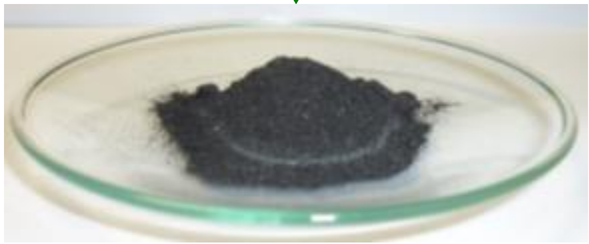
STEP B / Chemical treatment of fine fraction: Leachning

	%
Co	32.30%
Li	4%
Mn	1.80%
Ni	0.70%

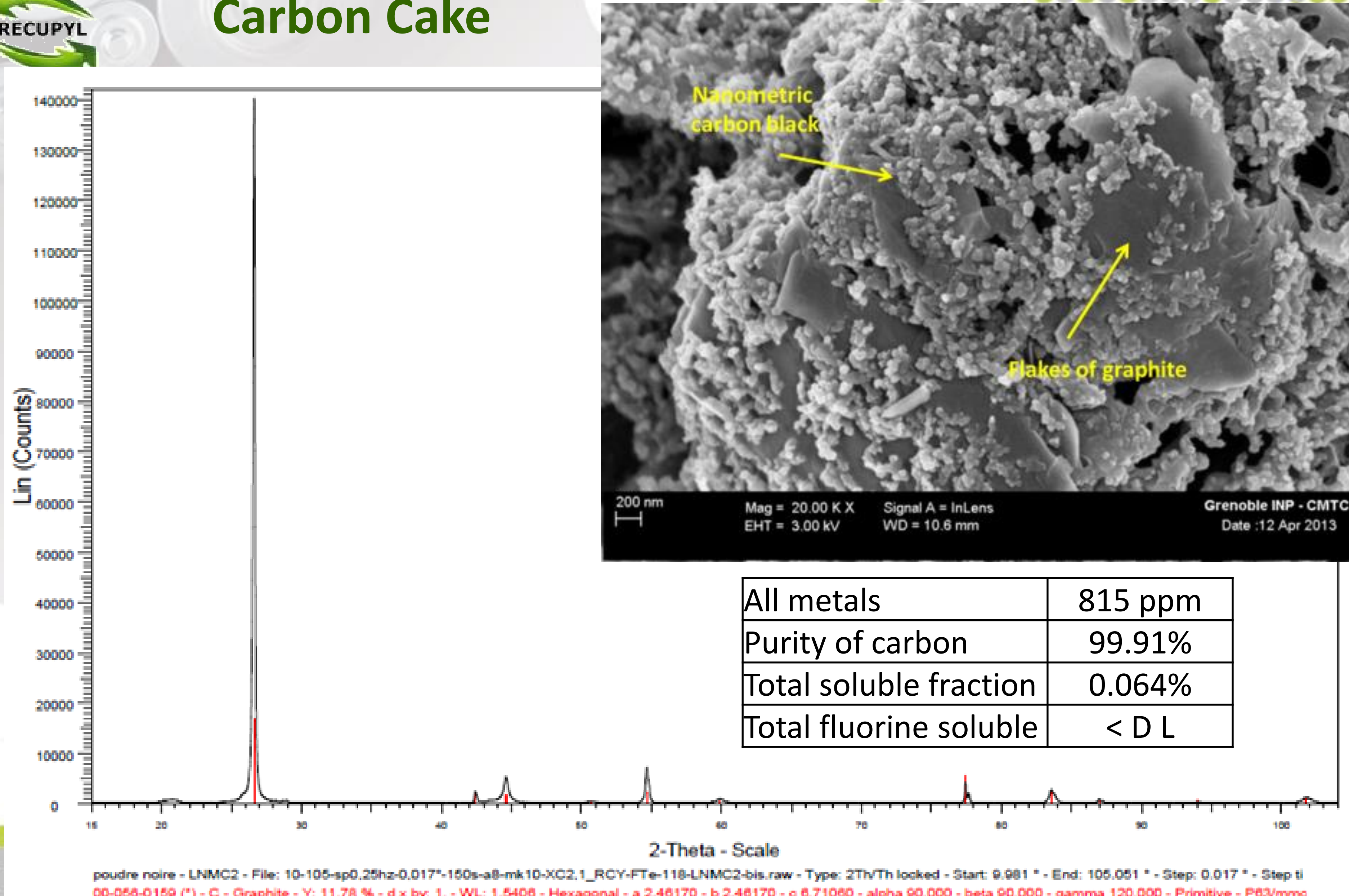
solution

	mother liquor g/l
Co	36.1
Li	4.5
Mn	1.7
Ni	0.6

Carbon

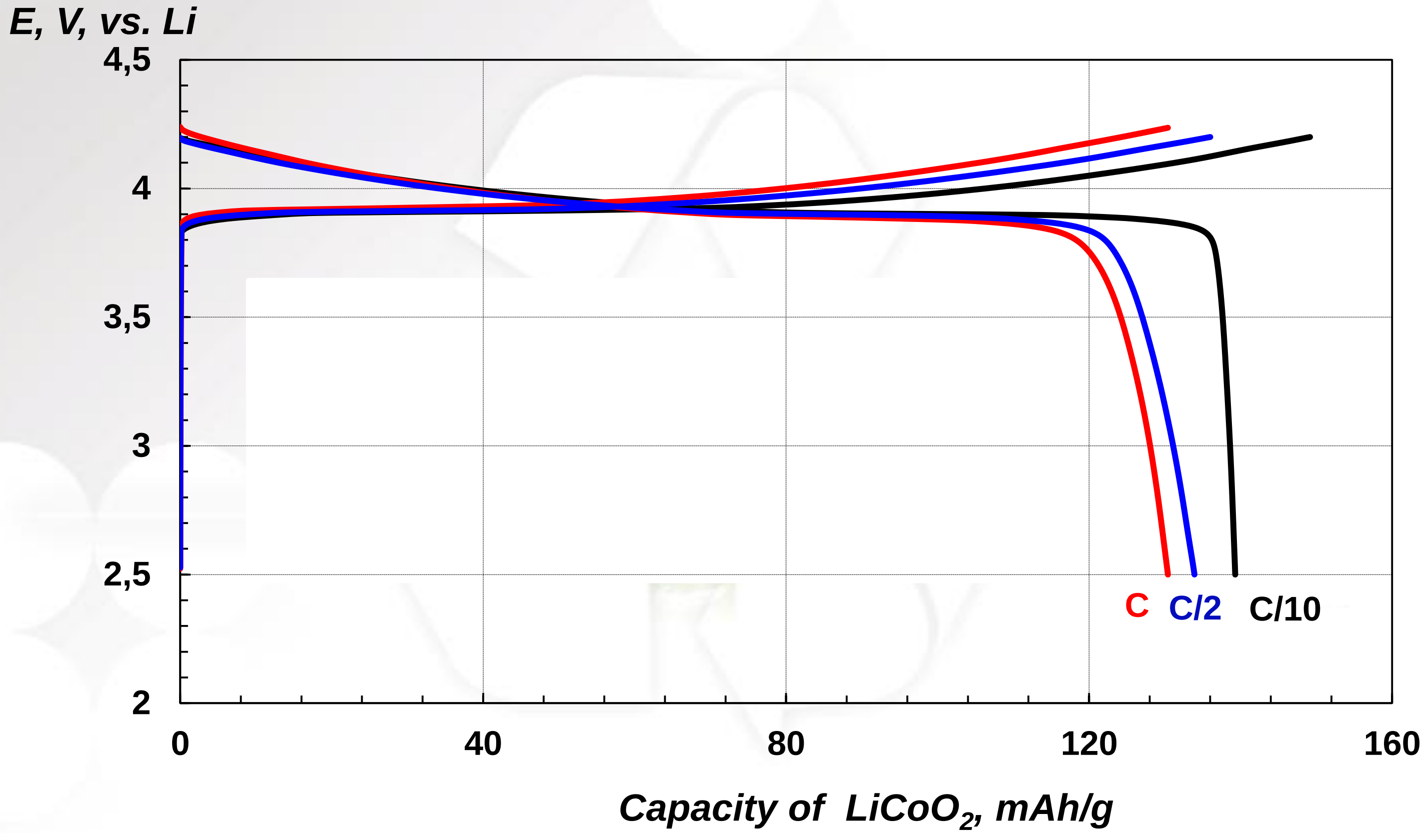


Carbon Cake



All metals	815 ppm
Purity of carbon	99.91%
Total soluble fraction	0.064%
Total fluorine soluble	< D L

Use of recovered carbon in portable Li-ion batteries



Profiles of charge/discharge potentials of the cathode based on $LiCoO_2$ /PVDF and RECUPYL carbon (mass ration 83:7:10 % w/w correspondently) at different current densities.

