LITHIUM ION BATTERY RECYCLING: INNOVATIVE HYDROMETALLURGICAL PROCESSES ADDRESSING BLACK MASS HETEROGENEITY

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Theory of the development of chemical processes
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Giornata della ricerca chimica

Smart materials – Ricerca collaborativa per la leadership industriale

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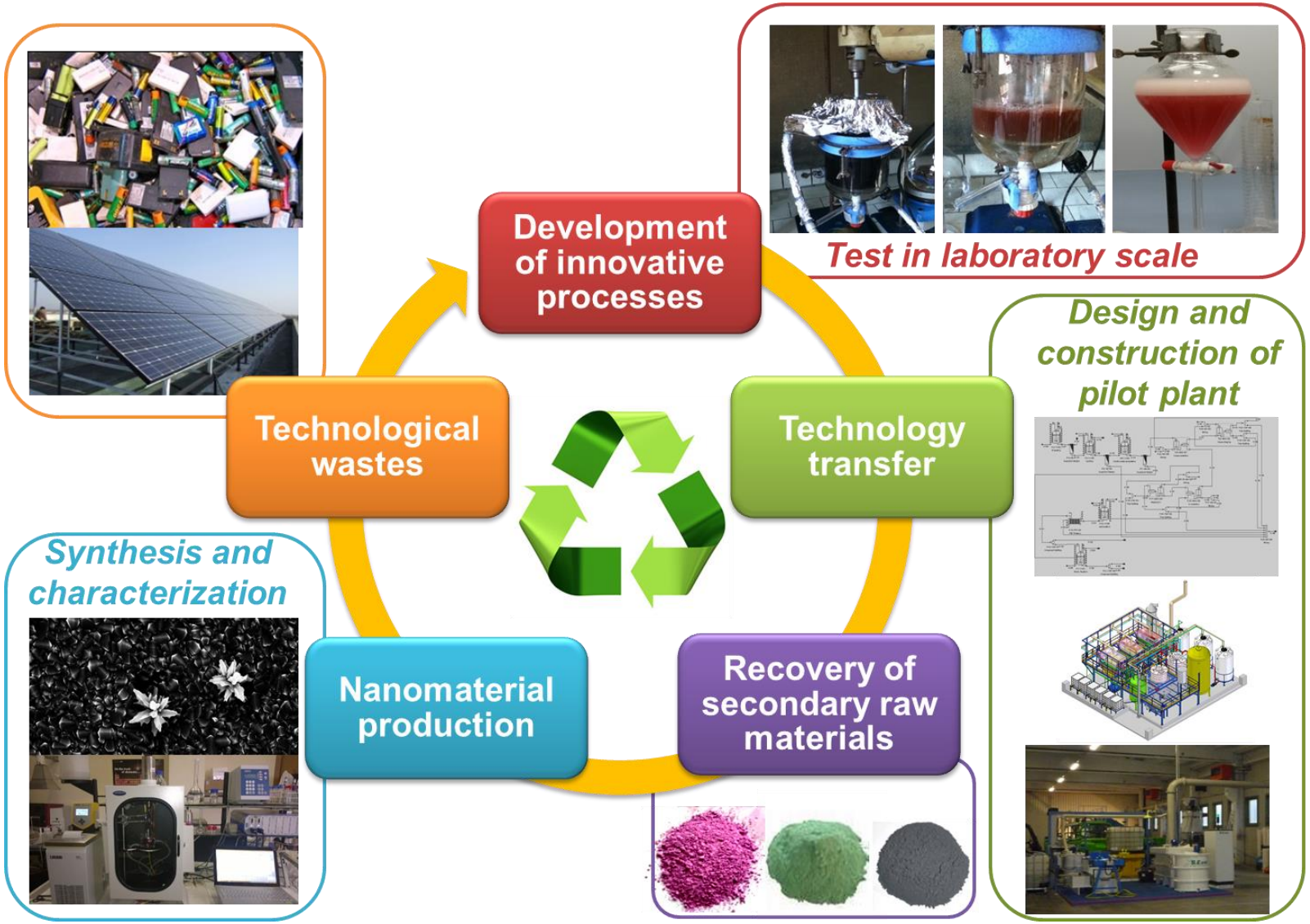
RESEARCH ACTIVITIES

Development of innovative processes for the valorization of by-products and wastes

