Lithium-ion batteries recycling

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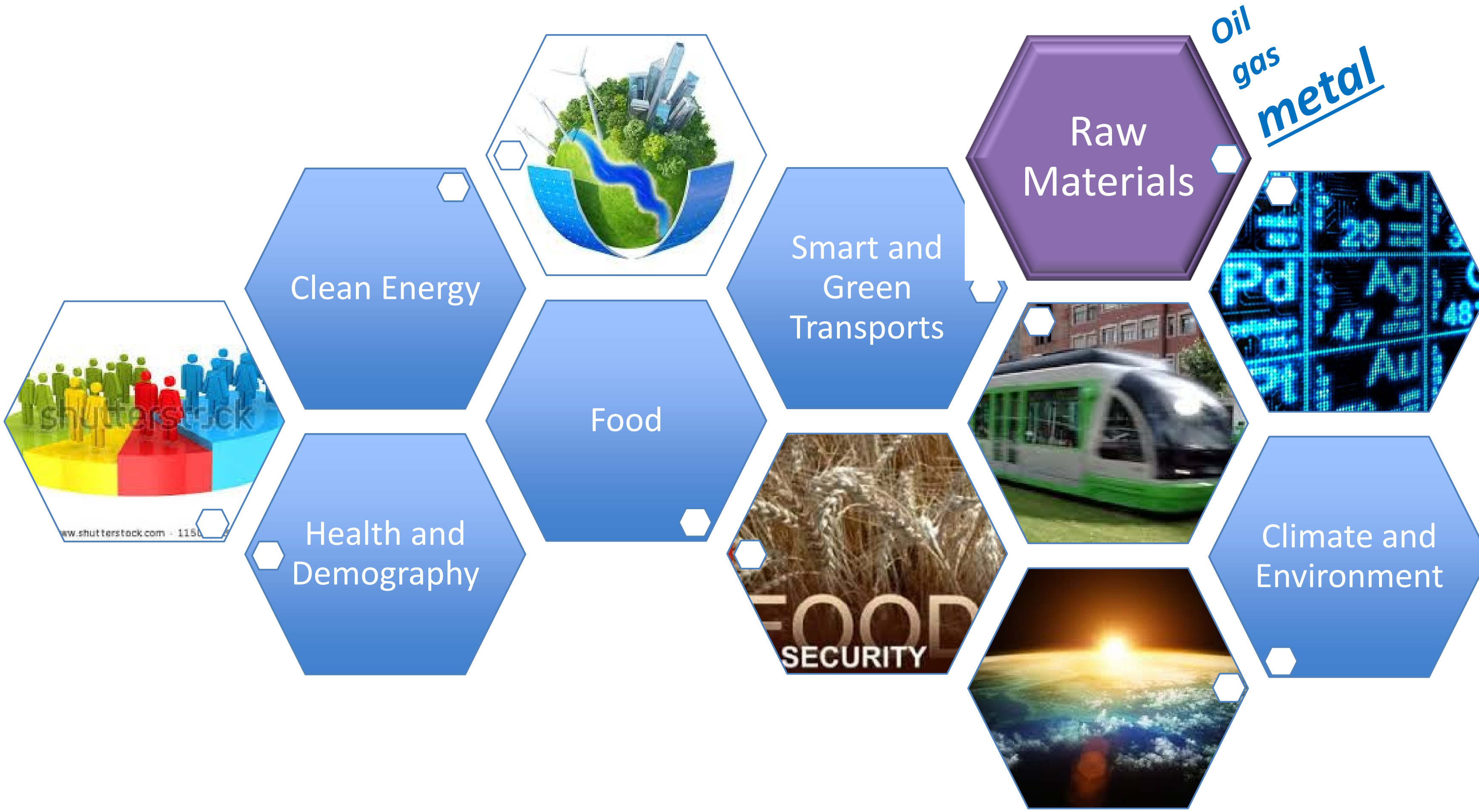
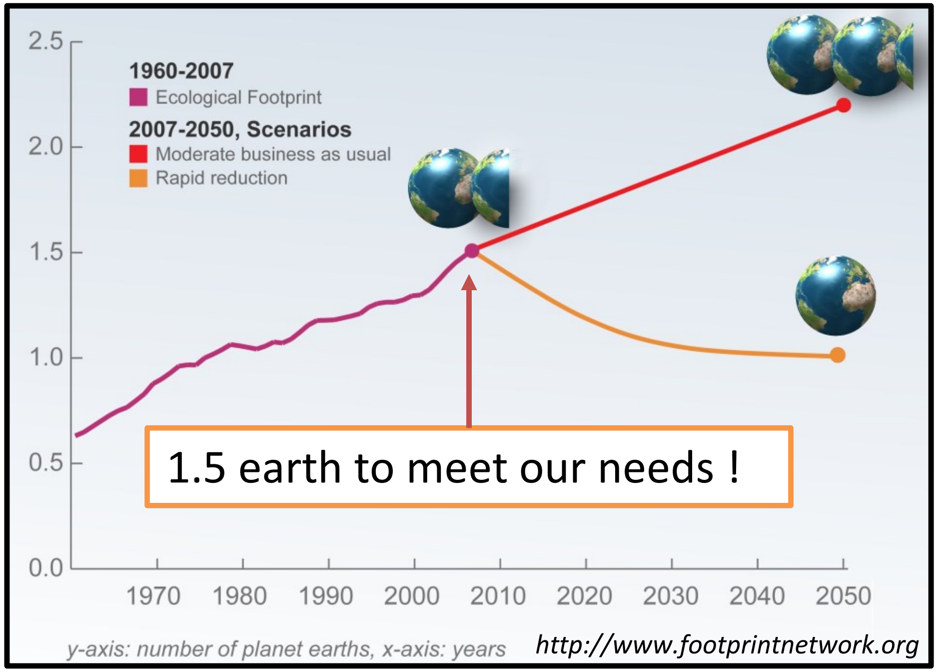
SOCIETAL CHALLENGES

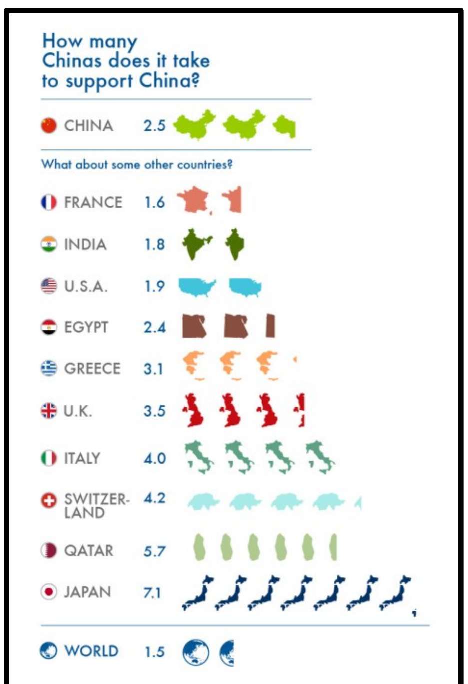


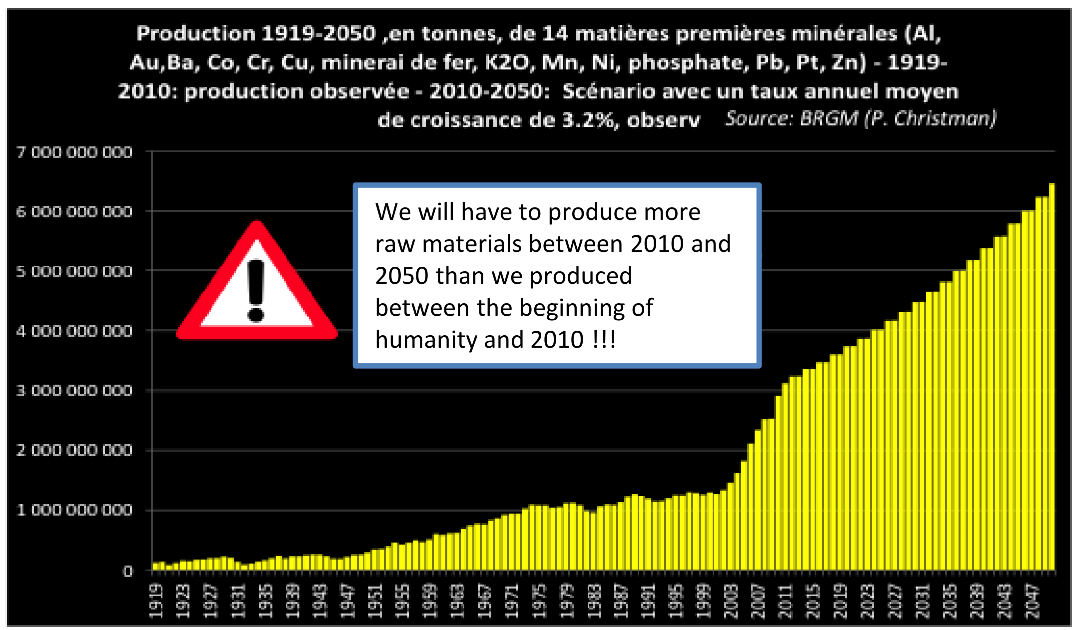


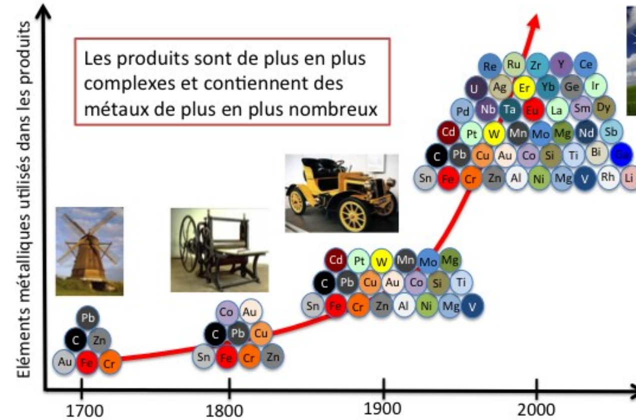
CONSUME MORE WITH LESS

Overshot Day (20 August 2015) = when resource use is expected to outstrip the capacity for production—and it's getting earlier every year

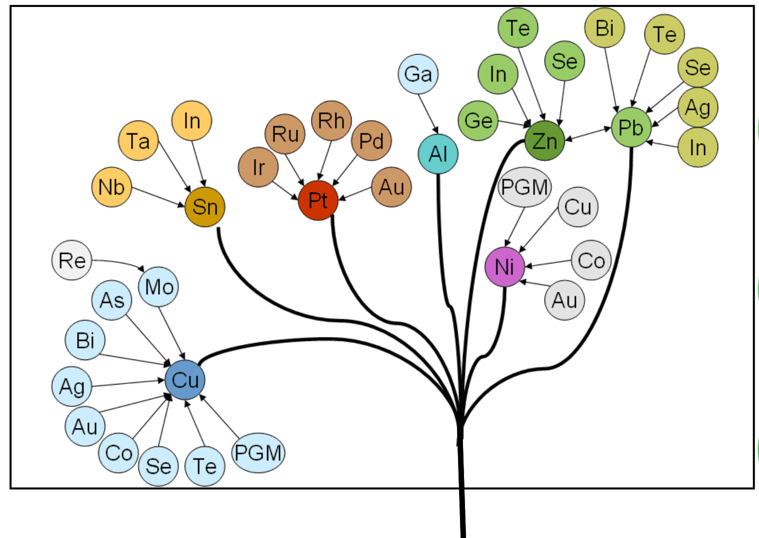
Humanity consumed the whole resource that the earth can produce in only 8 months !!!







