



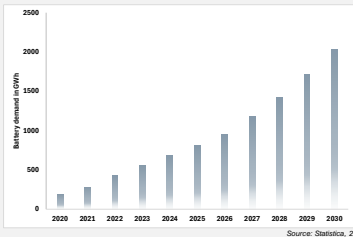
DIRECT CATHODE REGENERATION FOR MORE EFFICIENT SPENT LITHIUM-ION BATTERY RECYCLING

M.F. Gazulla, M. Rodrigo, L. Montañes, J. Gilbert

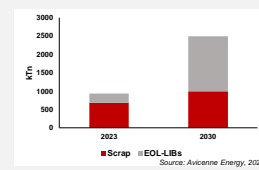
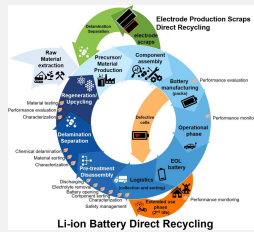
1. BATTERY MARKET FORECAST AND LIB RECYCLING

The total battery market worldwide is forecasted to increase exponentially due mainly to:

- Improvement in existing mobility and energy solutions
- Shift in energy production to renewable energies as an alternative to fossil fuel and nuclear
- Global objective of reaching zero CO₂ emissions



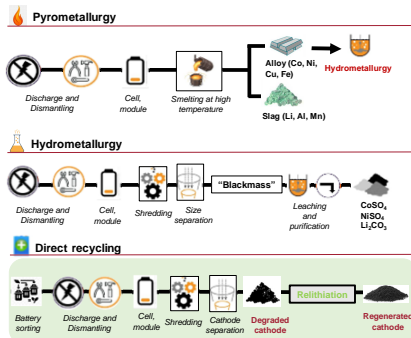
This increase in demand is accompanied by concerns related to the limited availability of natural resources and the waste of end-of-life lithium-ion batteries generated (EOL-LIB). Battery recycling offers a solution to lessen the environmental impact of battery industry and provides a valuable source of critical raw materials. In battery recycling, two different inputs can be distinguished: spent batteries and battery manufacturing scraps, the last referring to the byproducts and waste generated during manufacturing and assembly.



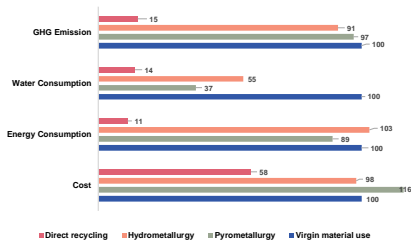
Scrap is the major part of battery recycling nowadays, although this trend will change with the years and the disposal of spent batteries, mainly from electric vehicles.

Direct recycling will play a key role in the recycling of both sources of secondary raw materials for battery manufacturing.

2. RECYCLING TECHNOLOGIES

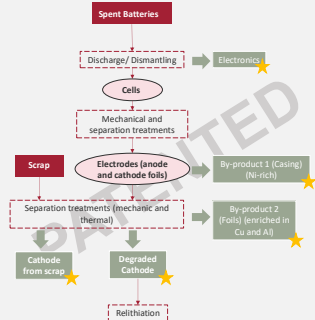


"Direct recycling has the lowest cost and impact on the environment"



3. BATTERY RECYCLING FROM ITC PERSPECTIVE

3.1. Separation of the active cathode material



The separation process is crucial for the subsequent direct recycling.

ITC has designed and developed a separation process that permits the separation of the active cathode material from the rest of the components with little contamination.

It can process EOL batteries and scrap.

Cathode obtained from scrap can be used directly in the manufacturing of new batteries

Cathode recovered from EOL batteries is degraded and must be submitted to a regeneration process to recover the Li lost and the structure.

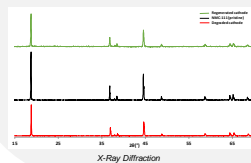
Gazulla, M.F.; Ventura, M.J.; Rodrigo, M.; Ordoña, M.; Andreu, C.; Zumaquero, E. From the spent lithium-ion battery to the ceramic pigment. *I. J. Environ. Waste Manage.*, 33(7), 59, 2024.

3.2. Direct regeneration

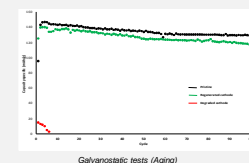
EXPERIMENTAL CONDITIONS

- Chemistry of the spent cathode: NMC 111
- Regeneration process: Hydrothermal

RECOVERY OF THE STRUCTURE



RECOVERY OF THE ELECTROCHEMICAL PROPERTIES



Gazulla, M.F.; Rodrigo, M.; Ventura, M.J.; Mallol, J.G.; Gómez, M.P.; Gilbert, J. Direct Recycling of Lithium-Ion Cathode: A Green Solution (Applied To Laptop Batteries). *J. Electrochem. Soc.*, 170 (8), 080528, 2023.

4. CONCLUSIONS



- Direct recycling is considered the most appropriate recycling method for Li-ion batteries from an economical and environmental perspective
- It brings about a solution for the shortage of critical raw materials
- ITC recycling strategy permits the recovery of all non-volatile components of a Li-ion battery



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