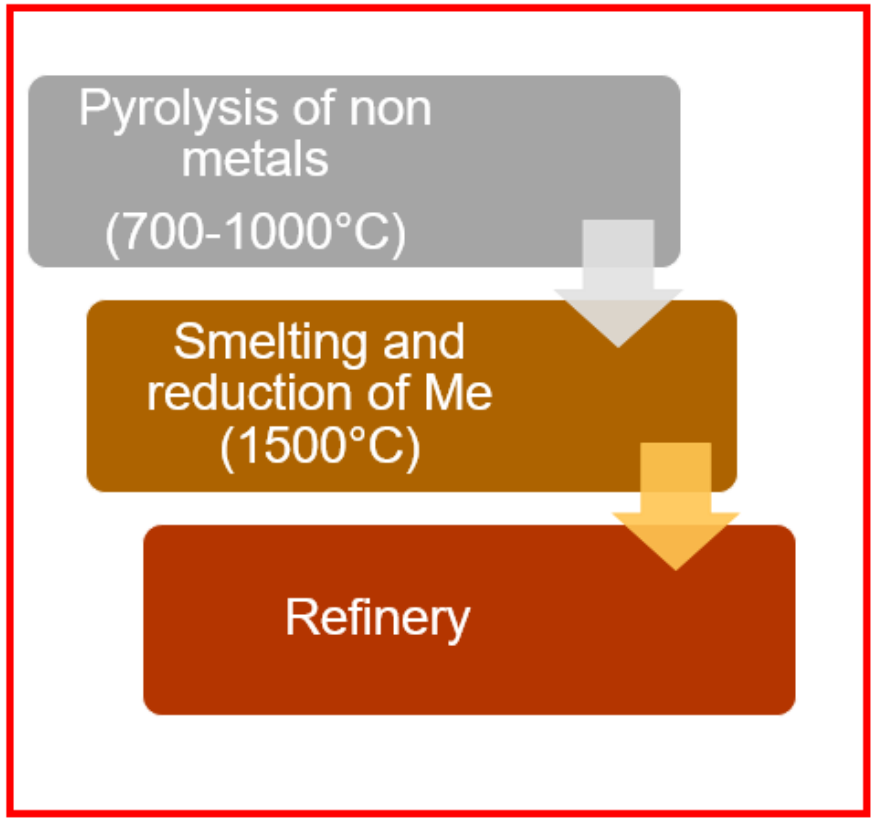
Interdisciplinary research group & Multi-scale approach



Applications
Development of new biosorbents from agro-industrial wastes
Metal abatement by sulphate reducing bacteria
Attenuation of Acid Mine Drainage generation
Microalgal cultivations on agro-industrial wastewaters
E-wastes recycling processes (batteries and PV panels)
Innovative materials from end of life batteries

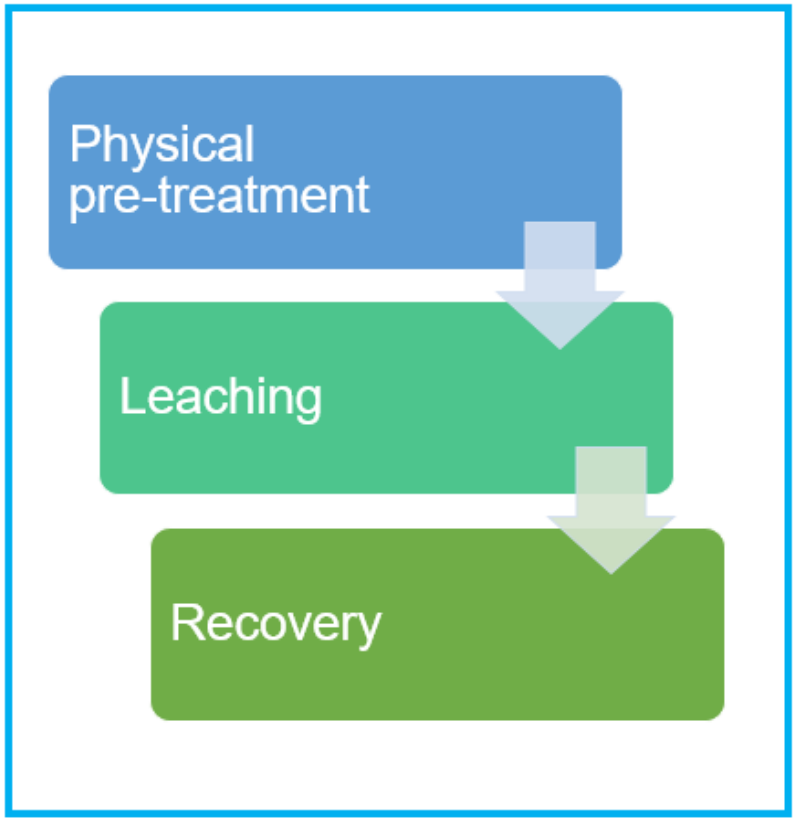
LIB BATTERY RECYCLING: process options

Pyrometallurgical processes



- High energy consumption
- High environmental impacts
- Low recycling rate
- No direct products for battery manufacturing

