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Assessing Energy Requirement in Spent Lithium-ion Batteries Recycling - A Simple Approach

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Lithium-ion Batteries

Light weight, Compact, and High capacity

Grid storage, Industry, Transportation, and

Consumer electronics

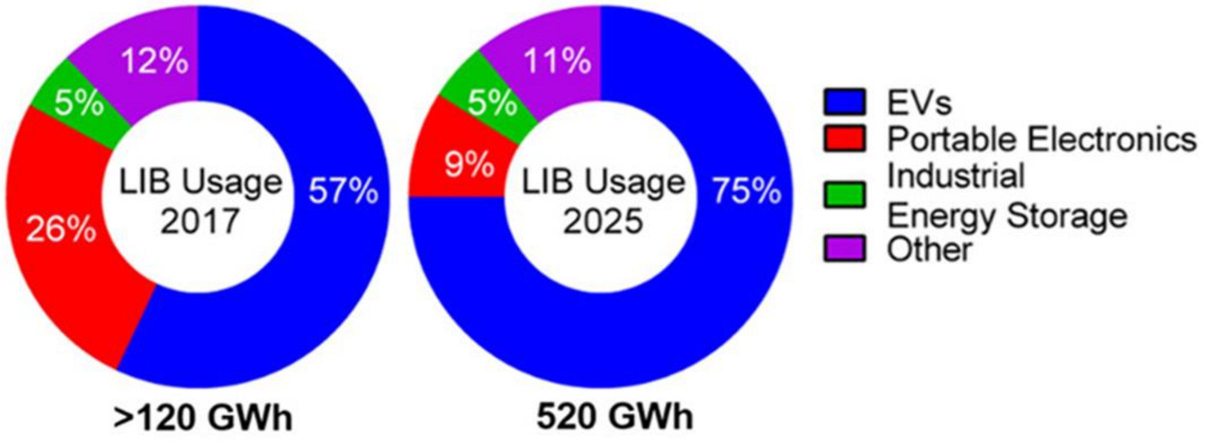