In order to face up the world demand, we must extract metals (and more generally raw materials) contained in more and more complex ores from mining and urban mining



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We must develop new processes to recycle spent material in a sake of sustainability and to secure raw material but there are several challenges…

Challenges in Recycle

A good opportunity to diversify the supply of raw materials

<u>Challenges:</u>

- Transform small-scale industry to autonomous and profitable large-scale industry
- Develop efficient and profitable processes
- Improve the recovery of spent materials (WEEE, plastics, batteries, etc.)

Challenges in Recycle

A resource is valuable providing that we know how to transform it!

Present processes have been developed to exploit less complex resources

Next processes should rely on:

- The complementarity of pyro and hydrometallurgy
- A fine knowledge of the resource
- The huge potential of innovation of the European actors

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Therefore, recycling appears as a good opportunity to secure raw materials.
However, Secondary resources will never replace primary resources !!
Each stage of the value chain of the product must be optimized…

PYRO AND HYDROMETALLURGICAL PROCESSES WERE INITIALLY DEVELOPPED FOR PRIMARY RESOURCES… THESE PROCESSES MUST BE ADAPTED TO SECONDARY RESSOURCES AND NEW COMPLEX ORES BY REDUCING PROCESSES COSTS AND ENVIRONMENTAL FOOTPRINT

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Lithium-ion batteries Recycling

1. Why to recycle?
2. How to recycle?
3. Conclusion

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1. Why to recycle?

a) Economic reasons

Electric vehicle feet is expected to significantly increase

Lithium batteries production will follow the electric vehicle production

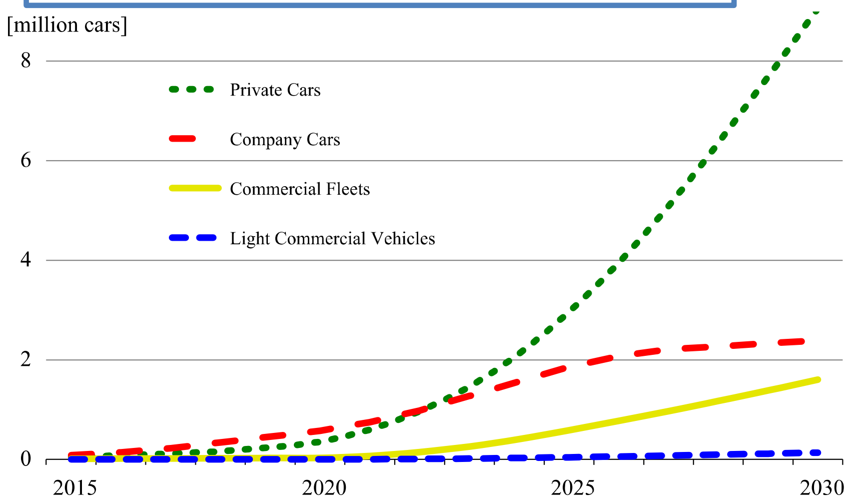


Fig. 3. Fleet size development.

Energy Policy 73 (2014) 147–157

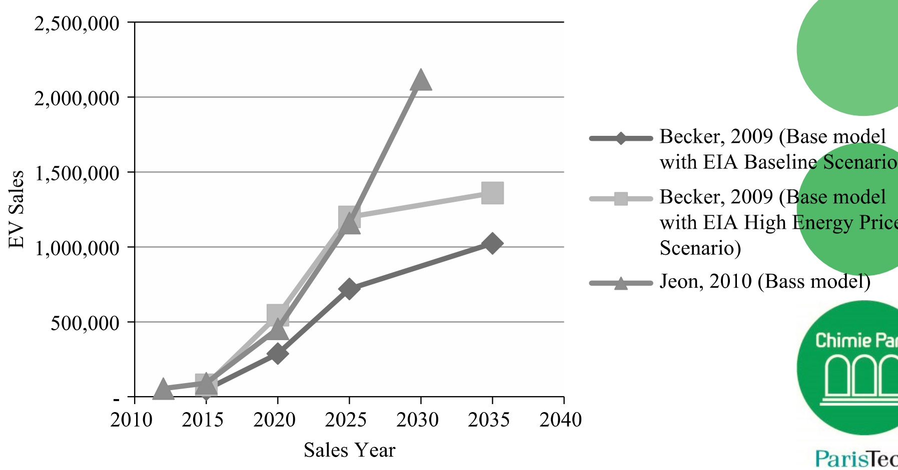


Fig. 6. EV penetration rate estimated using diffusion method [86,92].

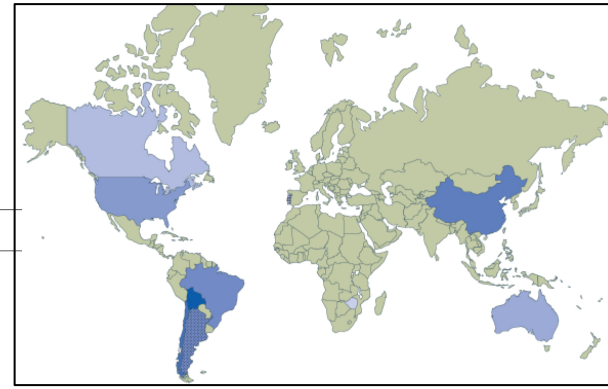
Renewable and Sustainable Energy Reviews 21 (2013) 190–203

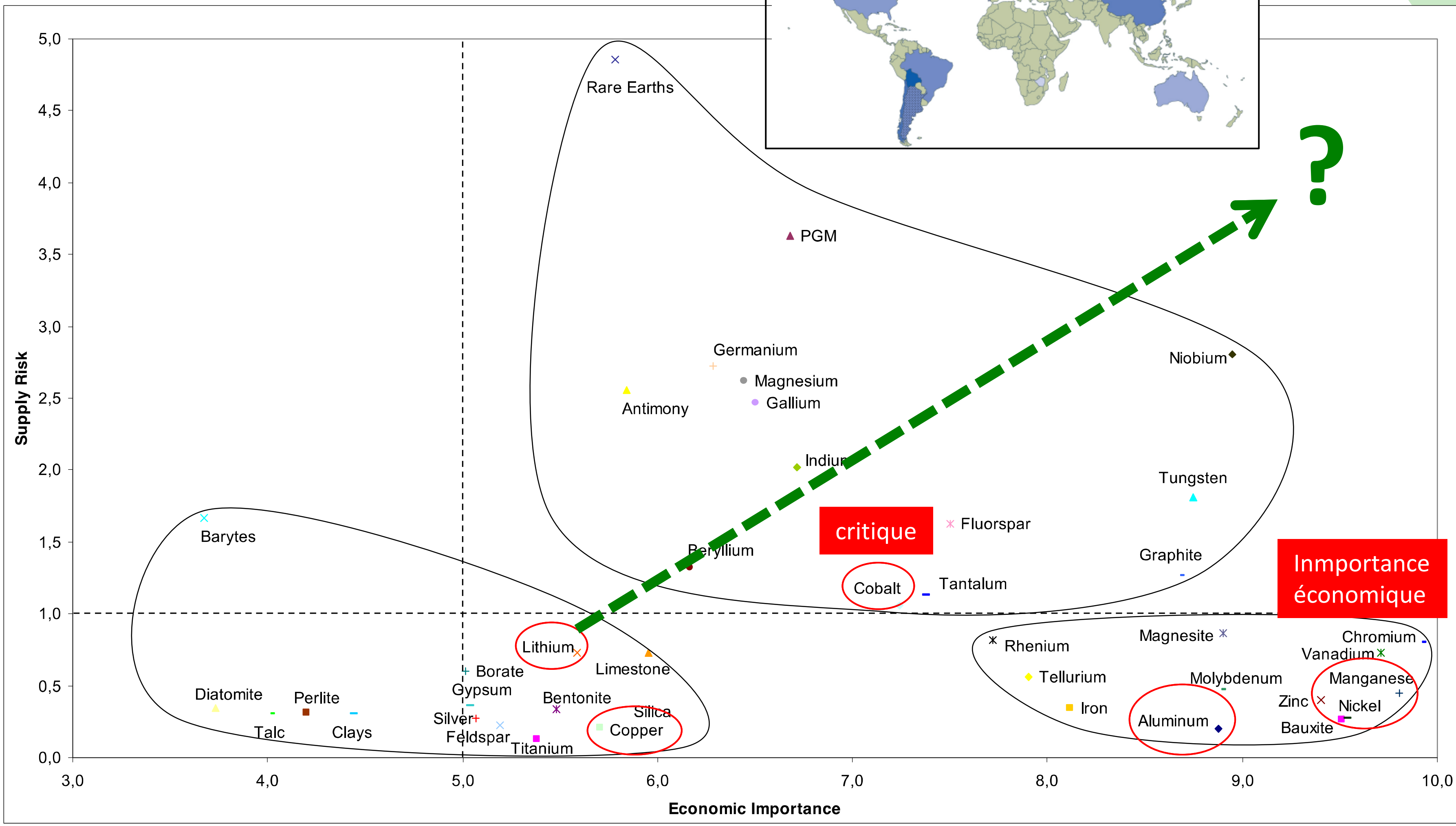
	Components	$/EV battery	Cost breakdown
Cell Components	Cathode	1,663	10%
	Anode	477	3%
	Electrolyte	447	3%
	Copper foil	184	1%
	Separator	608	4%
	Can header and terminals	1,050	6%
	Other materials	375	2%
	Total material	**4,803**	**29%**
Cells	Labor for cell manufacturing	2,586	16%
	Total cell	**7,390**	**45%**
Electronics	Mechanical components	2,053	12%
	Electrical Components	299	2%
	Electronics (battery mgmt. system)	1,381	8%
	Total Electronics	**3,733**	**22%**
Packs	Labor for pack manufacturing	268	2%
	Total Packs	**11,390**	**69%**
Warranty		228	**1%**
Gross Profit		4,979	**30%**
Total Cost		**16,596**	**100%**

Source: Lithium-ion Batteries for Electric Vehicles: THE U.S. VALUE CHAIN (oct 2010)

b) Geopolitical reasons

Where is Lithium?