Hydrometallurgical processes



- Lower energy consumption
- Lower environmental impacts
- Integral recycling of materials
- Direct synthesis of electrodic materials

BATTERY RECYCLING: our history

Alkaline Zn-Mn

Li-ion

NiMeH

Ag(0)

Li(0)

Li-ion

2004 — 2009 — 2012 — 2017 — 2020

MIUR pilot

Hydroweee Project
Mobile pilot (50 kg/batch)

Hydroweee Demo Project
Mobile plant (400 kg/batch)

LIBAT project
pilot (100 kg/day)

DRONE project
pilot (40 kg/day NMC)

4000 ton/y
(SEVal plant)

Revamping (2020)
Crocodile project

CROCODILE

HYDROMETALLURGICAL PROCESSES

I GENERATION — II GENERATION

LIB BATTERY RECYCLING: critical points

Sorting

Liberation

Hydro-metallurgical processes

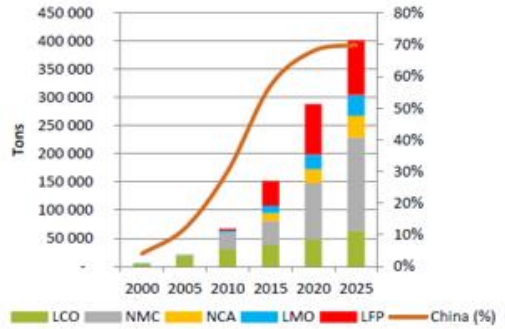
Sorting cannot divide according to LIB chemistry



Flammable solvents & multi-layered structure



Chemical heterogeneity of black mass from EoL LIB



- Cathode raw materials market
  - $LiCoO_2$ (LCO)
  - $LiMn_2O_4$ (LMO)
  - $LiMPO_4$[1] (LFP)
  - $Li[Ni_xMn_yCo_z]O_2$ - NMC
  - $Li[Ni_xCo_yAl_z]O_2$ – NCA

(1) M= Fe or Mn

Addressing LIBERATION

4 pilot scale campaigns dedicated to liberation: 2011, 2015, **2017-2020 (LIBAT)**, and 2020-2024 (DRONE)