Figure: Projection of LIB market share based on application#

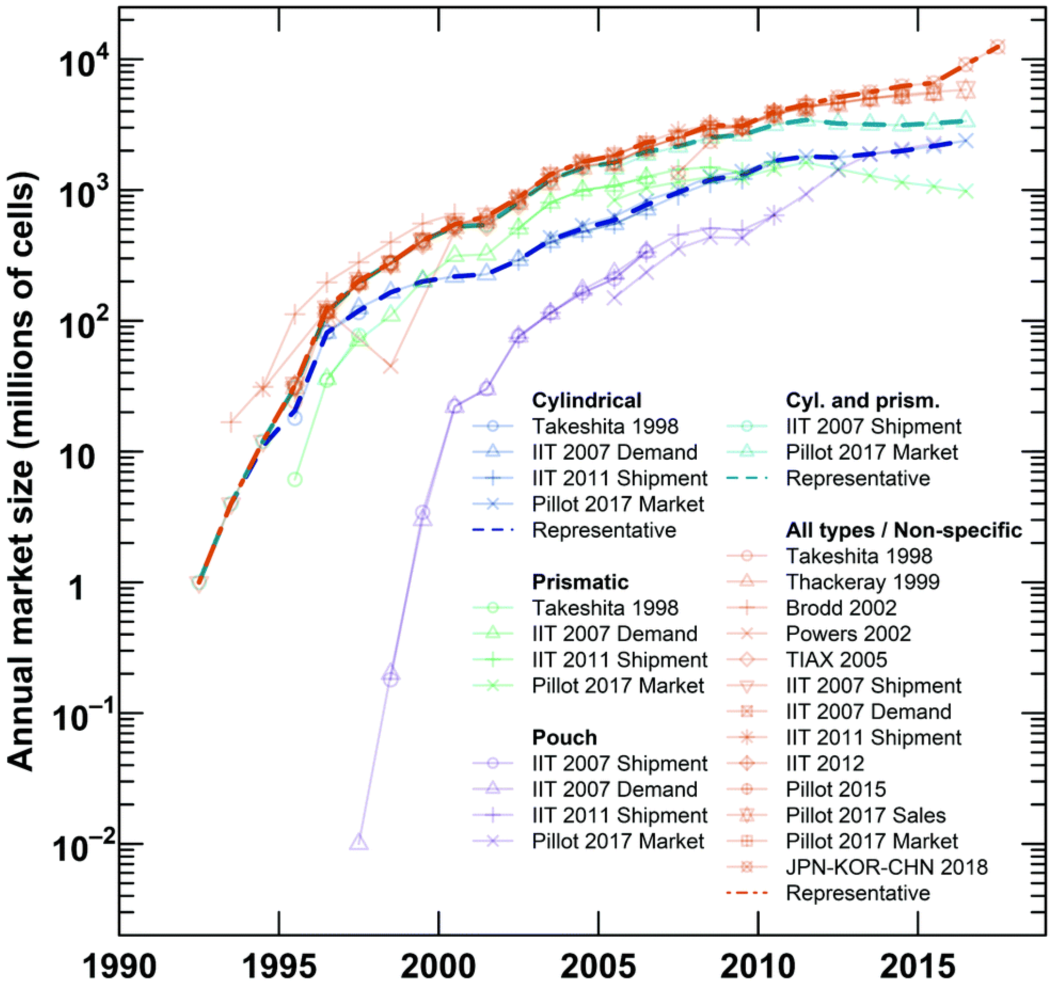


Figure: Lithium-ion market size measured in number of cells (from the year 1994 to 2015)*

* Ziegler, M.S. and Trancik, J.E., 2021. Energy & Environmental Science, 14(4), pp.1635-1651.

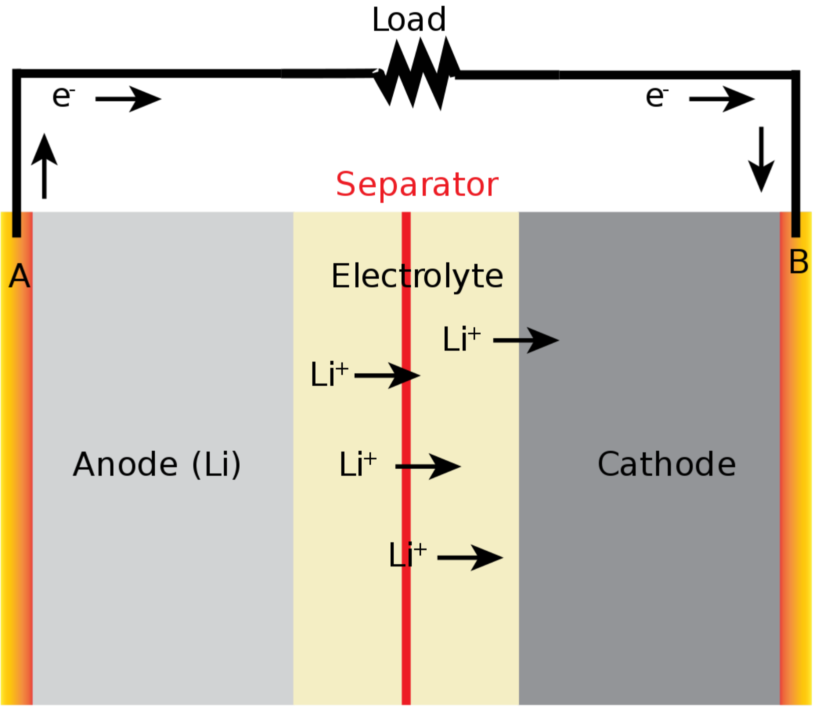
Or, T., Gourley, S.W., Kaliyappan, K., Yu, A. and Chen, Z., 2020. Carbon Energy, 2(1), pp.6-43.

