ECU
EDITH COWAN UNIVERSITY

RECYCLE 100

9th INTERNATIONAL SECONDARY LEAD & BATTERY RECYCLING CONFERENCE

Green Solvent-Based Recycling of Lithium from Spent Lithium-ion Batteries

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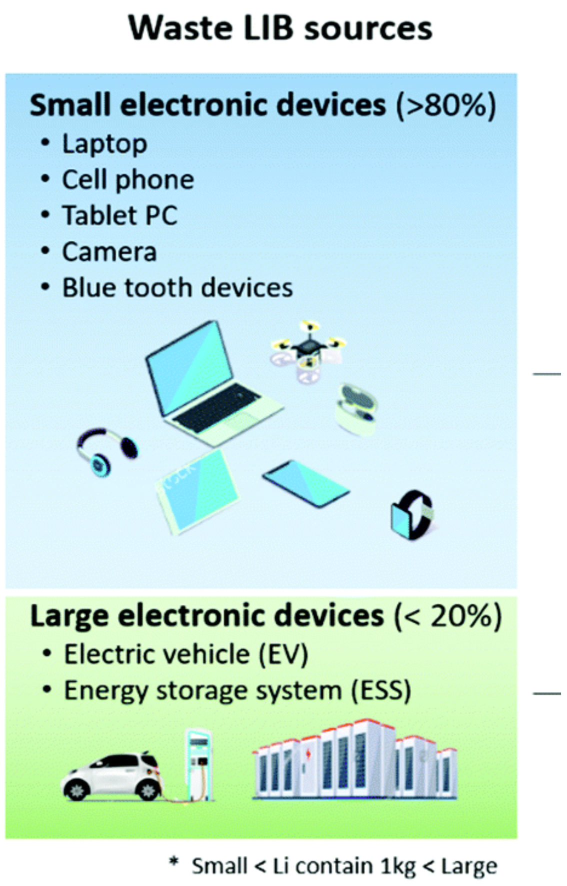
Creative thinkers made here.

Why recycling?

Battery Type		Rechargeable	Key Applications
Lithium-Ion (Li-ion)		Yes	EVs, smartphones, laptops, tablets, power tools, grid storage
Lead-Acid		Yes	Car starter, backup power (UPS), solar, forklifts, telecom
Nickel-Cadmium (NiCd)		Yes	Aviation, medical equipment, power tools, railway signaling
Alkaline		No	Remote controls, clocks, flashlights, toys
Zinc-Air		No (mostly)	Hearing aids, medical devices, experimental EVs