Cryo-mechanical section at SEVal

Cryo-mechanical treatment and physical separations for black mass recovery

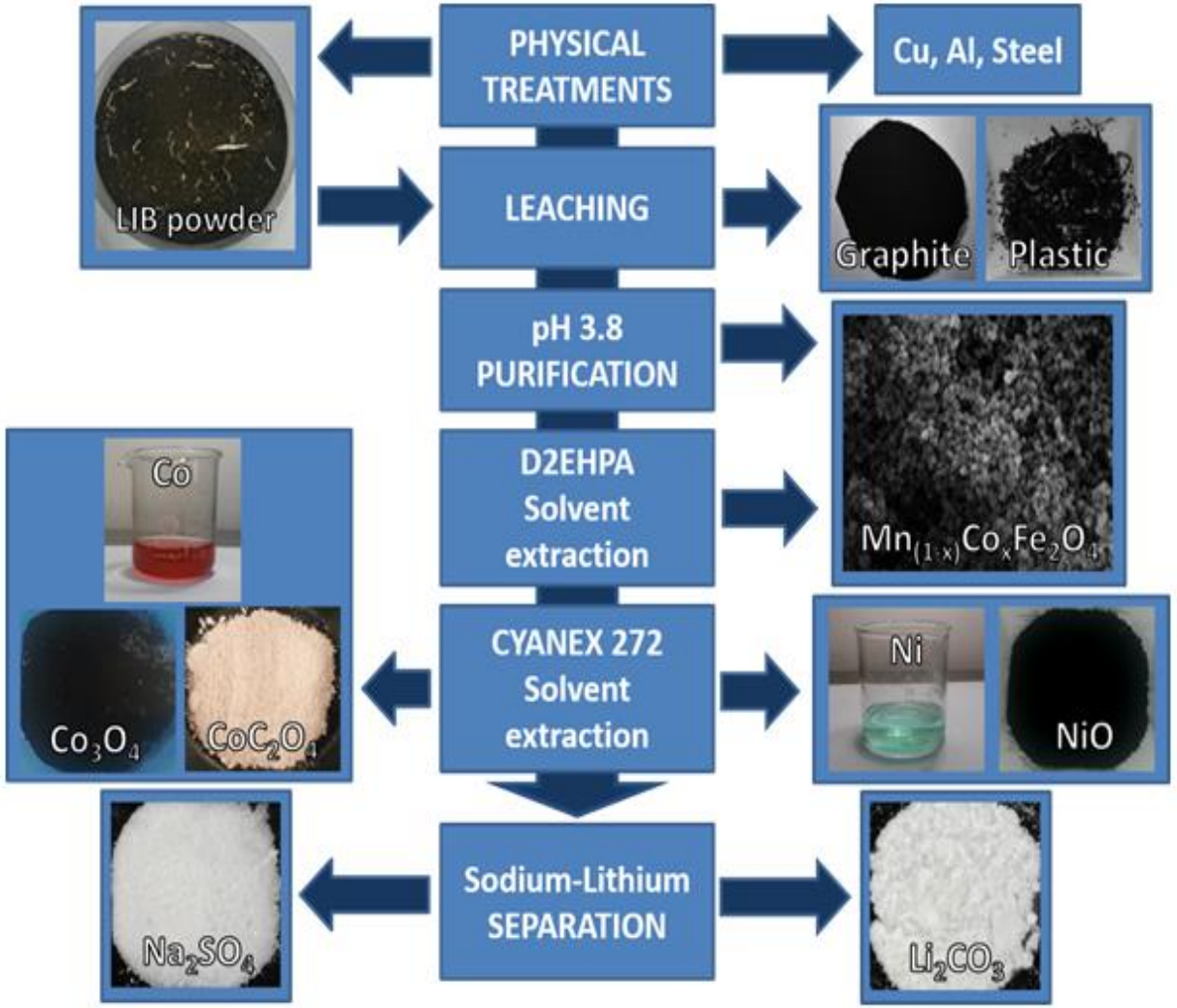
LIFELIBAT project
Recycling of Primary Lithium Battery by mechanical and hydrometallurgical operations

http://www.lifelibat.eu/it

Addressing CHEMICAL HETEROGENEITY

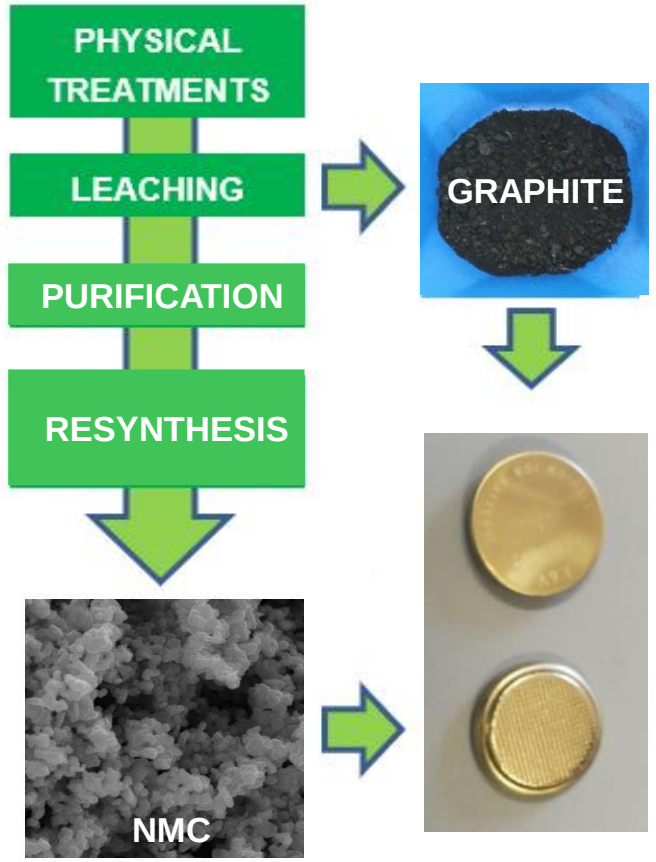
I generation processes

- Sophisticated downstream for metal separation
- Salt and oxides recovery



II generation processes

- Minimization of downstream operations
- Process integration for re-synthesis of electrodes