Learnings

How recycling of spent Lithium-ion Batteries is necessary ?

Why assessment of energy during the recycling process is important ?

Types of LIBs: Based on Cathode Chemistry



A/B: Current collectors; negative (A), positive (B)

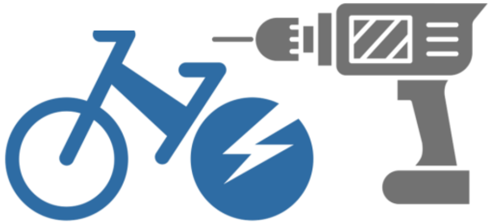
Figure: Schematic of lithium-ion battery*

Laptops and Mobiles

Cathode:

$LiCoO_2$ (LCO)

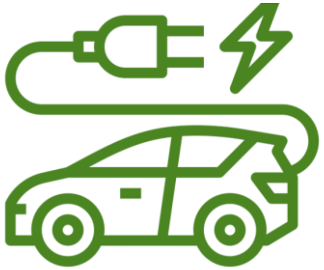
E-Bikes and Power tools



Cathode:

$LiMn_2O_4$ (LMO);
$LiFePO_4$ (LFP)

Electric Vehicles



Cathode:

$LiNi_xMn_yCo_zO_2$ (NMC);
$LiNi_{0.8}Co_{0.15}Al_{0.05}$ (NCA)

* https://commons.wikimedia.org/wiki/File:General_discharging_Li_battery_diagram.svg

Or, T., Gourley, S.W., Kaliyappan, K., Yu, A. and Chen, Z., 2020. Carbon Energy, 2(1), pp.6-43.