Source: commission européenne

c) Regulations

Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators

d) Sustainability

CONTENT

1. Why to recycle?
2. How to recycle?
3. Conclusion

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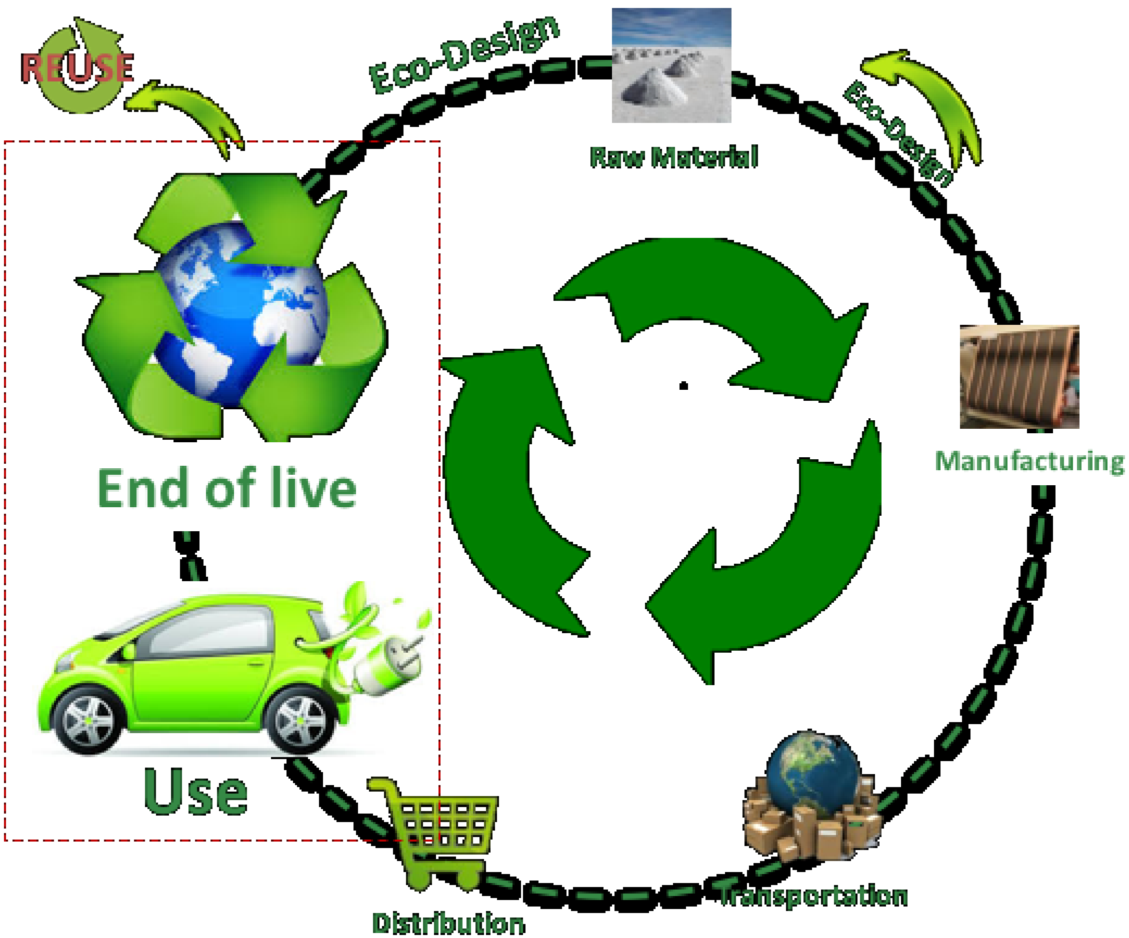
2. How to recycle?

We must think about:

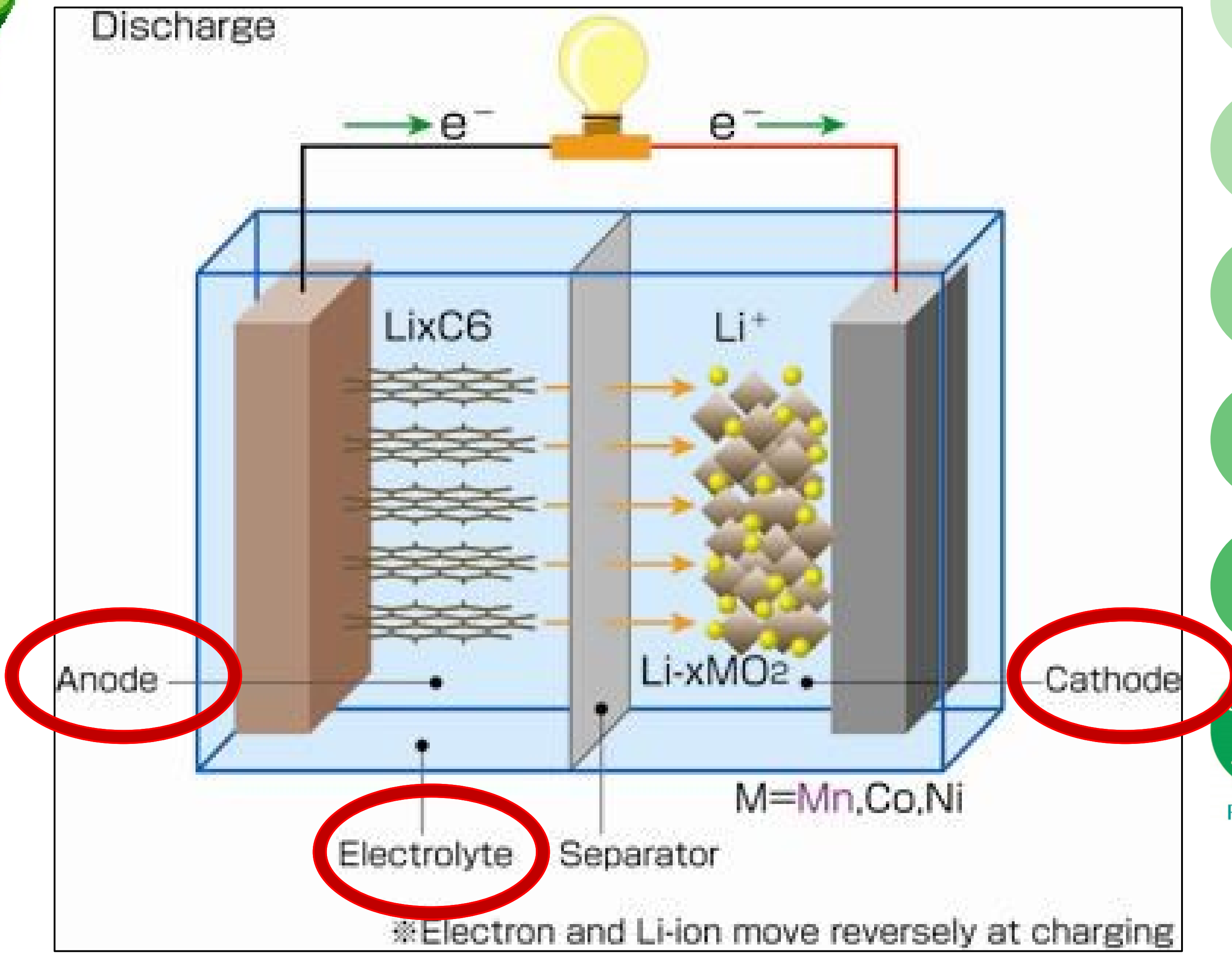
- Developing efficient, cheap and sustainable processes to recover valuable materials from spent batteries
- These processes must be able to adapt to the large variety of technologies

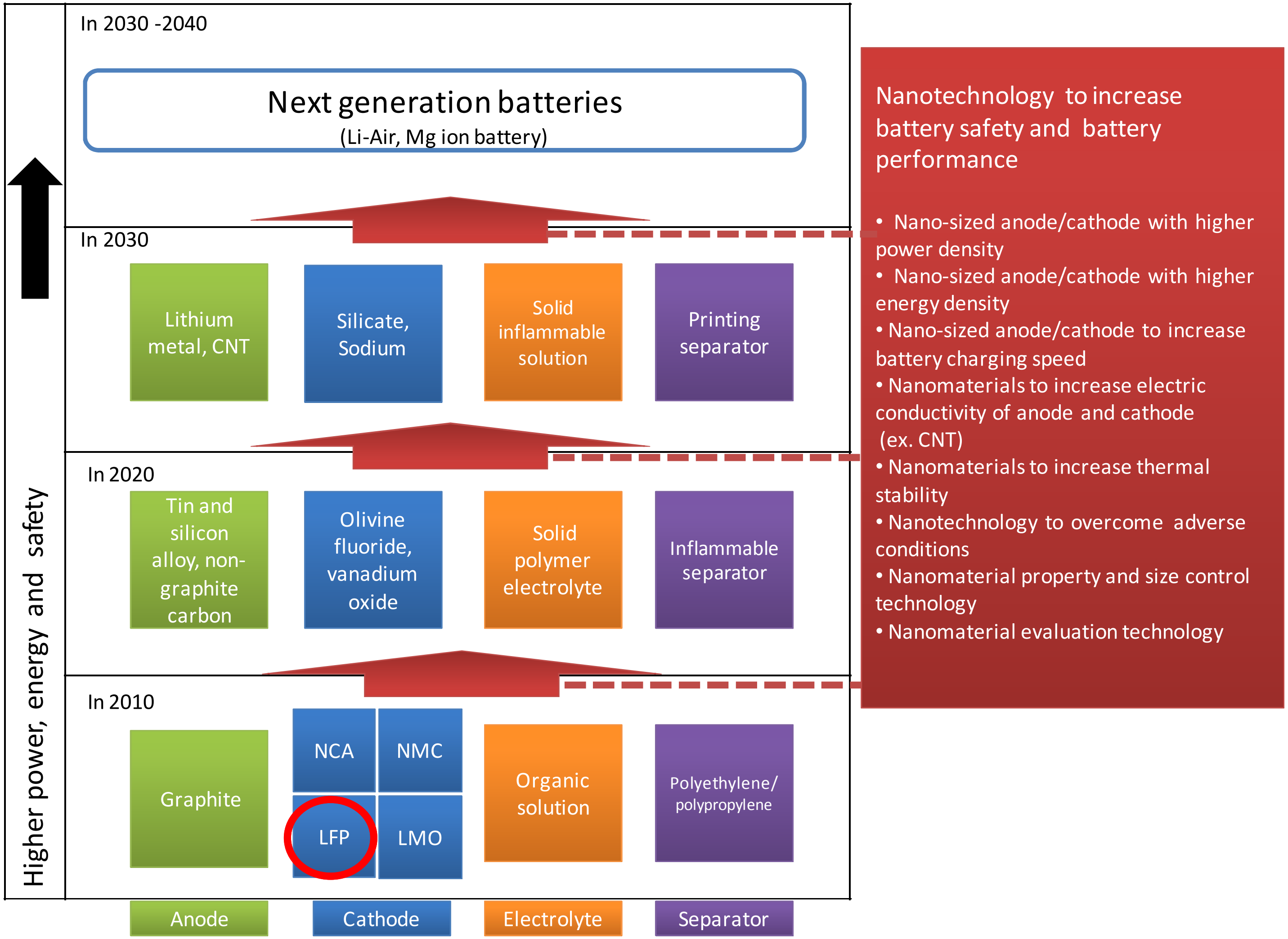
- Processes must be developed by thinking about the whole value chain (the process depends on what happens before and after the recycling stage