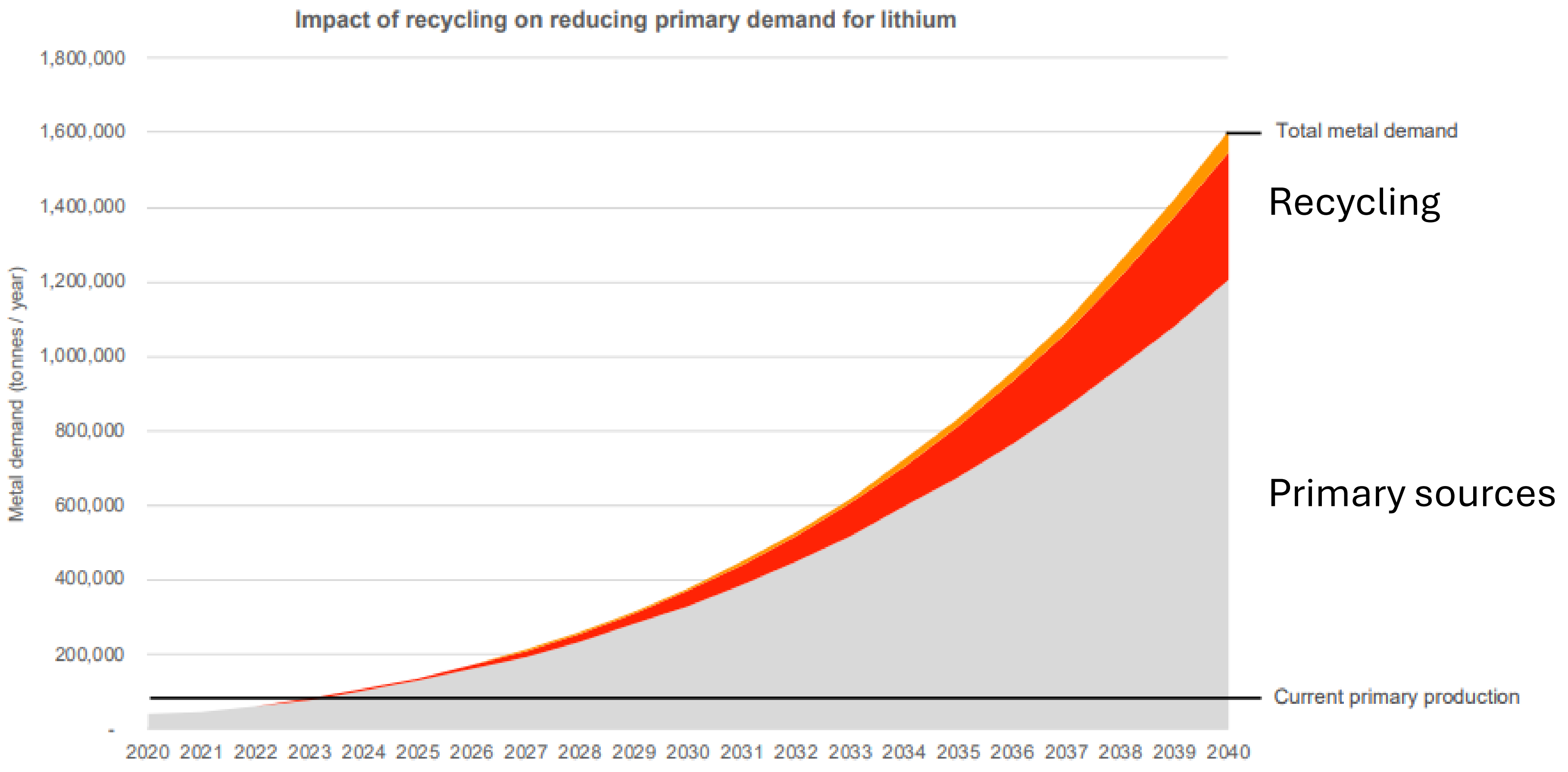
Why recycling?