Recycling of Spent LIBs

Life of LIBs: usually 3-8 years

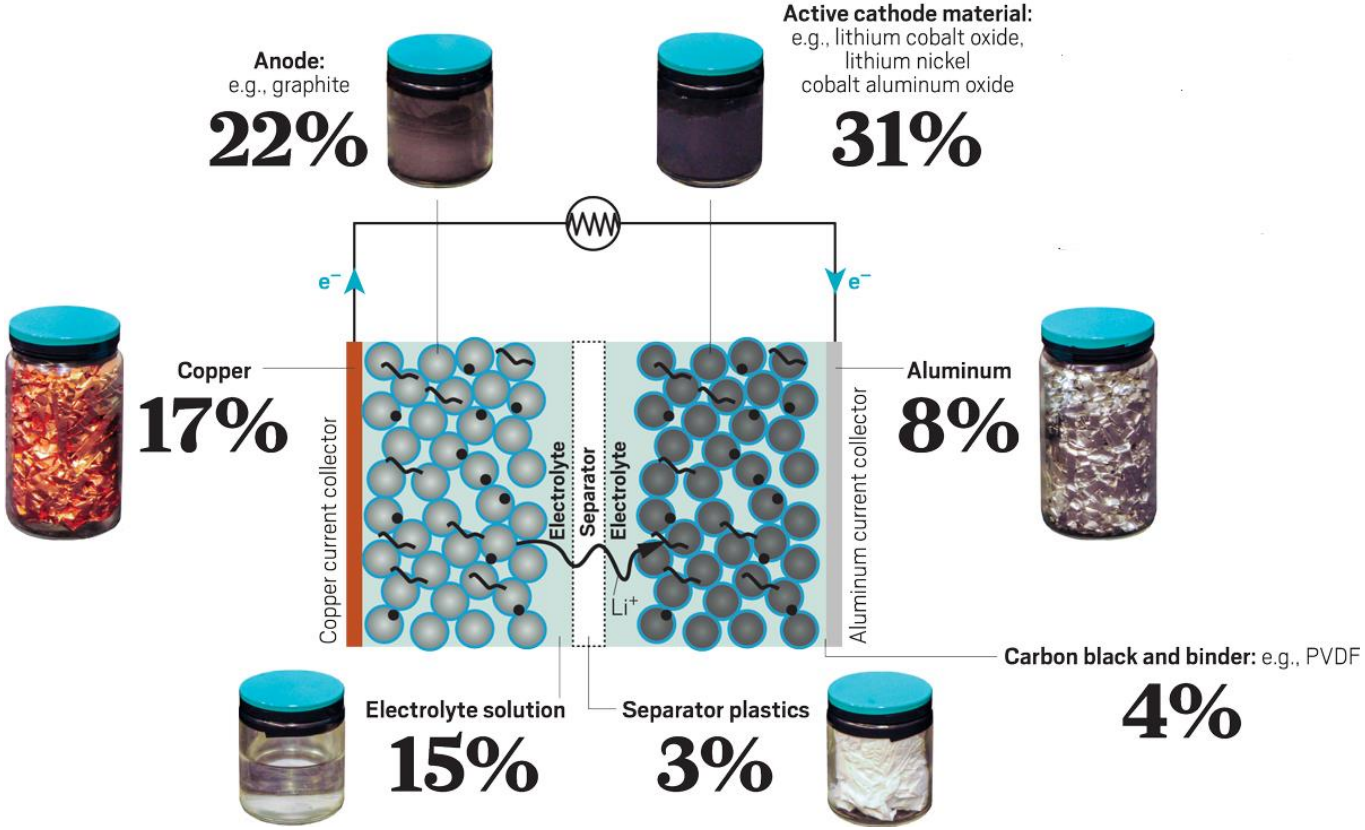


Figure: Recyclable components inside a LIB cell

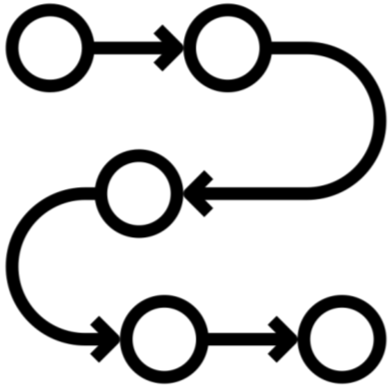
- Valuable components especially Li, Co and Ni
- Environmental issues:
  - Presence of harmful components in LIBs
    - ❖ Toxic organics (electrolyte solution)
    - ❖ Transition metals
    - ❖ Metallic lithium
  - Mining directly from earth:
    - Creates more pollution,
    - Creates more health issue
    - Have high process cost

over recycling

It's time to get serious about recycling lithium-ion batteries, Mitch Jacoby, July 14, 2019, Volume 97, Issue 28