2.1. Valuable components to recycle

Recycling

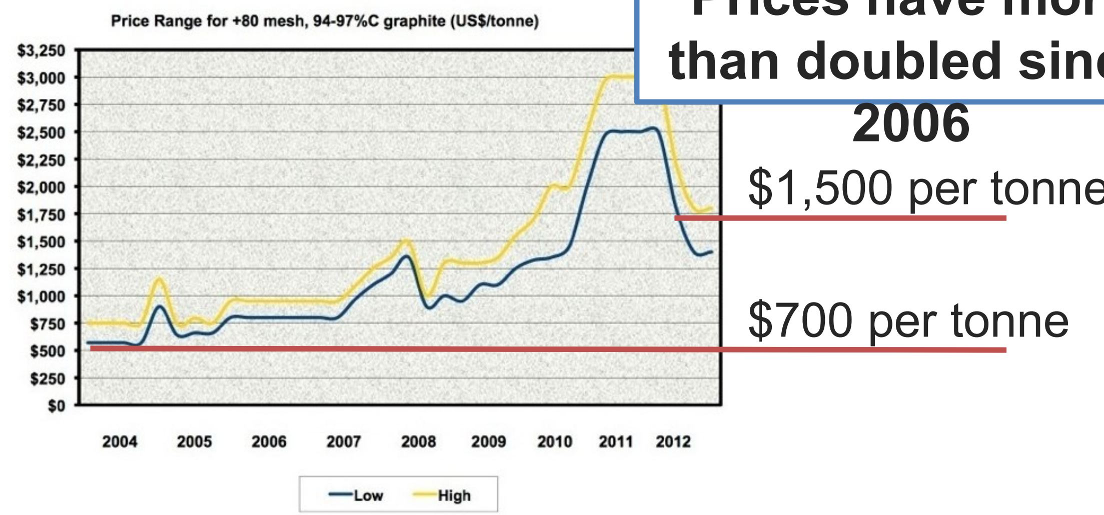




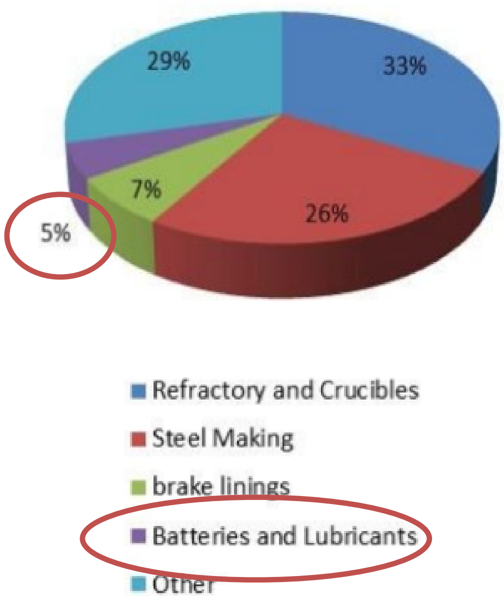
Source: Lithium-ion Batteries for Electric Vehicles: THE U.S. VALUE CHAIN (oct 2010)

Large variety of technologies in constant evolution… the process must adapt

NEGATIVE ELECTRODE = Graphite today and in the near future (cost=3%)



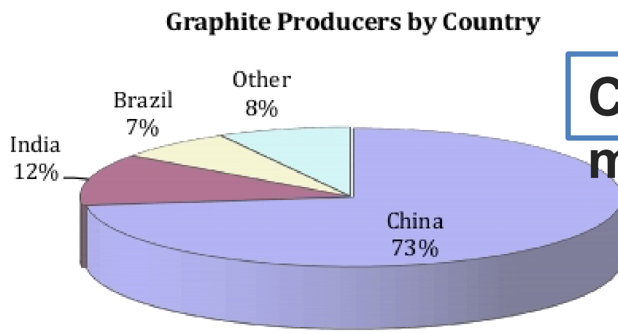
Prices have more than doubled since 2006



Today, 5% of graphite is used in LiBs
Tomorrow, this percentage will grow: 1.1 million tonnes currently being brought to market will no longer be enough to face electric vehicle market.

Recycling

NEGATIVE ELECTRODE = Graphite today and in the near future (cost=3%)



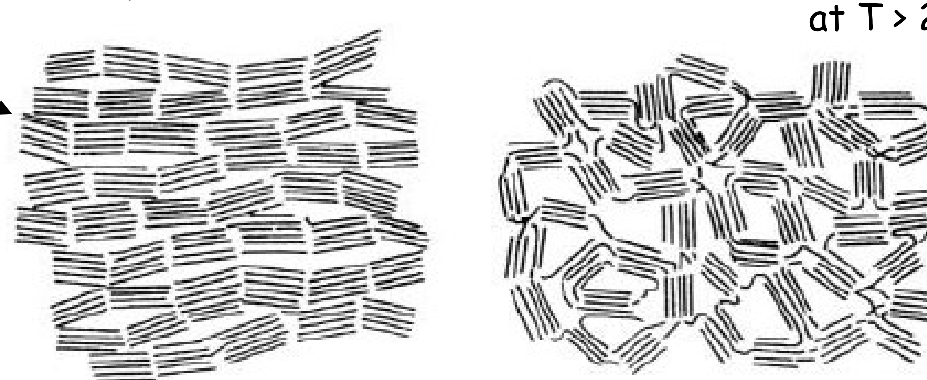
China has monopoly

→ **Substitute natural graphite by artificial graphite produced from natural carboneous materials**
→ **Recycling graphite from Lithium-ion batteries**

Turbostatic disorder

Soft carbon
(can lead to graphite)

Hard carbon
(cannot form graphite even at T > 2000°C)



small crystallites
in almost the same direction
→ low warm → ↗ order
→ graphitization

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Recycling

NEGATIVE ELECTRODE = Graphite today and in the near future (Cost=3%)

There is only few researches on graphite recycling and industrial processes for LiBs recycling do not recycle graphite

We must develop efficient processes capable to recycle graphite that can be used in other applications or in lithium-ion batteries (quality of graphite?)

We must also develop negative electrodes based on the use of artificial graphite and increase the variety of negative electrode technologies (silicone?)

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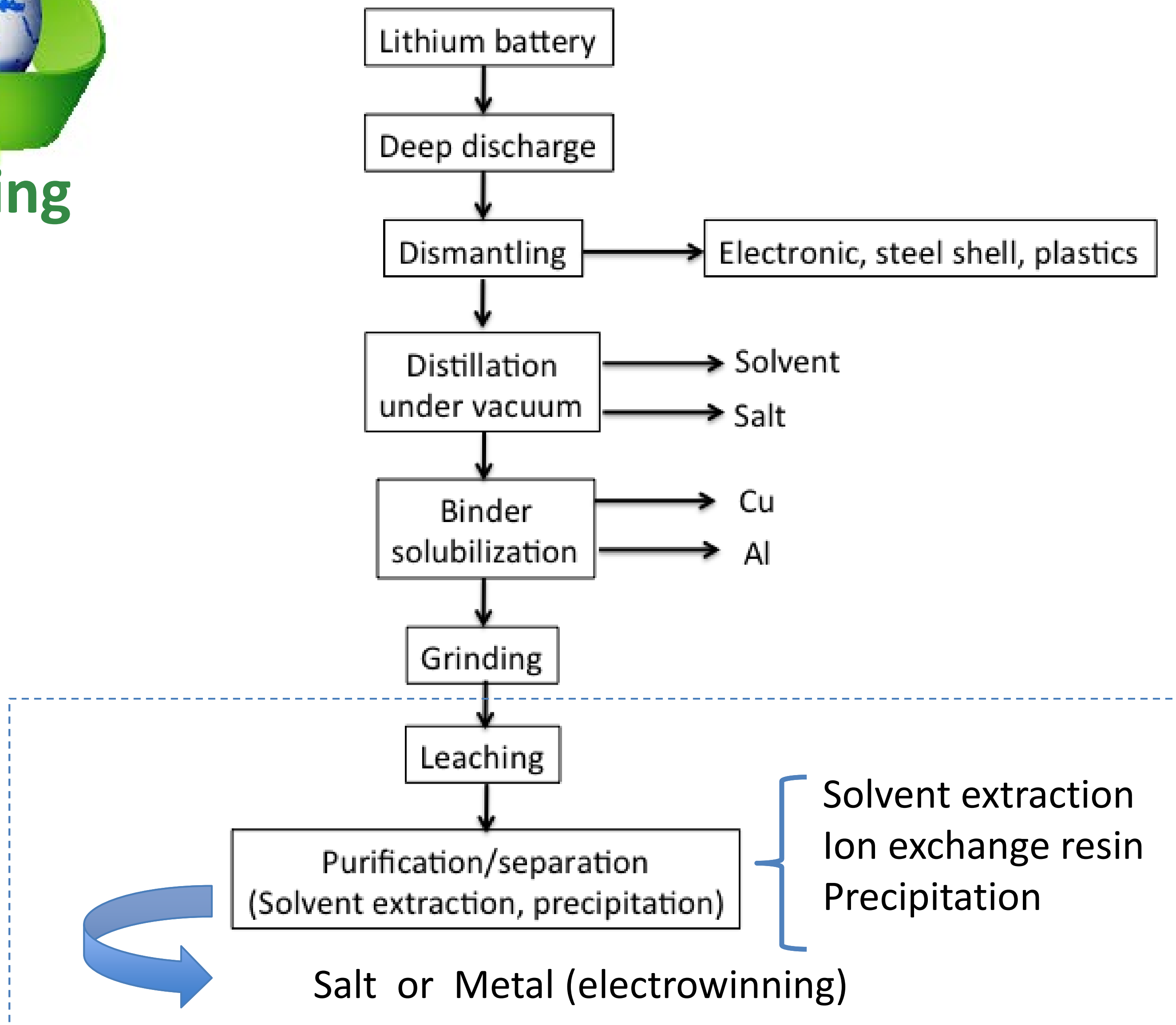
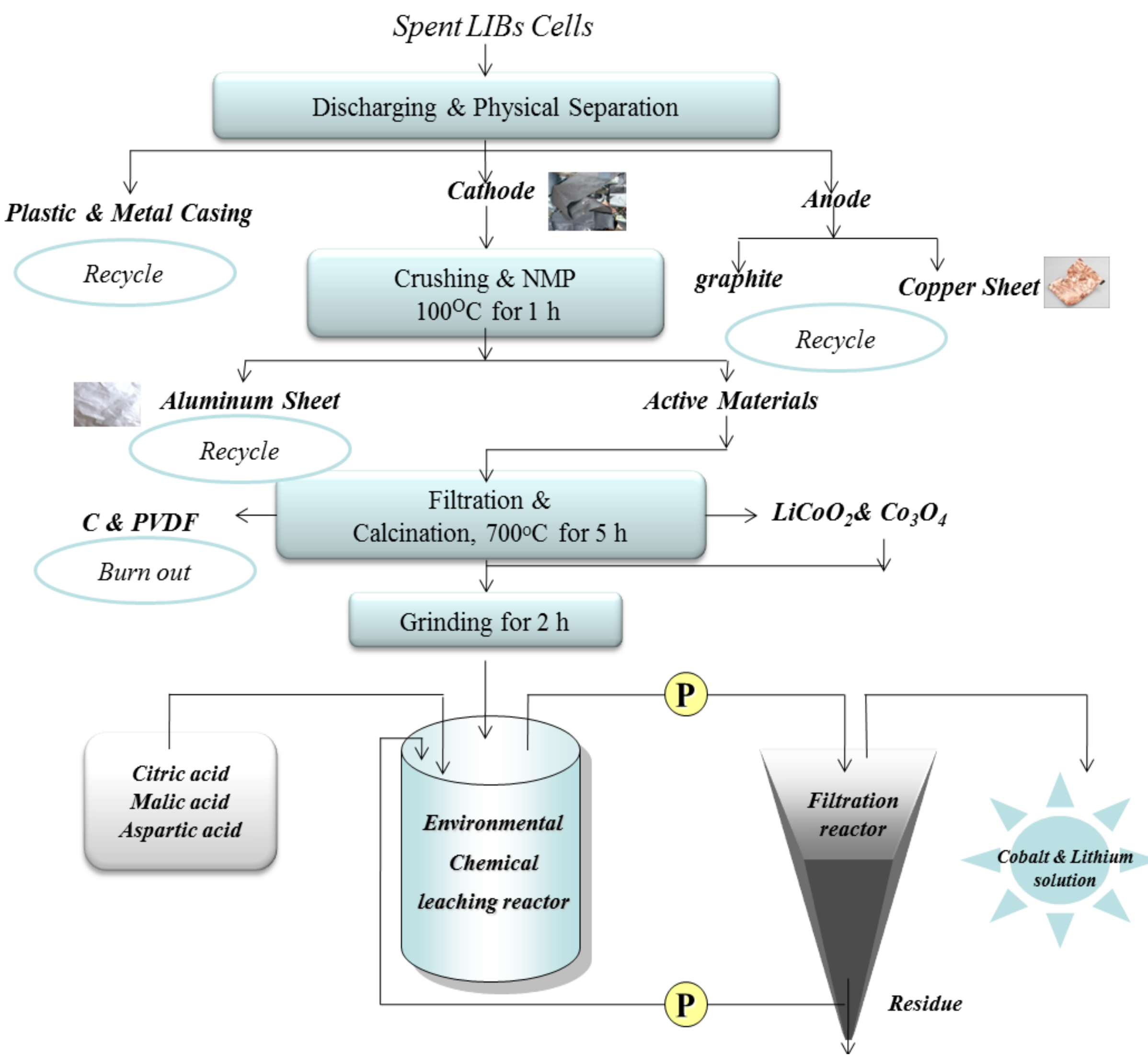
Recycling