Current state of waste Lithium batteries



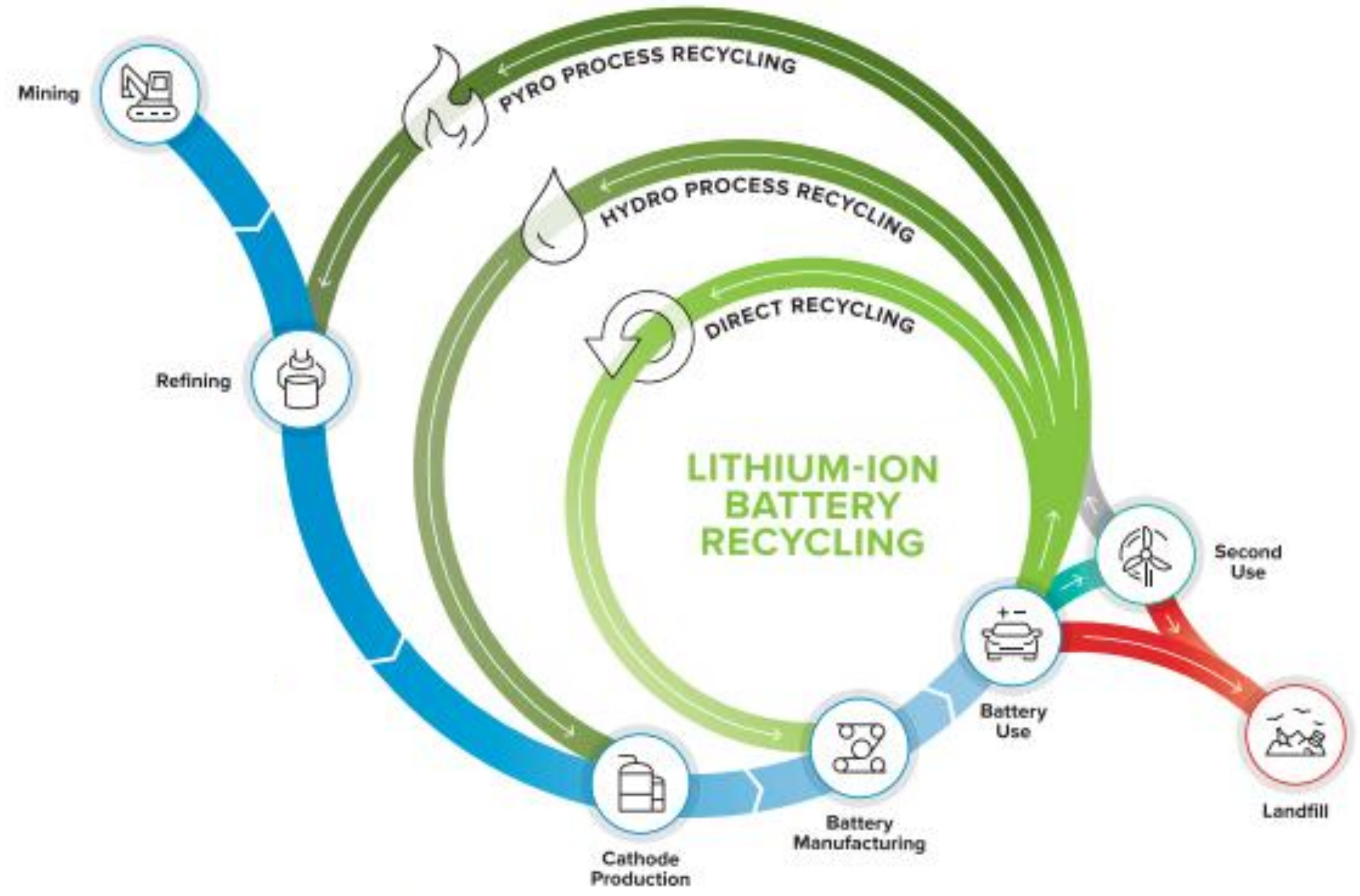
[11]) Zsolt Dobó, Truong Dinh, Tibor Kulcsár,A review on recycling of spent lithium-ion batteries, Energy Reports, https://doi.org/10.1016/j.egyr.2023.05.264

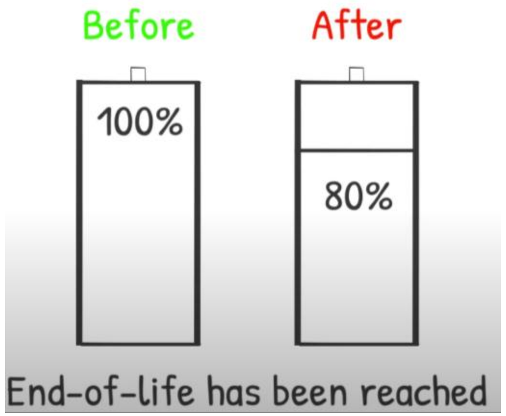
Lithium demands



Dominish et al. (2021). Reducing new mining for electric vehicle battery metals: responsible sourcing through demand reduction strategies and recycling. Institute for Sustainable Futures, University of Technology Sydney.