Answer 1: Re-synthesis on NMC

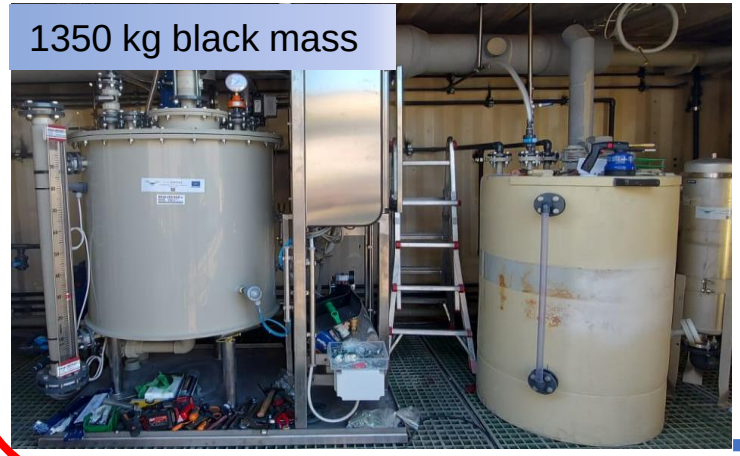
Addressing CHEMICAL HETEROGENEITY: Drone project (2020-2024)

Answer 1: Re-synthesis on NMC

Cryo-mechanical section

Neutralization section

Hydrometallurgical section



DRONE project
Direct pROduction of
New Electrode materials
from battery recycling
https://lifedrone.eu/

NMC precursors

graphite 470 kg recovered

NMC production section

NMC

Addressing CHEMICAL HETEROGENEITY: Drone project (2020-2024)

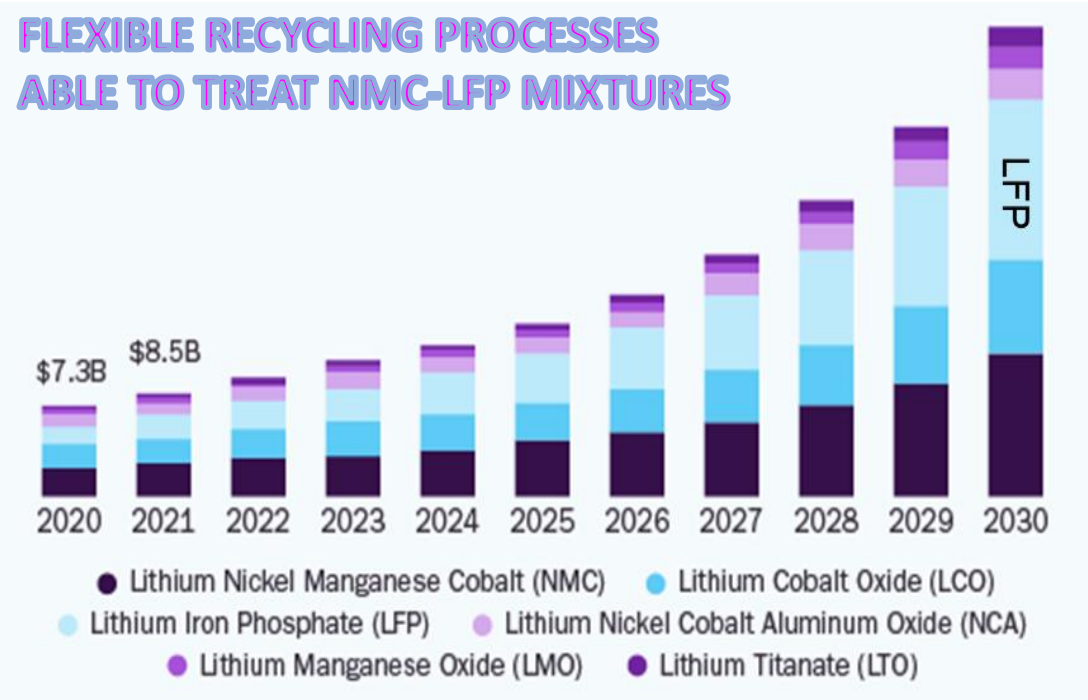
Answer 2: Black mass engineering (LFP for NMC leaching)