Step B Chemical treatment : metal recovery

Mother solution

	mother liquor g/l
Co	36.1
Li	4.5
Mn	1.7
Ni	0.6

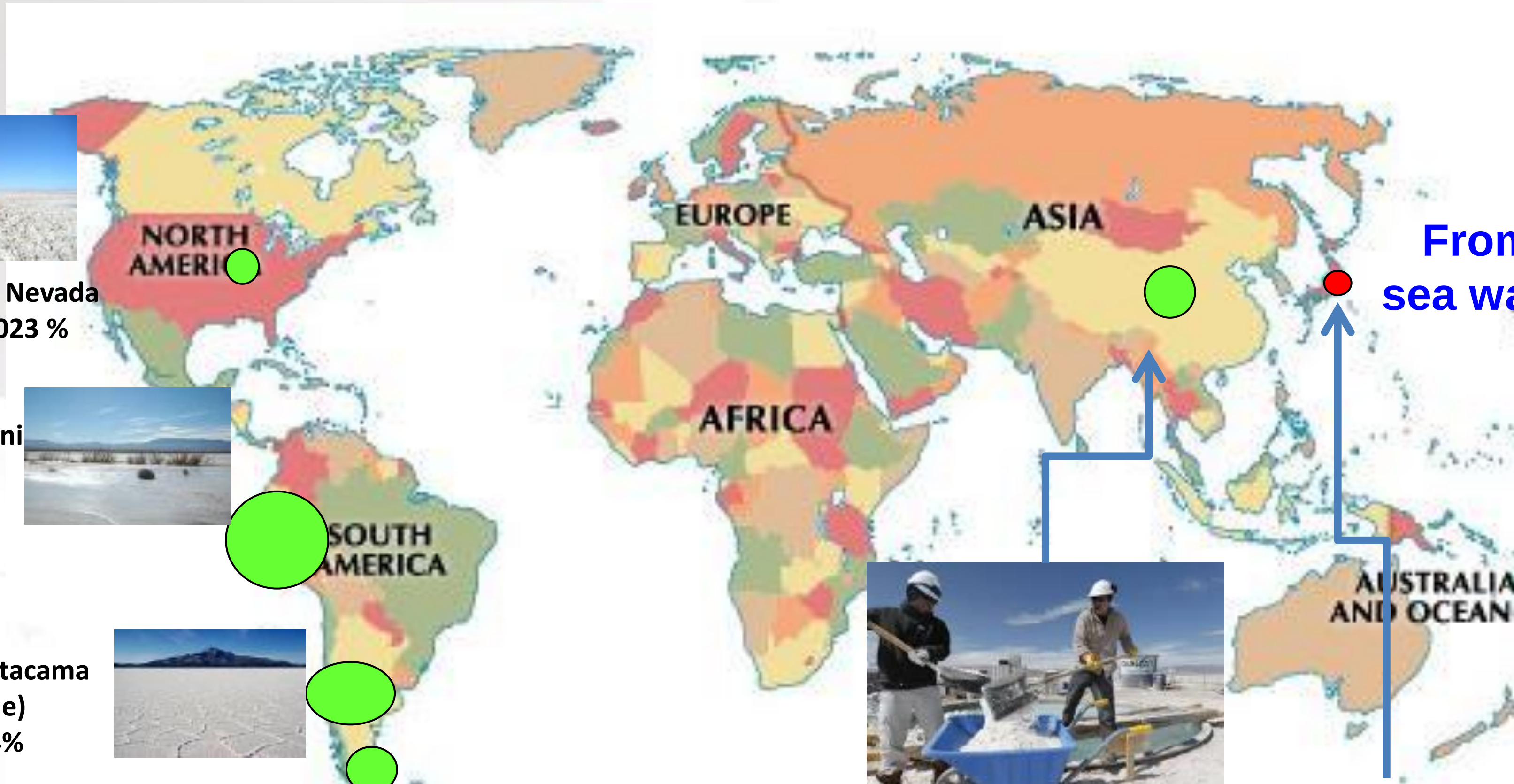
Cobalt cake

Solution
After filtration

Co	0.3 g/l
Li	4.05 g/l
Mn	5ppm
Ni	200 ppm

The issue of Lithium

Geo-strategy of lithium world resource



Silver peak Nevada (USA) 0,023 %

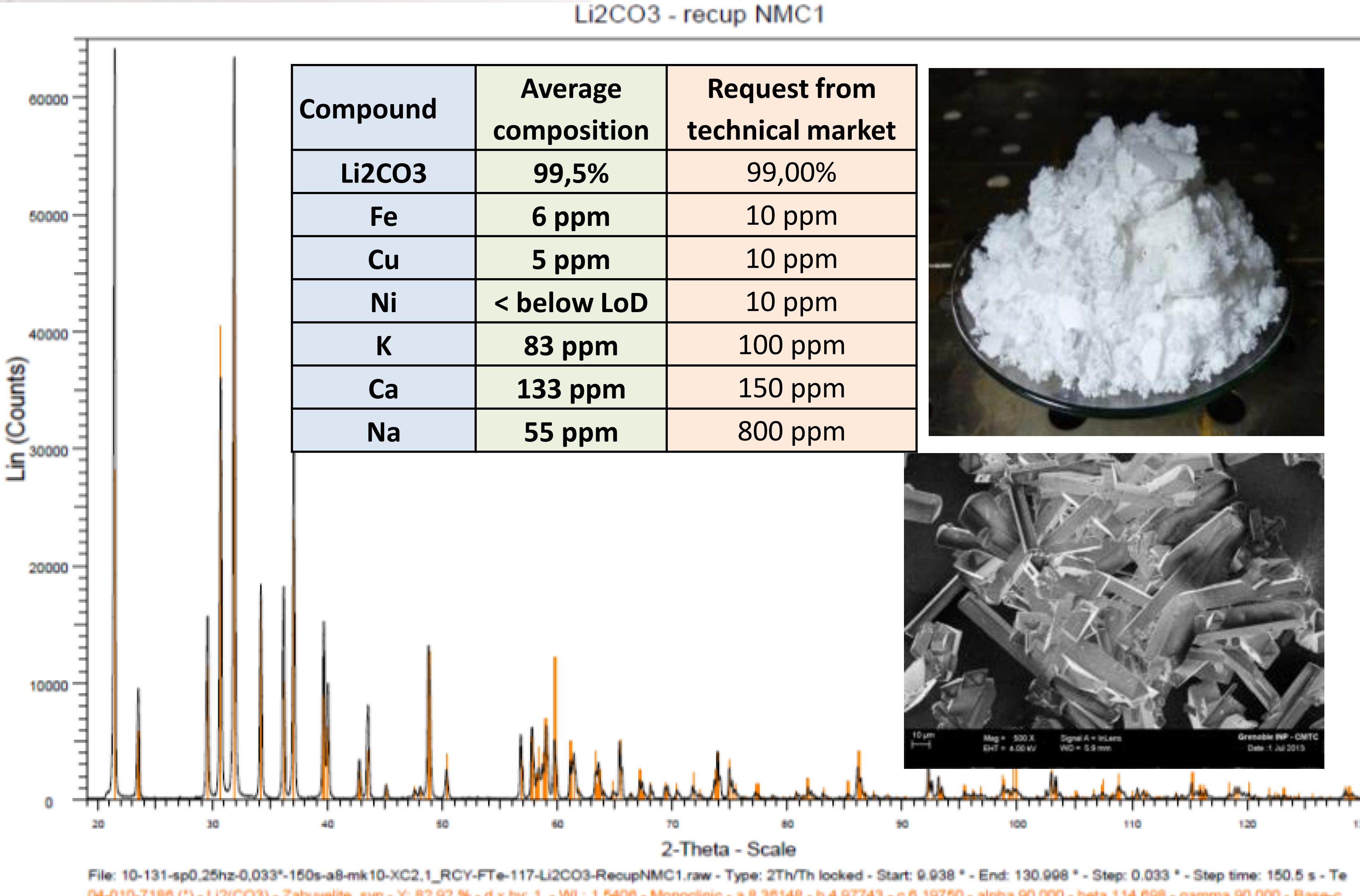
Salar de Uyuni (Bolivia) 0.025%