POSITIVE ELECTRODE (Cost=10%)





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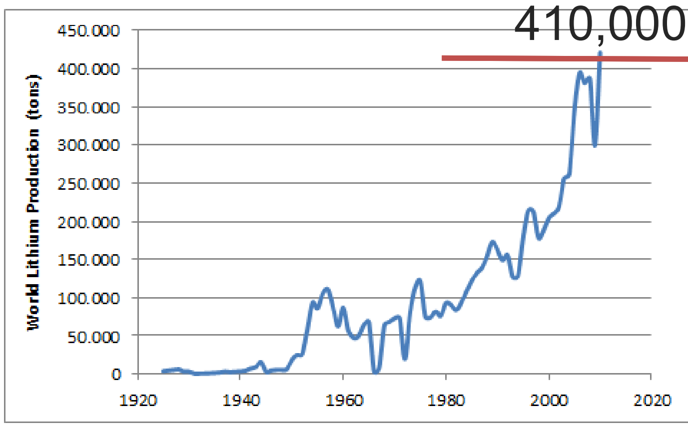
Many flow sheets based on different chemistry are available in the literature

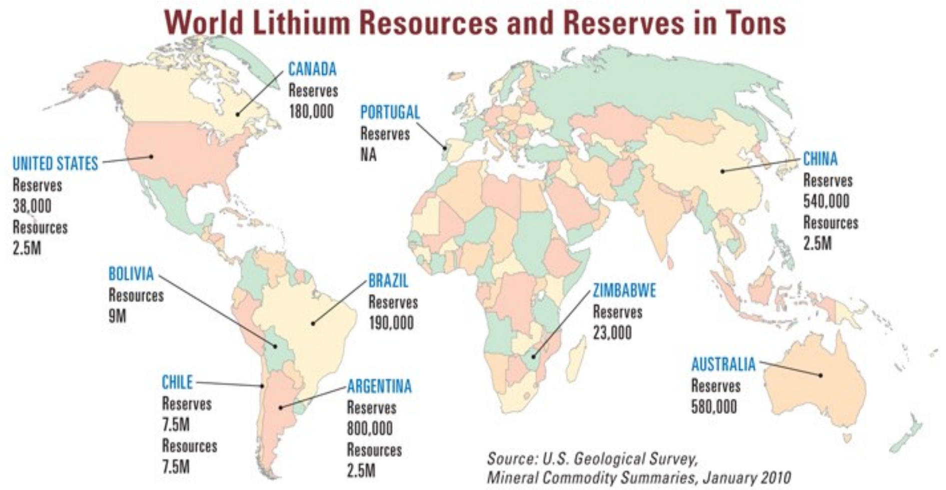
ELECTROLYTE (Cost=3%)

Recycling

Electrolyte = Lithium salts (high grade)+organic solvents

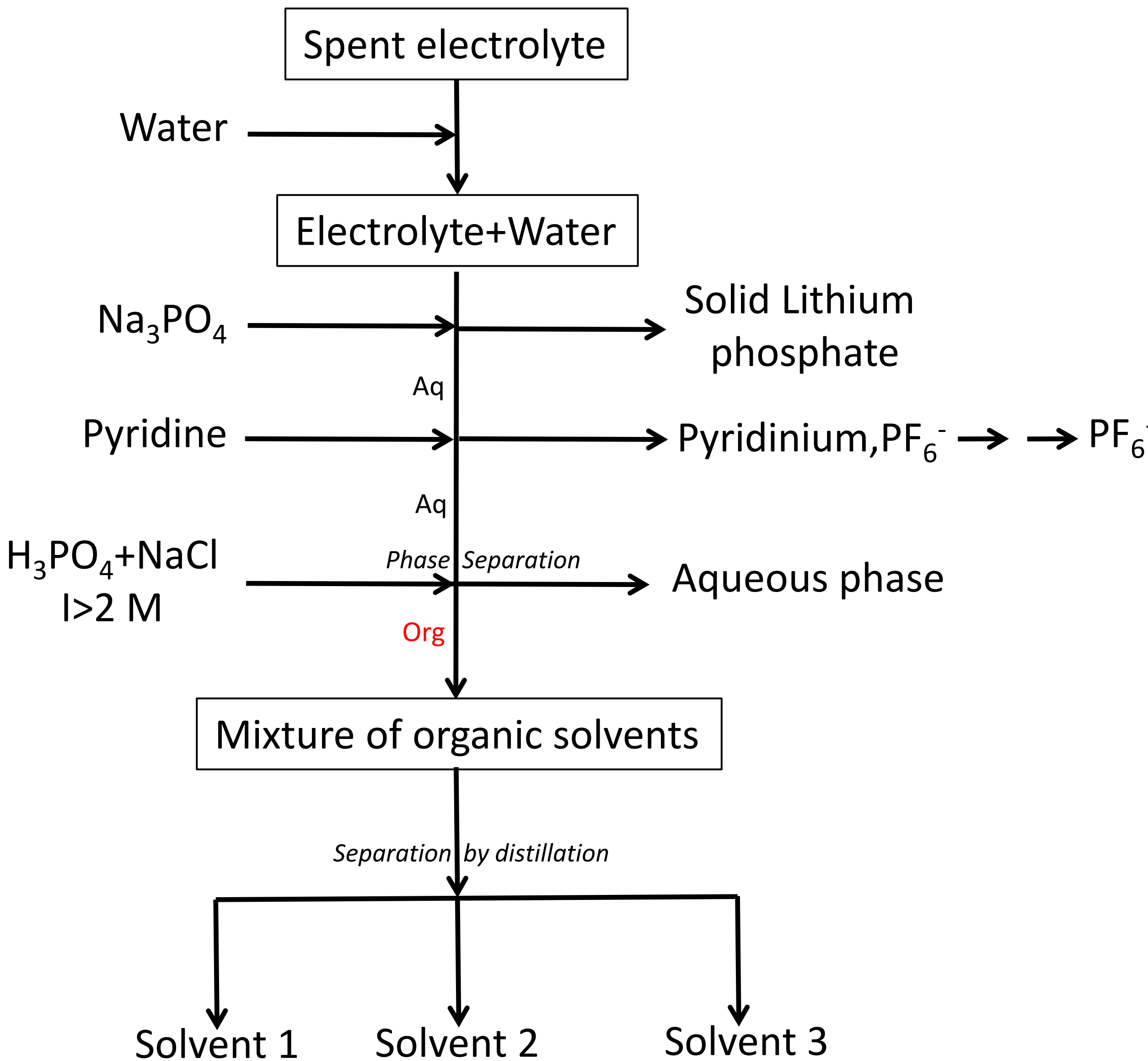
410,000 tonnes L





Recycling

ELECTROLYTE (Cost=3%)



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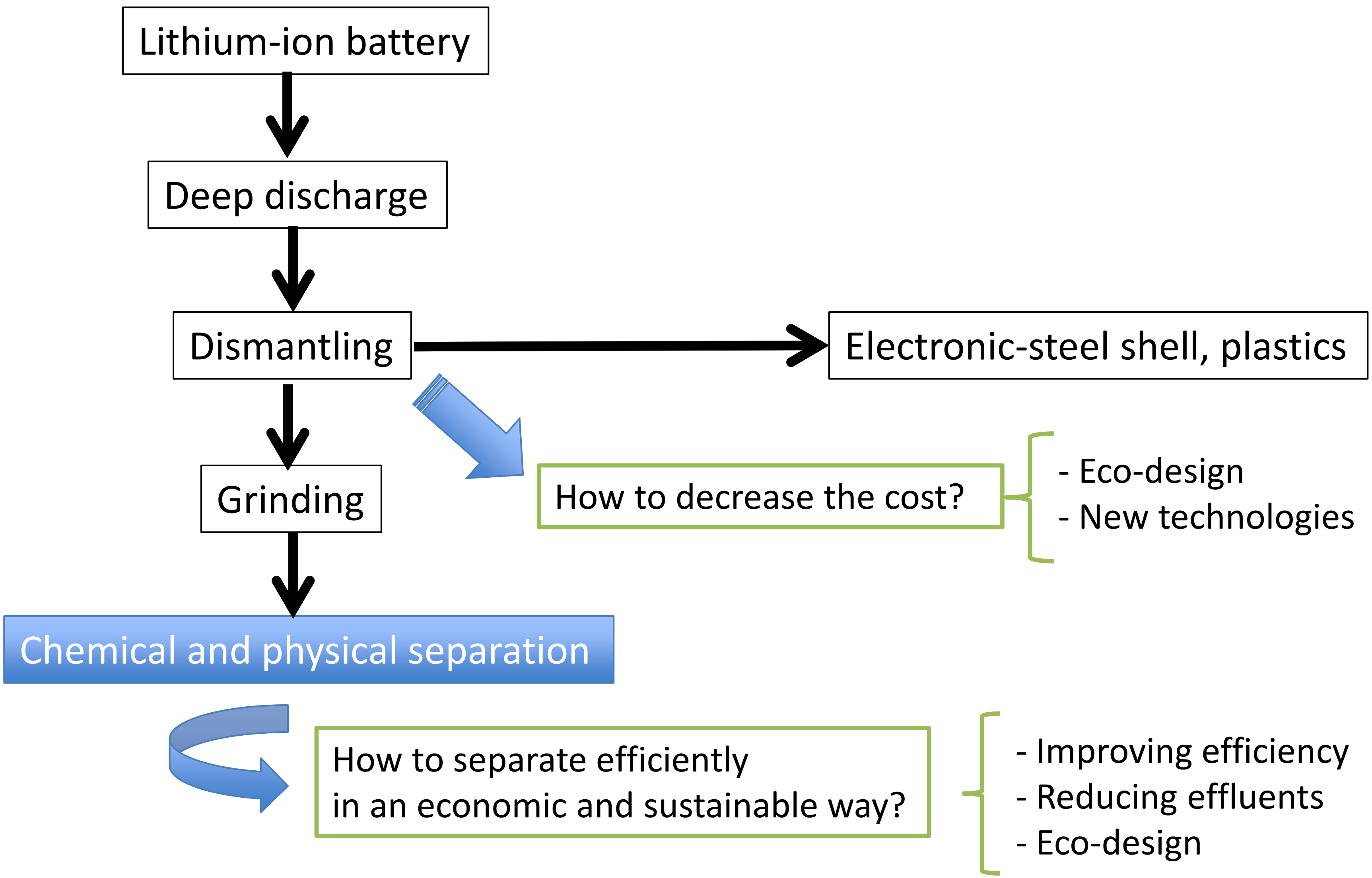
2.2. Recycling processes