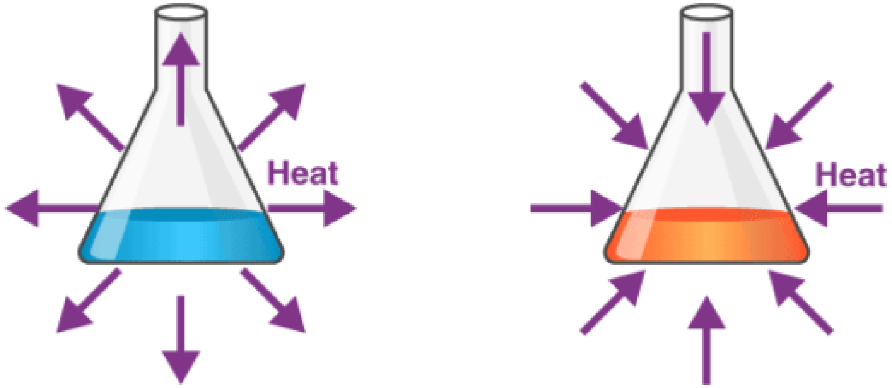
Motivation

Chemical Process

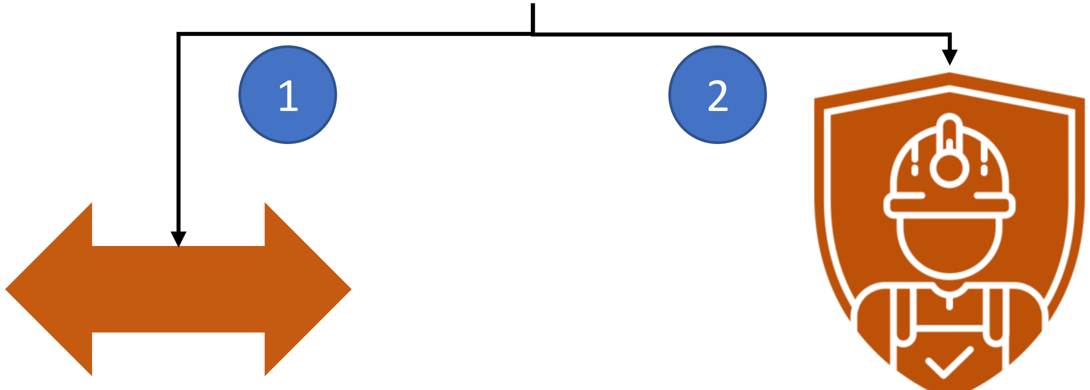


- Material flow
- Energy flow

Enthalpy change of chemical reaction



Temperature control of exothermic/endothermic reactions



Le Chatelier principle

Damage of local reactor sites

Method: Process Selection

Spent LIBs

Disassembled cathode

Cathode foil

Cathode material

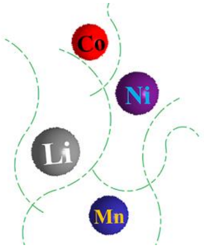
NaOH Soaking (25℃)

Carbothermal reduction (700℃)

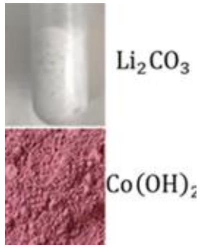
Active cathode material

Leaching solution contains metal-ions

Sulfuric acid leaching (80℃)



Chemical precipitation (pH & T (25℃ & 100℃) changes)



Method: Modelling

Mass balance: Balanced stoichiometric chemical equation

Energy balance: First principle of thermodynamics

Total heat of reaction(Q) = Enthalpy change of the reaction (ΔH)

ΔH = Standard enthalpy of reaction + Sensible heat of reaction + Latent heat

Major assumptions

- Heat of mixing, Pressure dependence on enthalpy, W_s, ΔE_k, ΔE_p all are considered 0.
- Complete conversion
- No kinetic parameters considered
- Solute – solute interactions avoided