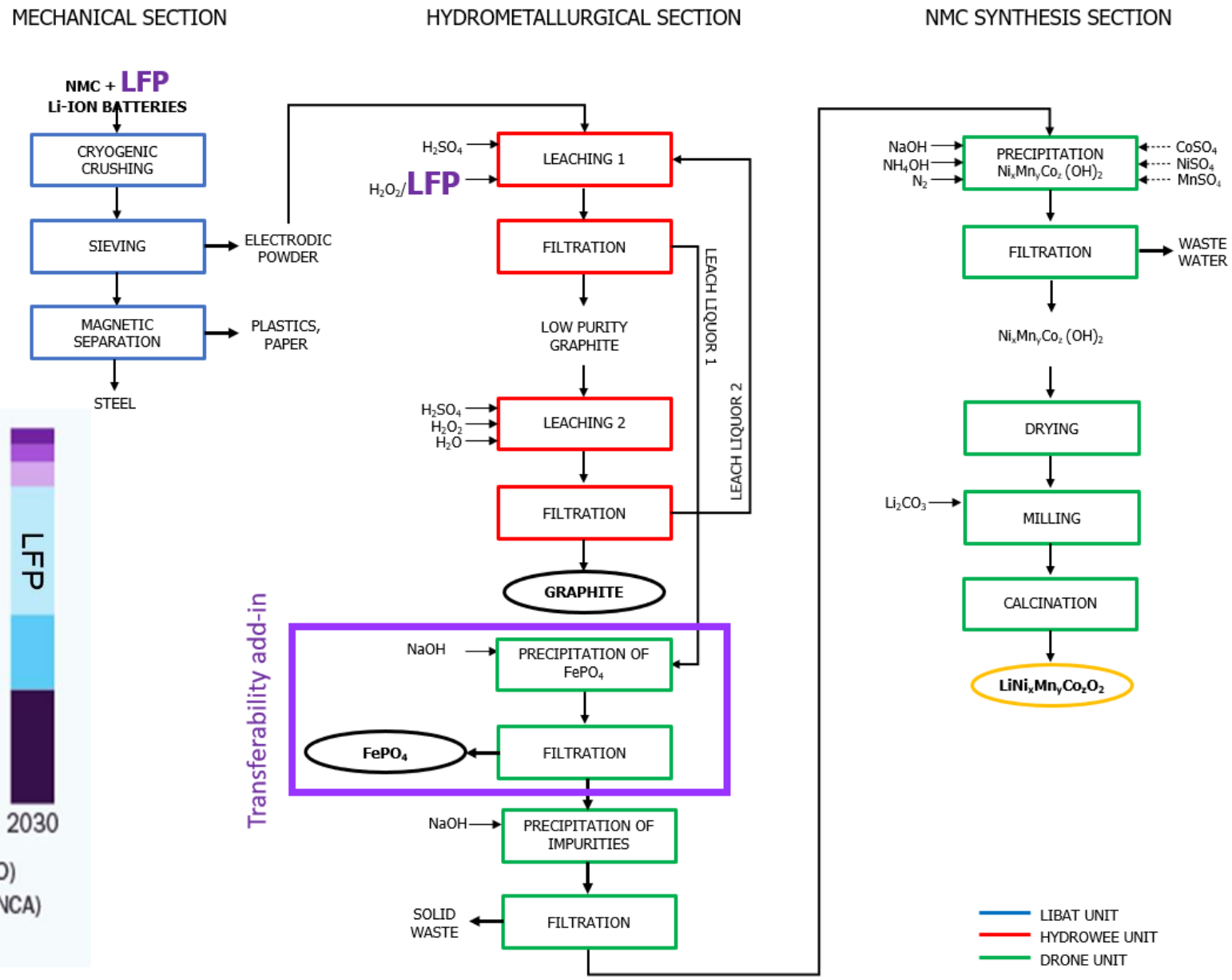
$LiFePO_4$ batteries (LFP)

- Not harmful and costly metals (Co, Ni)
- High thermal stability and safety
  (Also used as blender and coater of NMC)

- Scarce incentive for recycling
- Lower energy density than NMC
  (90–160 Wh/kg vs. 150-220 Wh/kg)

NEED FOR
FLEXIBLE RECYCLING PROCESSES
ABLE TO TREAT NMC-LFP MIXTURES





Thank you for your attention!

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