General Flow sheet in hydro- and pyro-metallurgy



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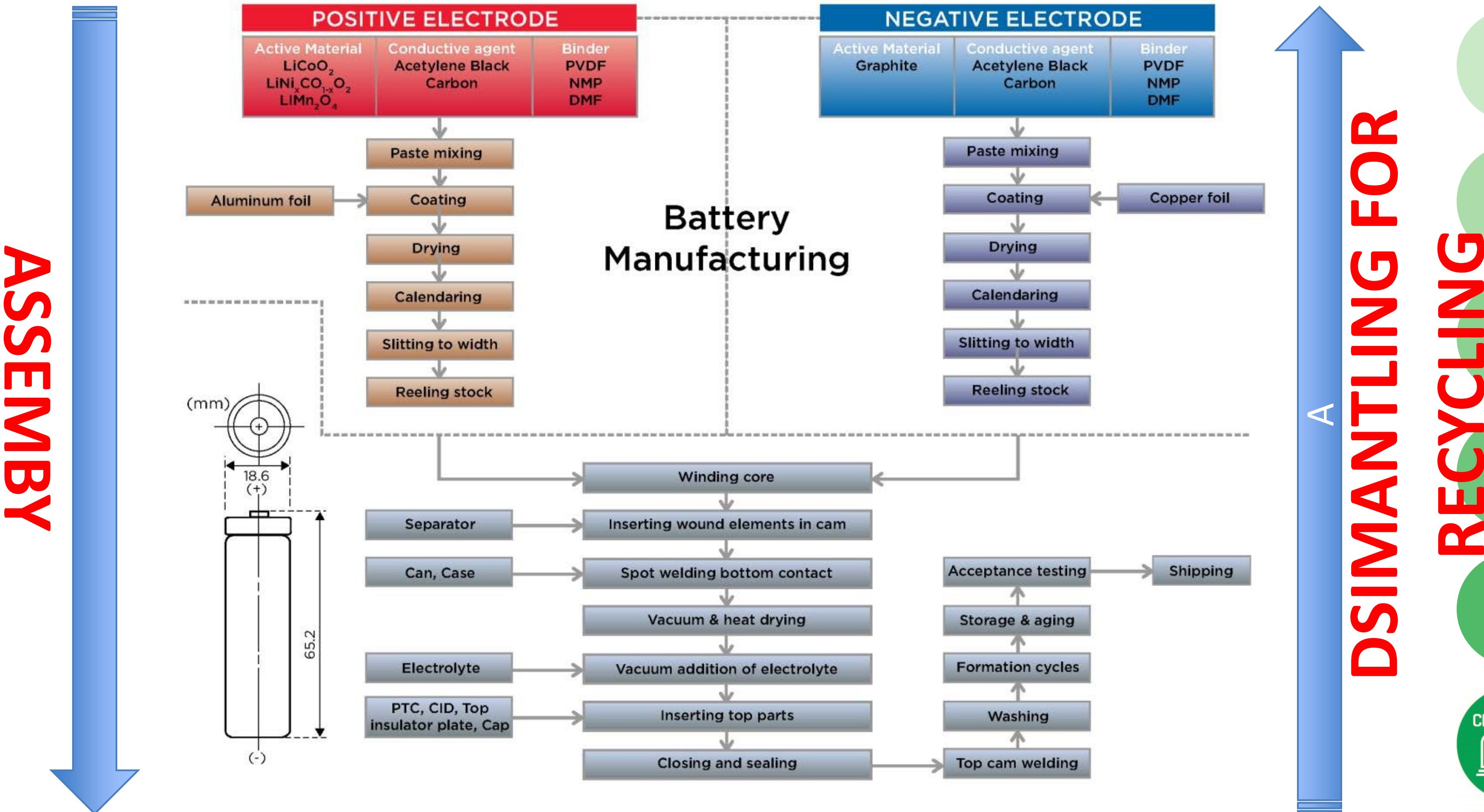
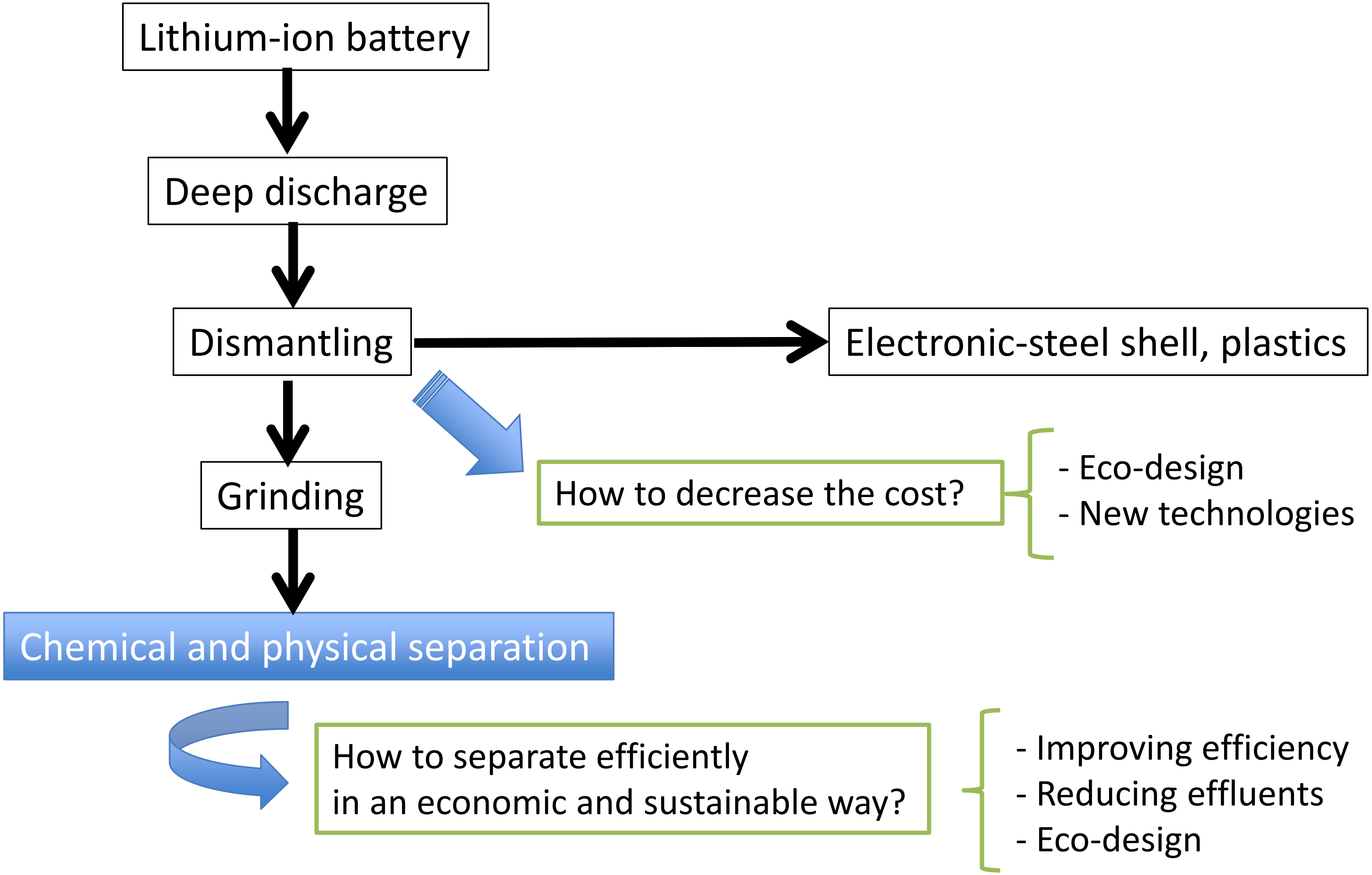


Battery assembly process

Source: Gaines, 90th Annual Meeting of the Transportation Research Board (Janv 2011)



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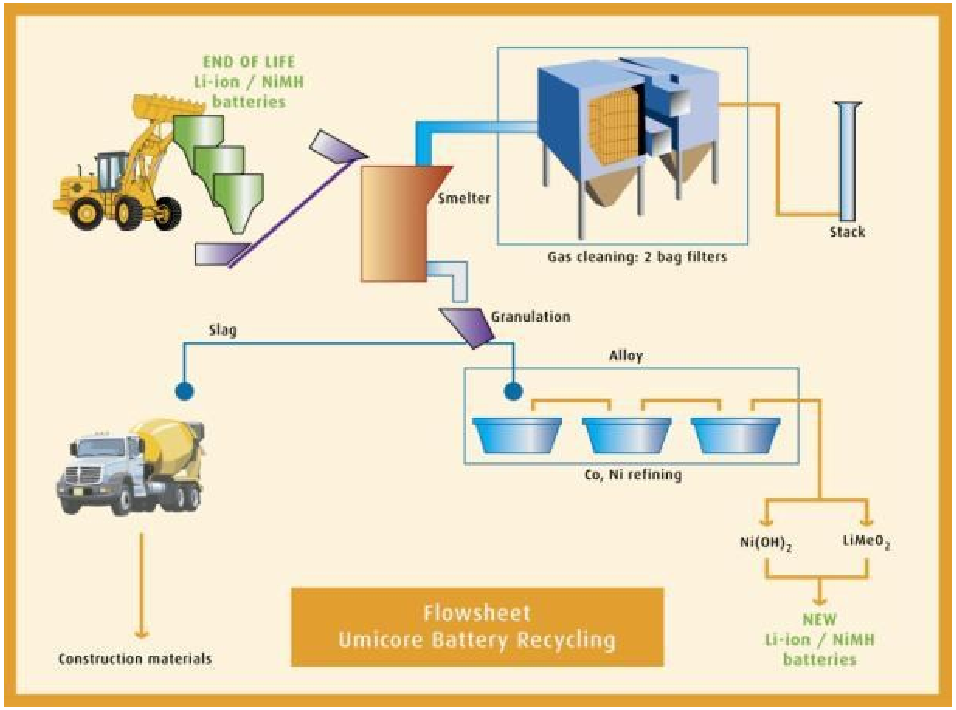
2.2.1. Pyrometallurgical processes for LiB recycling