Salar de Atacama (Chile) 0.14%

Salar de Hombre Muerto, (Argentina)

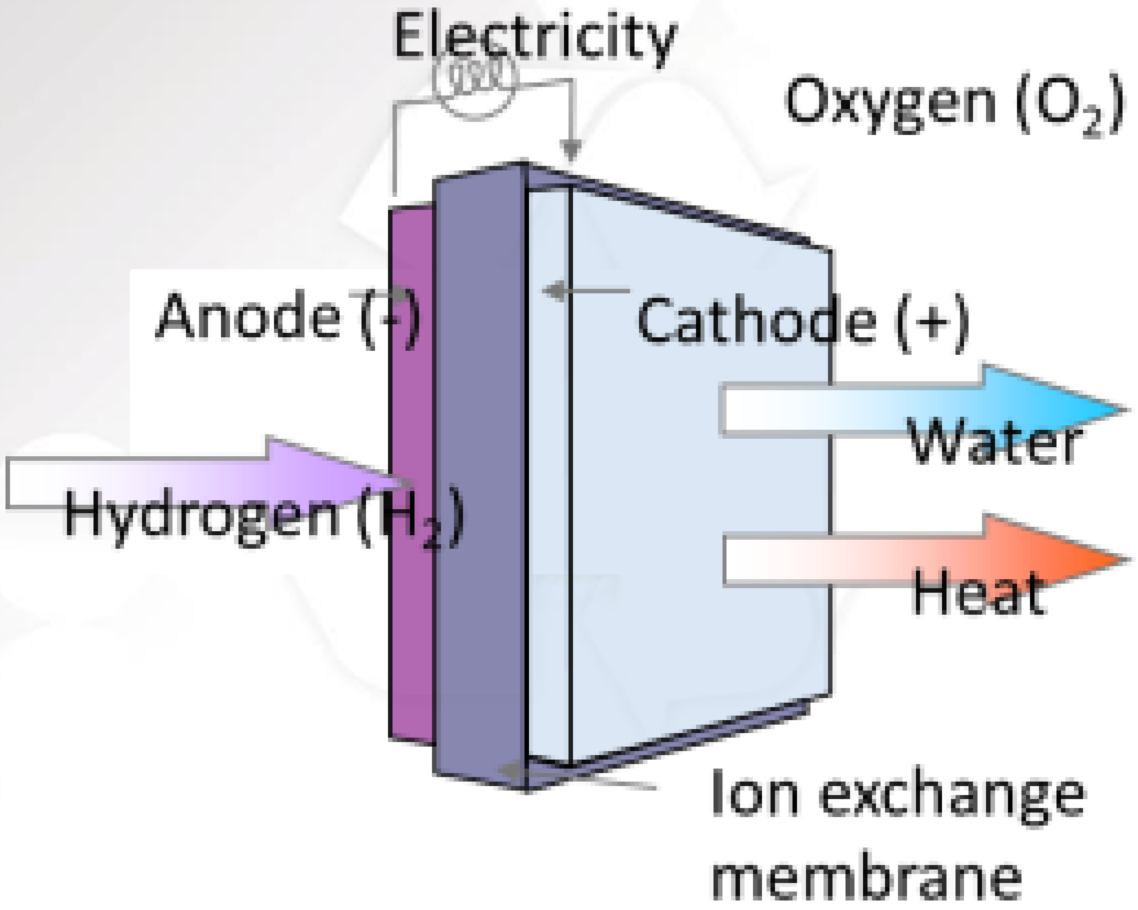
From sea water

Characteristic of recovered Li_2CO_3



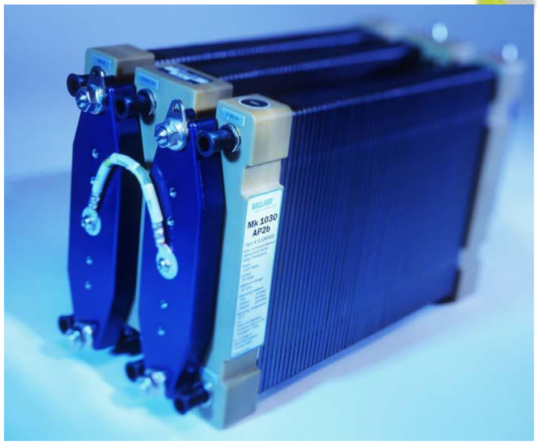
Compound	Average composition	Request from technical market
Li2CO3	99,5%	99,00%
Fe	6 ppm	10 ppm
Cu	5 ppm	10 ppm
Ni	< below LoD	10 ppm
K	83 ppm	100 ppm
Ca	133 ppm	150 ppm
Na	55 ppm	800 ppm