Results

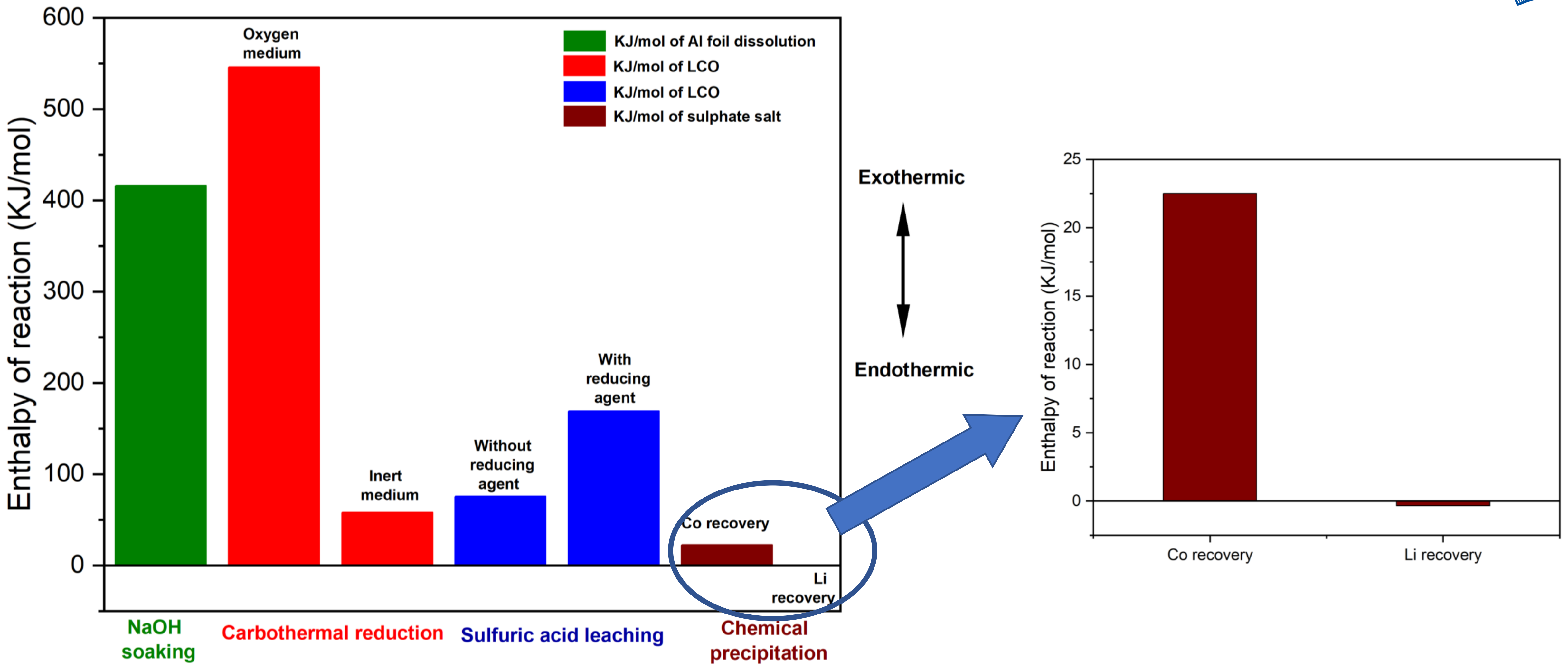


Figure: Enthalpy of reaction at different stages of selected recycling process

Results

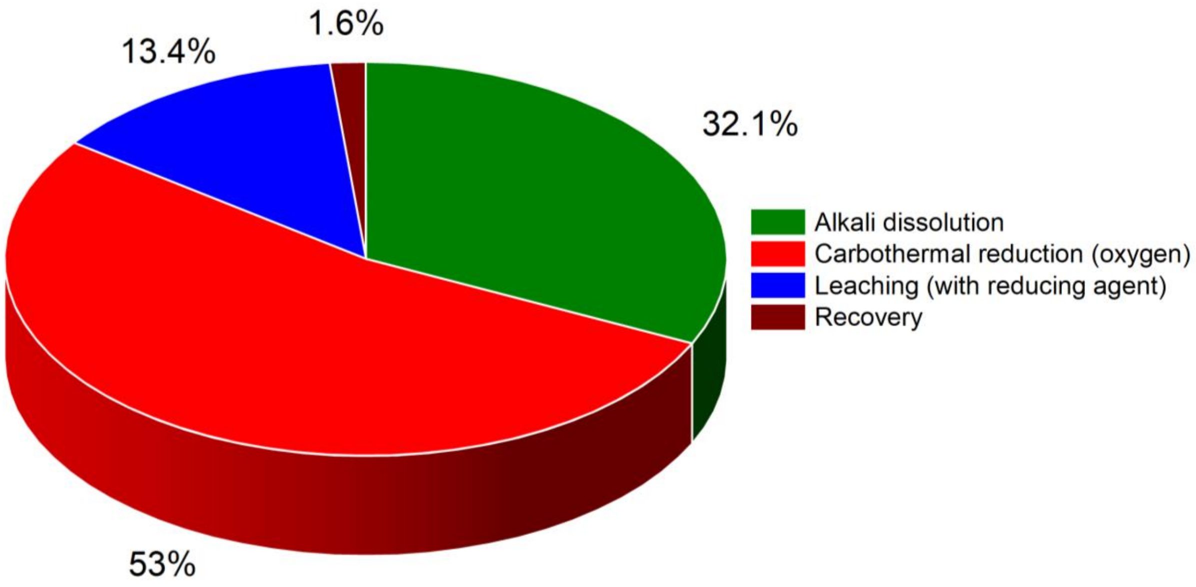


Figure: Released energy distribution (**if carbothermal reduction in presence of oxygen**)

Released energy = 1052.50 KJ per kg of spent LIBs

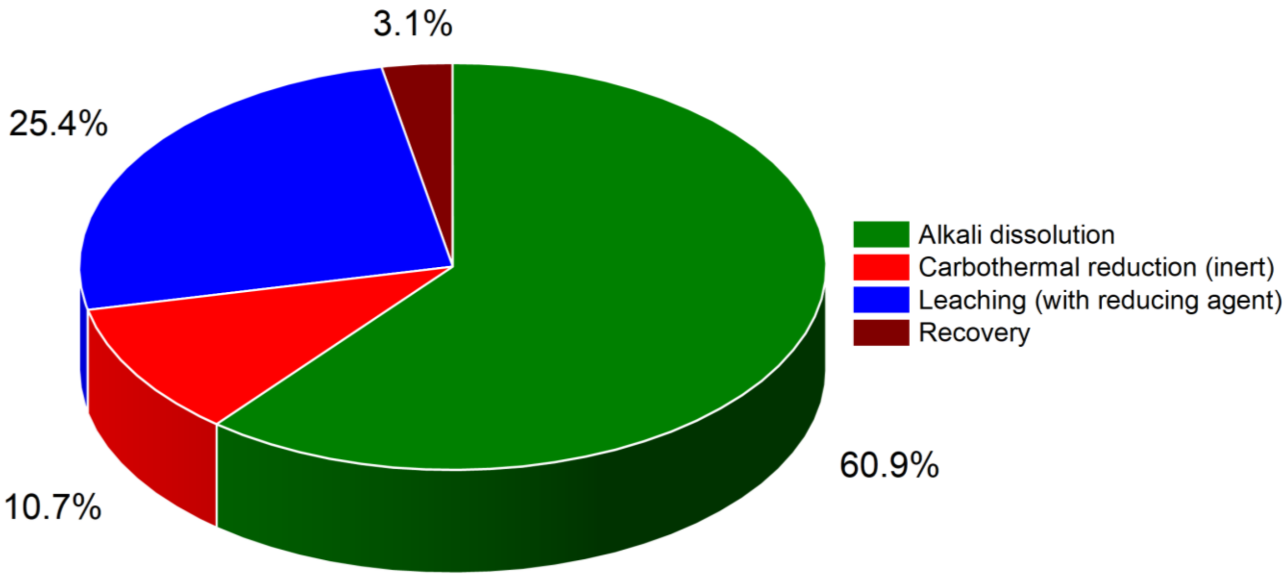


Figure: Released energy distribution (**if carbothermal reduction in inert medium**)

Released energy = 554.37 KJ per kg of spent LIBs

Drawbacks and Future Work

- **Assumed:** 100 % conversion efficiency
- **Ignored:** CoO during the leaching process
- **Not included:** waste leachate after recovery
- **Not included:** energy required to remove harmful gases and non-condensable liquids

Future work

Sulfuric acid leaching is not-eco friendly	Mass and energy balance
☐ Organic acid leaching	☐ NMC cathode

Conclusions

- Stoichiometric mass-energy balance: simpler approach
- Evaluated heat of reaction of chemical reaction
- Helps in process design during larger-scale recycling

Grazie

Thank You

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References

All icons in this presentation is taken from Noun Project:

https://thenounproject.com/