Umicore recycling process

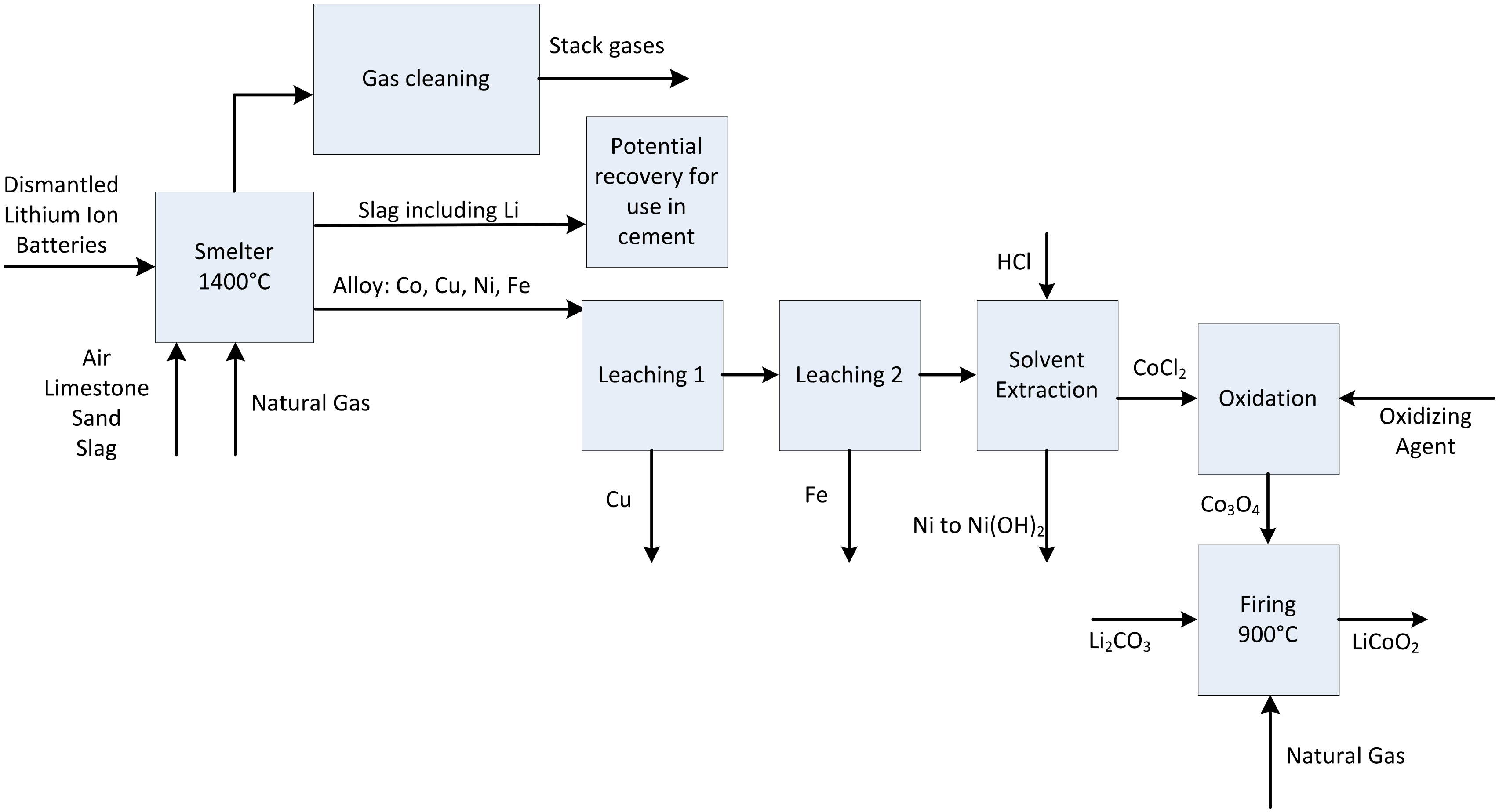


- Plastics, electrolyte solvents, and carbon electrodes are burned in the smelter (carbon = reducing agent and heat fuels the smelter).

- Co and Ni are the main products; Fe can be recovered as well
- Al and Li go to the slag for low-value uses.

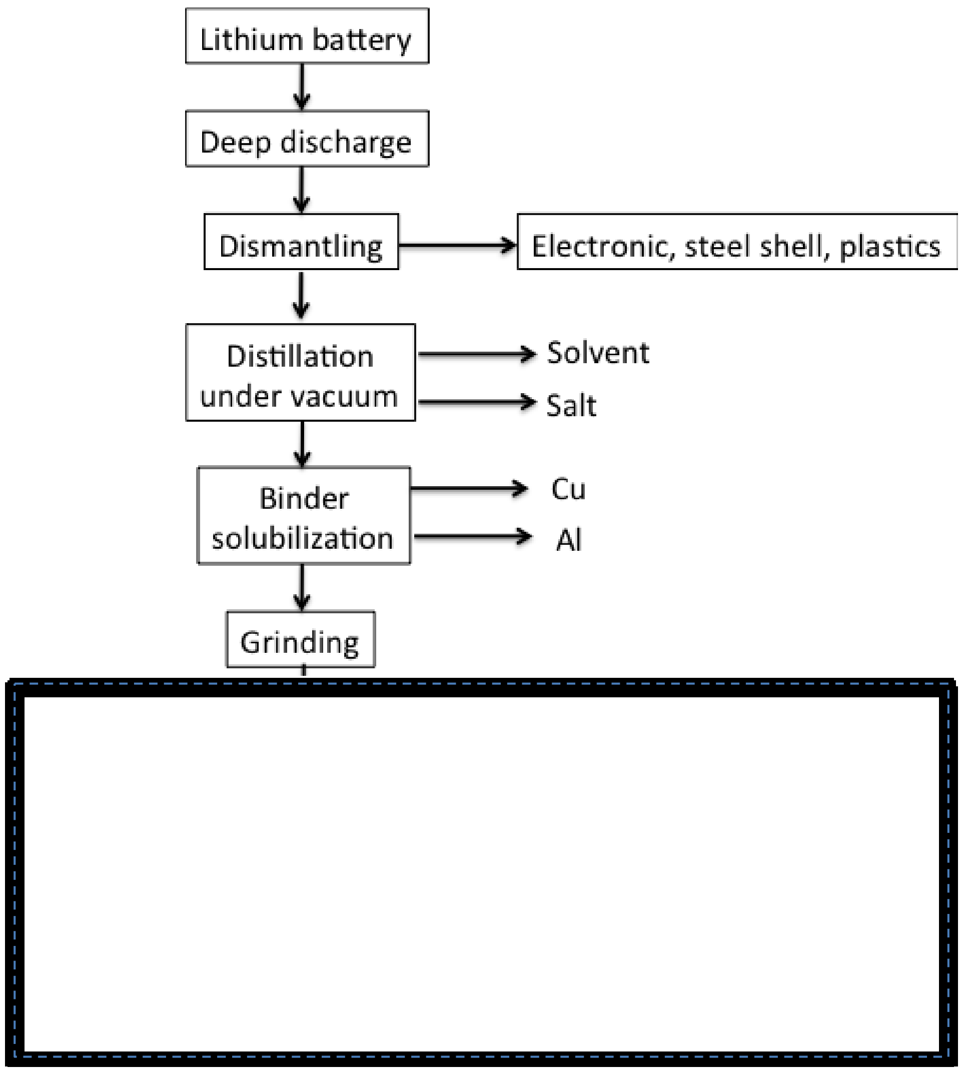
- 93% recovery rate for Li-ion batteries (metals 69%, carbon 10%, plastics 15%), but a much smaller percentage actually comes out as usable high-value material.

Detailed in the Umicore recycling process



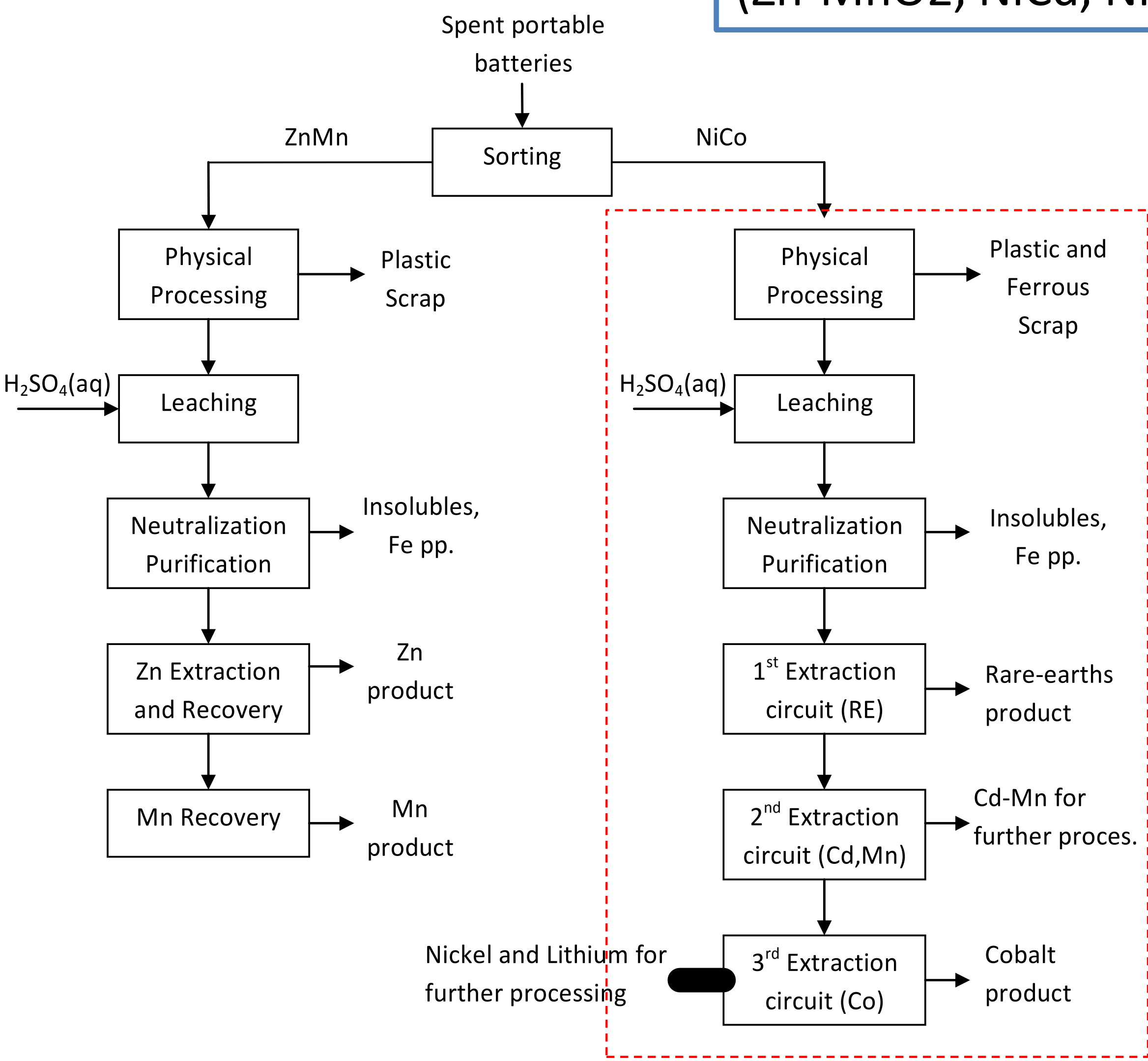
How to recycle?