Fuel Cells Recycling



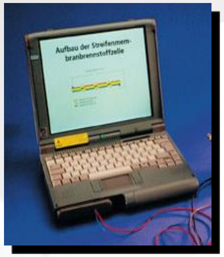
F.Tedjar, Ph. Verdoia,
First EU Experience of Recycling High Power Fuel Cells, BATTERY 2012, Nice (France),

Large scale of applications



Fuel cells applications

portable



Transportation

Spatial

Stationary

10 W | 100W | 1 kW | 10 kW | 100kW | 1 MW

TECHNOLOGIES

Cell type	Electrolyte	Temperature (°C)	Area of use and power range
Alkaline (AFC)	potassium (liquid)	80	space - transportation 1 - 100 kW
Proton exchange membrane (PEMFC)	polymer (solid)	80	portable, transportation, stationary 1W - 10 MW
Phosphoric acid (PAFC)	phosphoric acid (liquid)	200	stationary, transportation 200 kW - 10 MW
Molten carbonate (MCFC)	molten salts	650	stationary 500 kW - 10 MW
Solid oxide (SOFC)	ceramic (solid)	700 to 1 000	stationary - transportation 100 kW - 10 MW

RECUPYL

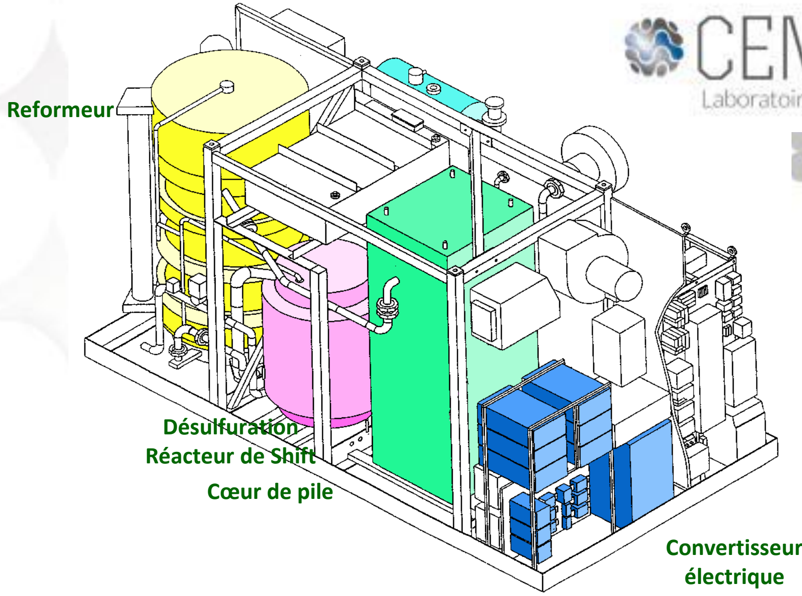
Dismantling and Recycling
First 200kW Fuel cell arriving at end-of-life

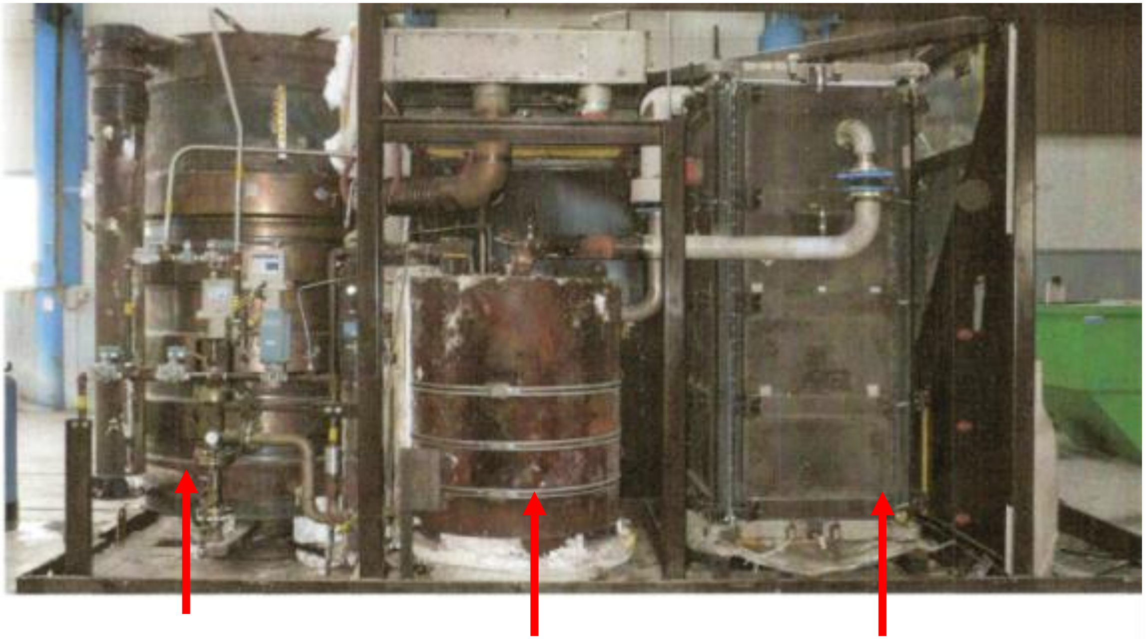
Project granted by EDF-GDF
after European Call For Tender:

EDF
Electricité de France

Gaz de France

Dismantling (1)





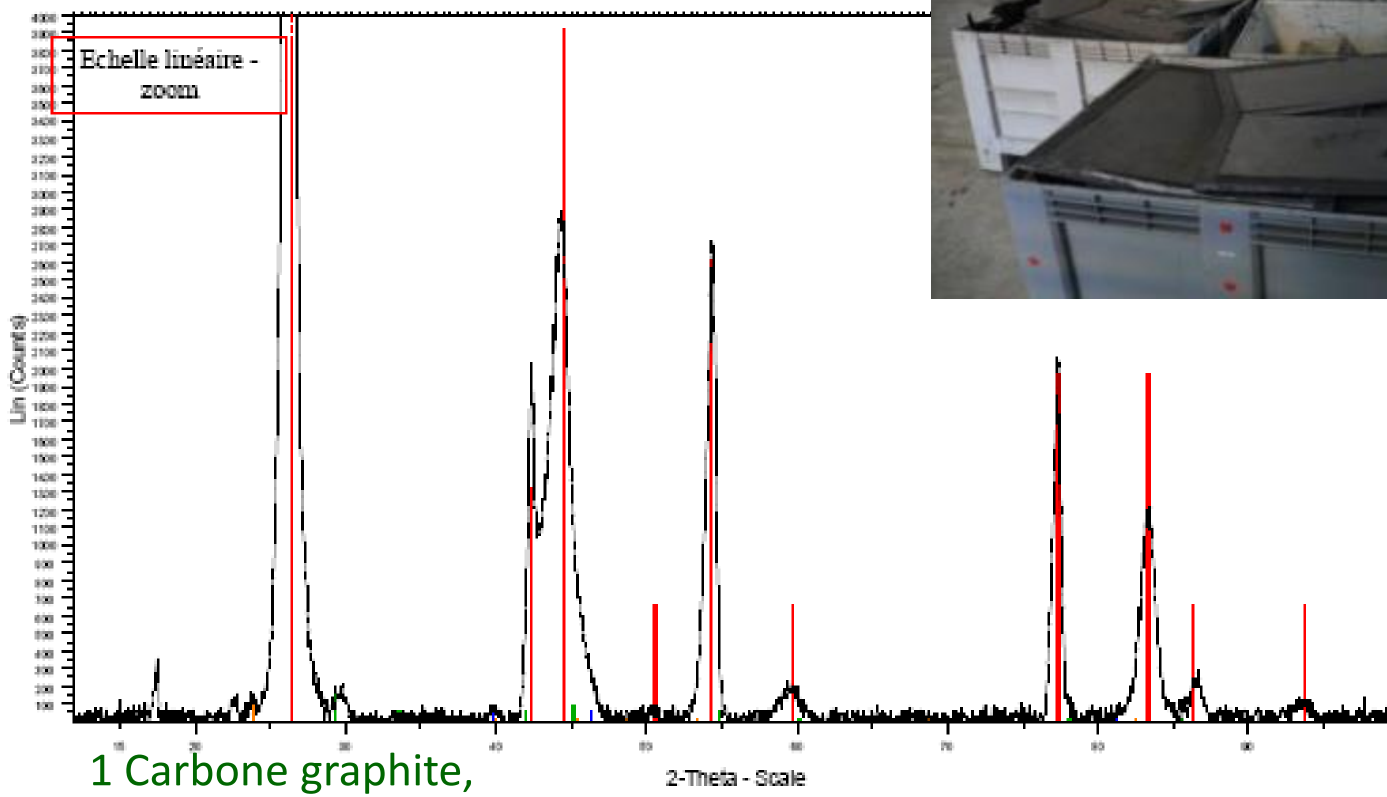
Reforming desulfurator Heart of cell

RECUPYL

Dismantling (2)

CEMAM
Laboratoire d'excellence

Identification of platinum into carbon matrix



1 Carbone graphite,

2- Possible Phosphate before deep washing

Mass balance and recycling rate

Item	concentration	gross mass	Net recovered
Carbon steel	100%	12720	12720
Stainless steel	100%	2642	2642
catalyst 1		360	
Zinc	41.1%		148
Cuivre	37.8%		136
Residue	11.0%		
Catalyst 2		90	
Zn	72.0%		63
Alumina	1.0%		
Ni	27.0%		24
electrode+ Graphite	0.05%	1974	0.987
electrolyte waste	0.00%	210	
electronic waste	77%	2560	1980
Packaging	0.0%	1100	
	Total weight kg	21656	17714

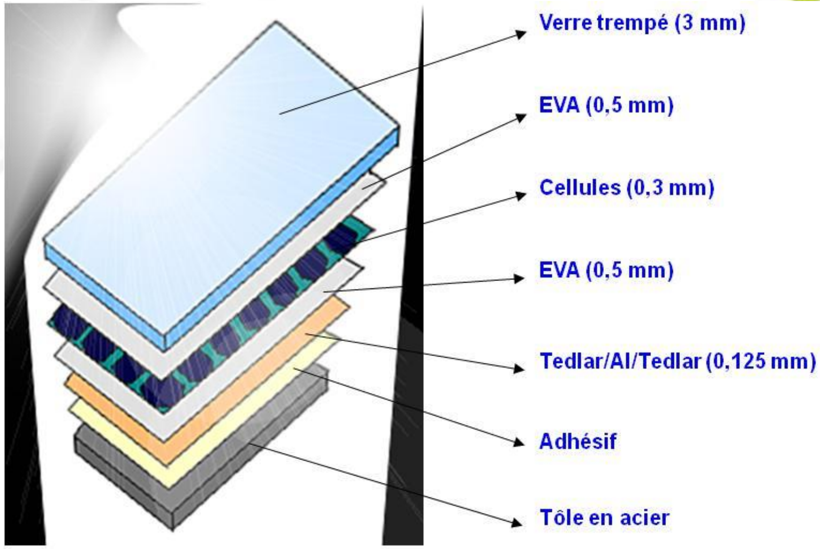
Recycling rate 88 %

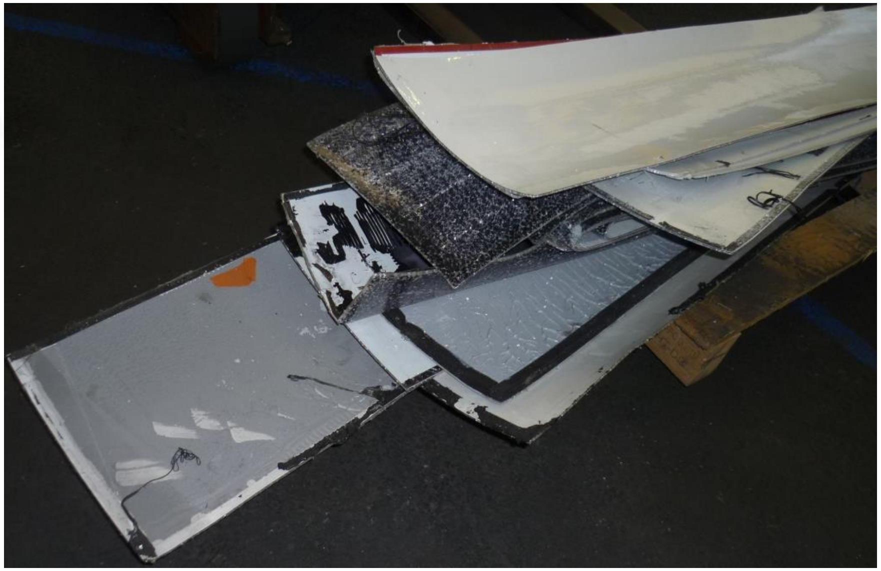
Segment of solar panels

The segment of solar cells
One of the key segment for sustainability and energy transition

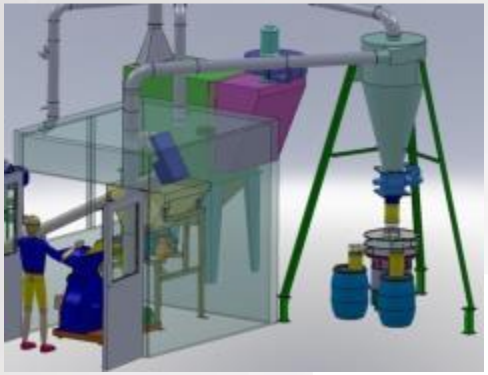
But we need to anticipate End-Of-Life

General veiw of solar panel

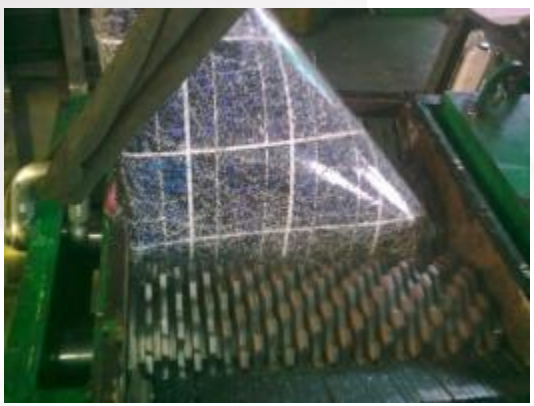




First mechanical step



Prototype

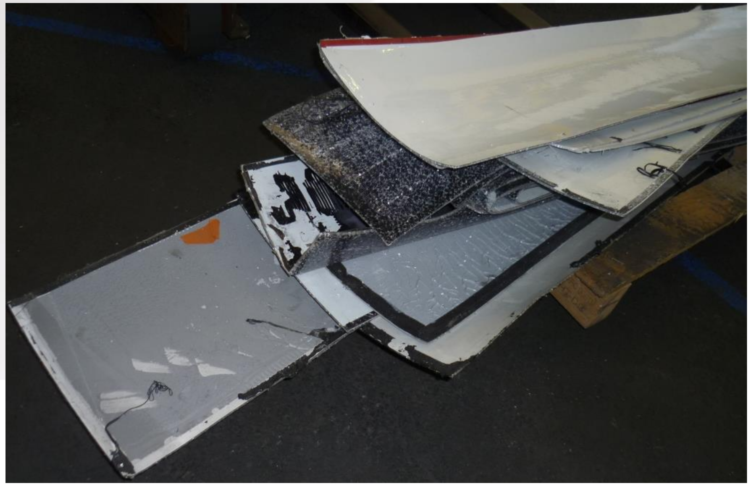


Polymers And coarse Metal fraction

glass

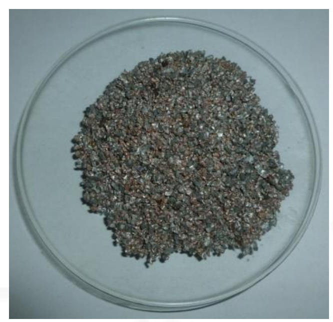
Fine fraction (metals)