2.2.2. Hydrometallurgical processes for LiB recycling



BATMIX Process

Inlet: Mixture of different battery technologies (Zn-MnO2, NiCd, NiMH, NiCo from Li batteries)



Sieving (polymer/ferrous scrap separated from electrode materials (disaggregated=small)

Jarosite or goethite

D2EHPA

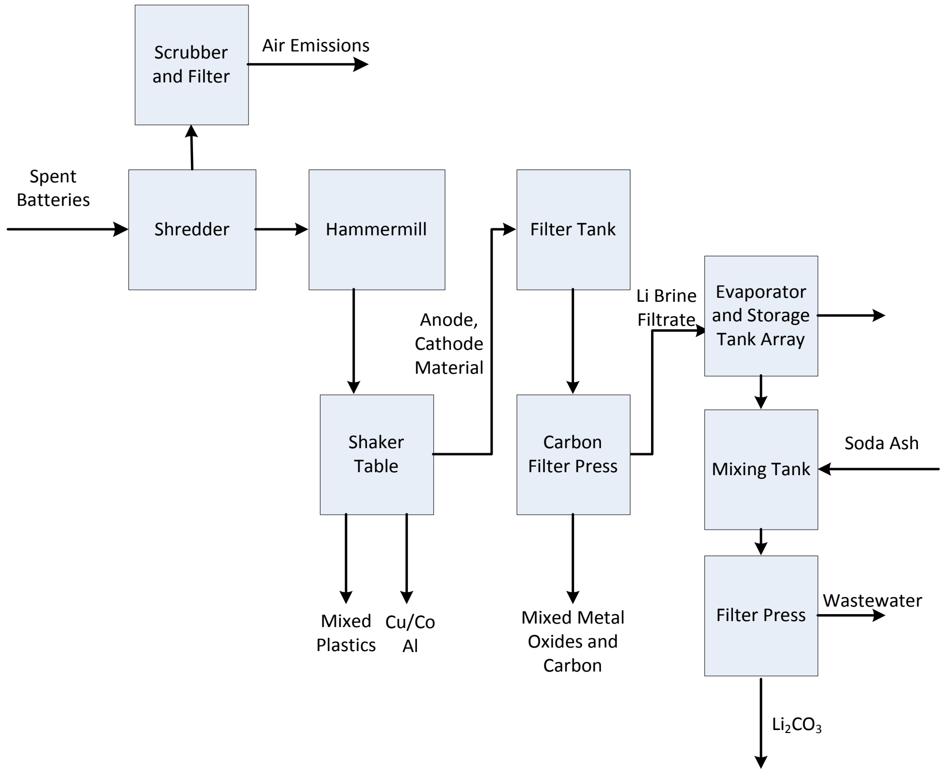
D2EHPA

pH
Phase volume ratio

Cyanex 272

pH
Phase volume ratio

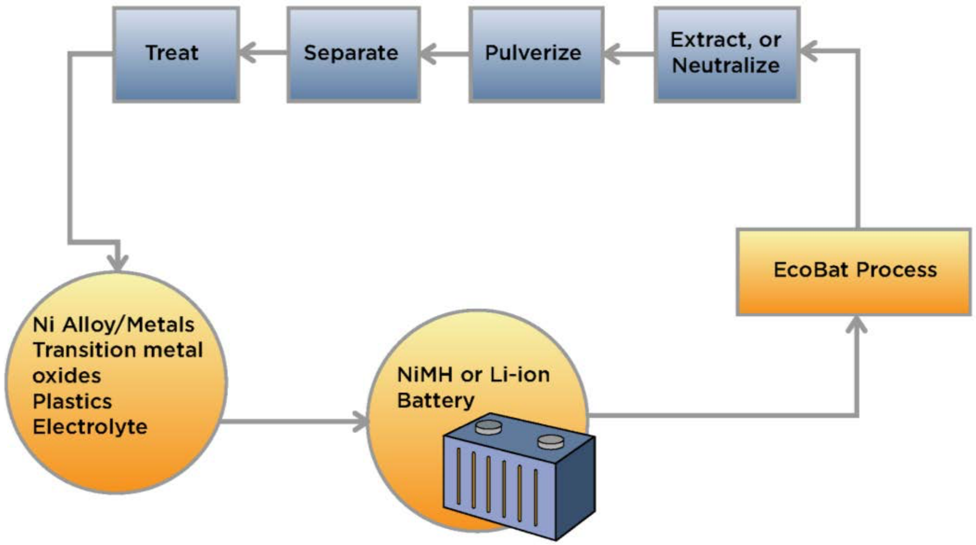
TOXCO Process



- Battery pack is discharged for safety reasons
- Control circuits are removed and tested for possible reuse
- Wires and some other metals are removed for recycling
- Packs are disassembled
- A series of mechanical processes are used to reduce the size of the cell materials
- Products=copper cobalt and lithium carbonate

- Recycling process is mainly mechanical and chemical → Minimum emissions and energy consumption (low temperature)
- 60% of the pack materials can be recycled, and a further 10% reused.

ECOBAT Process



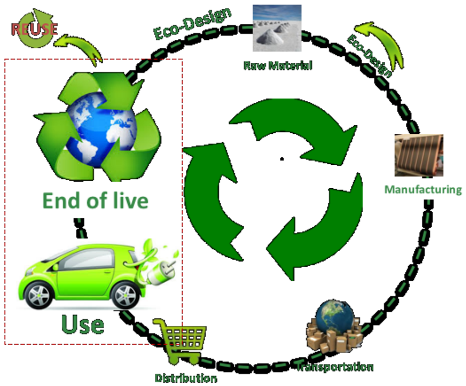
- Minimal energy use (no high-temperature processing)
- Many of the process details are proprietary, and so cannot be specified here.
- Electrolyte recovery using supercritical CO_2 for salt reuse.
- Separation processes based on surface properties and solubility.
- Over 80% of the material is actually recycled to useful products with potential value of the recovered materials quite high.
- Experimental results are excellent for both cobalt and phosphate cathodes.
- Processing a mixed feed would require additional separation steps to yield high-quality final products.
- Issue: scaling up this process.

3. CONCLUSION

Most of the processes are pyrometallurgical processes but there is no doubt that hydrometallurgical processes will be more sustainable and efficient to produce high-grade products

However, the best compromise is to combine hydro- and pyro-metallurgical processes to achieve the best performances (pyro-pretreatment)

UTMANING
CHALLENGE



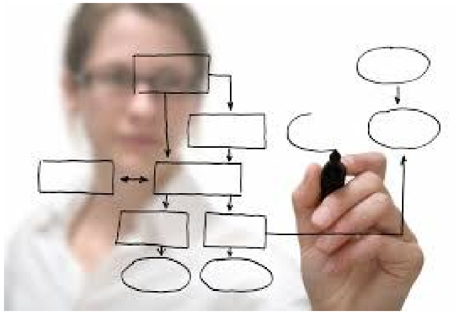
Integrated view of the chain value

Recycling process must be viewed as a part of the chain value

Managing spent LiB at the end of life from the user to the mechanic

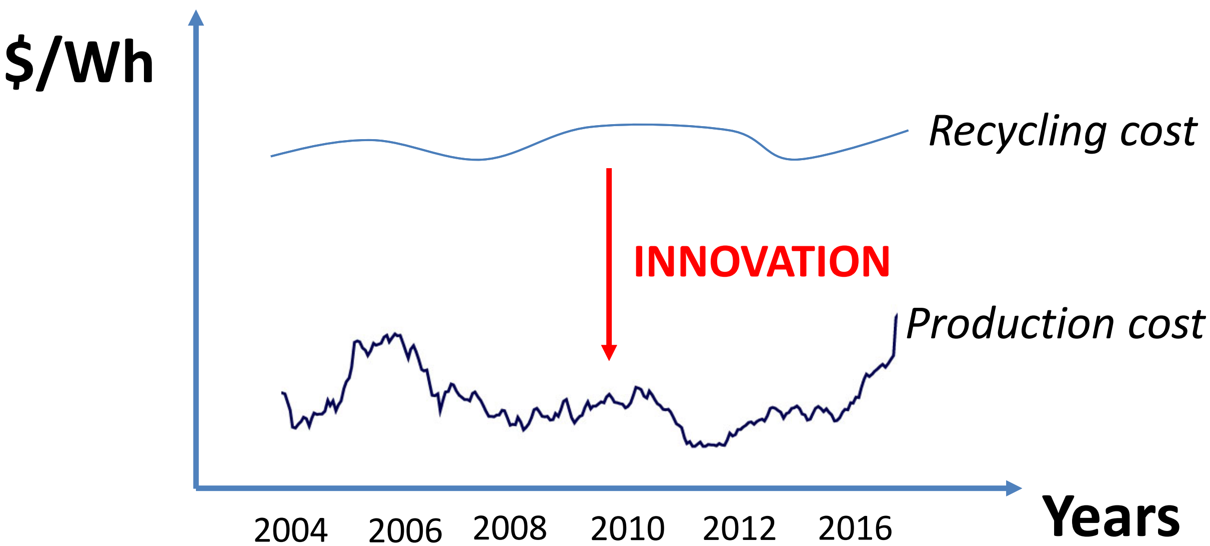
Eco-design the materials and the batteries

Supporting the development of technologies based on the use of alternative materials instead of Li, Co, Ni and graphite based materials



New processes capable to process various types of streams and capable to anticipation future technologies

Be able to face up the volatility of raw materials price by making innovation for reducing the recycling cost



Decrease recycling price by getting easier the dismantlement

LIAM

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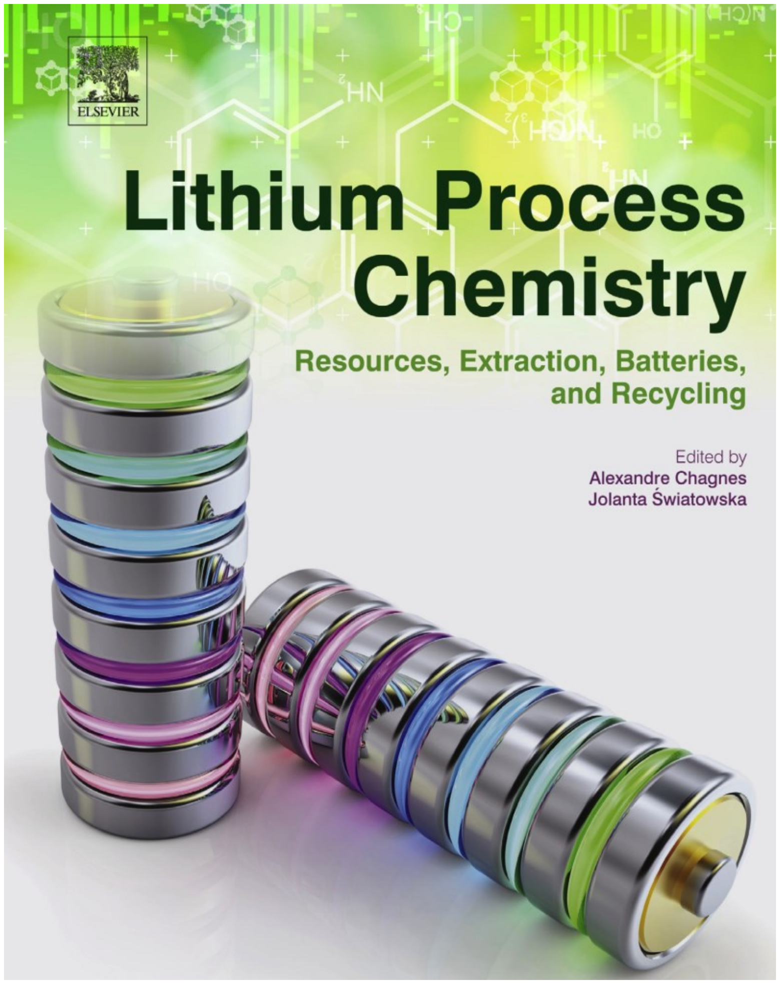
29 robots over 30 meters to disassemble 40 iphones at the same time within 11 seconds

→ Capacity=2.4 million iphones a year

If you are interested by Lithium batteries, lithium batteries recycling and e-wastes recycling…



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Och tack för er uppmärksamhet !

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