Used Solar Cells converted to valuable materials



Glass

Mix of polymers



Metals
(connections)

Active materials
As Si and CGIS*

In first conclusion

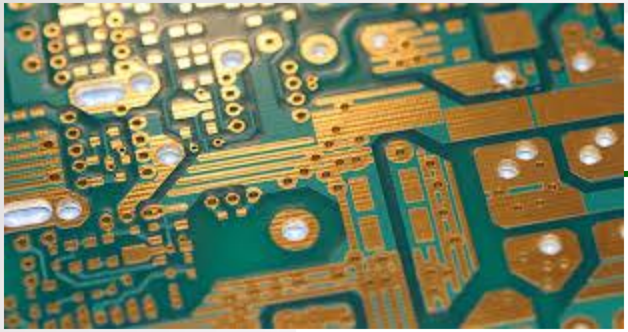
If the old alchemists ...

Tried to change lead into gold

RECUPYL

......the new "alchemist"

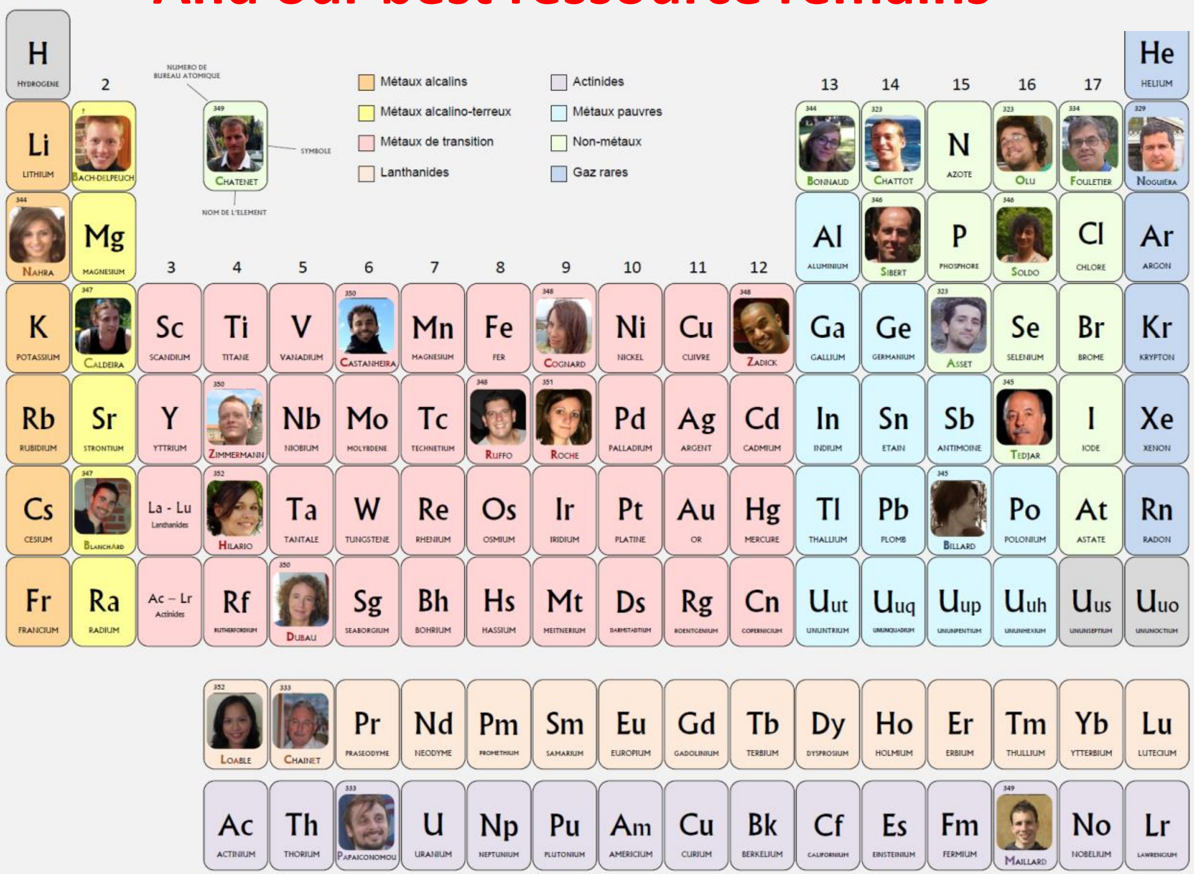
Changed the waste into gold



But in second conclusion

If the ressource are “finite”, innovation is infinite

And our best ressource remains



Équipe meca

Équipe chimie

Thank you for your attention