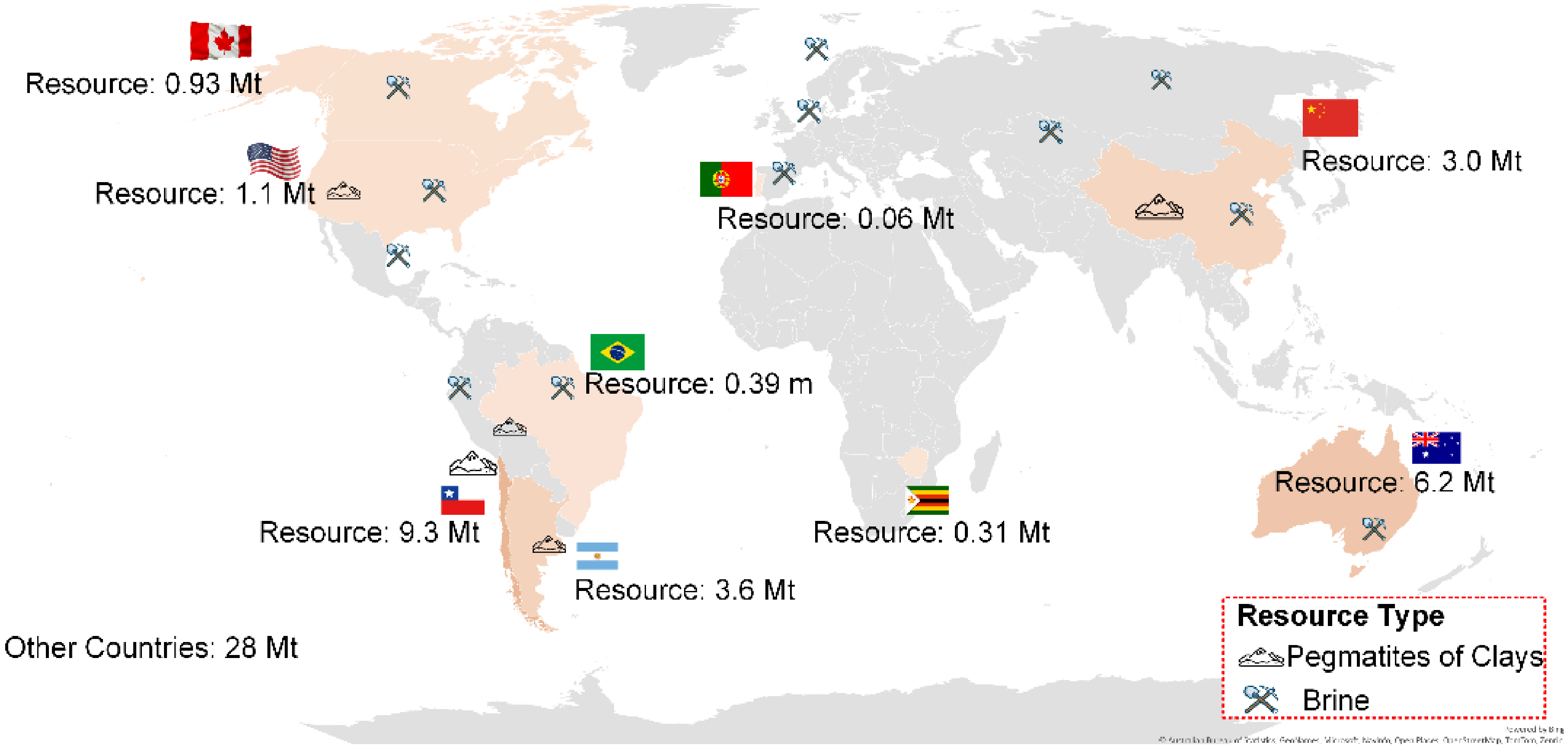
Recycling of LIBs





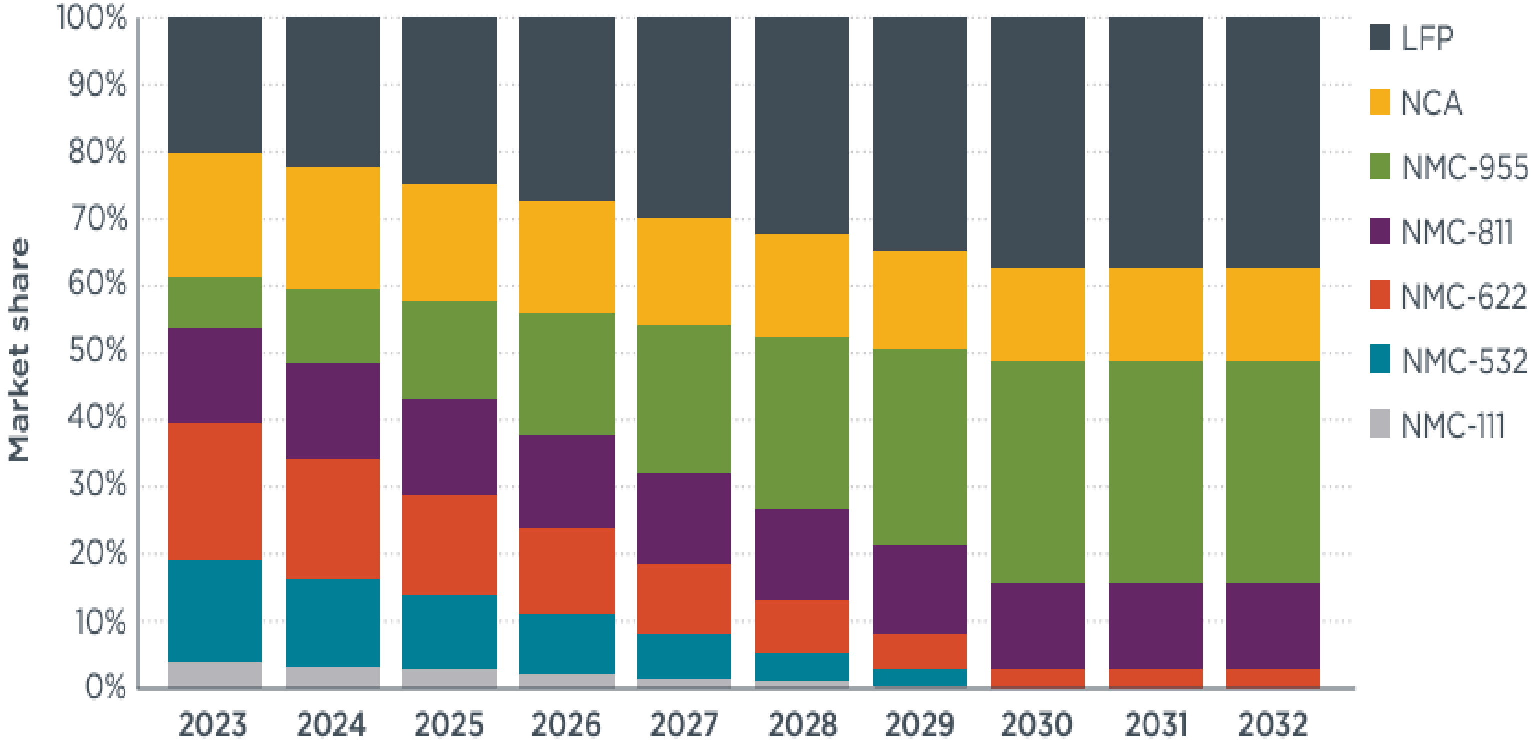
 Argonne national laboratories – ReCell factsheet

The lithium landscape



Ali, A. et al. (2025). A comprehensive review on the recovery of lithium from lithium-ion batteries and spodumene. Journal of Environmental Management

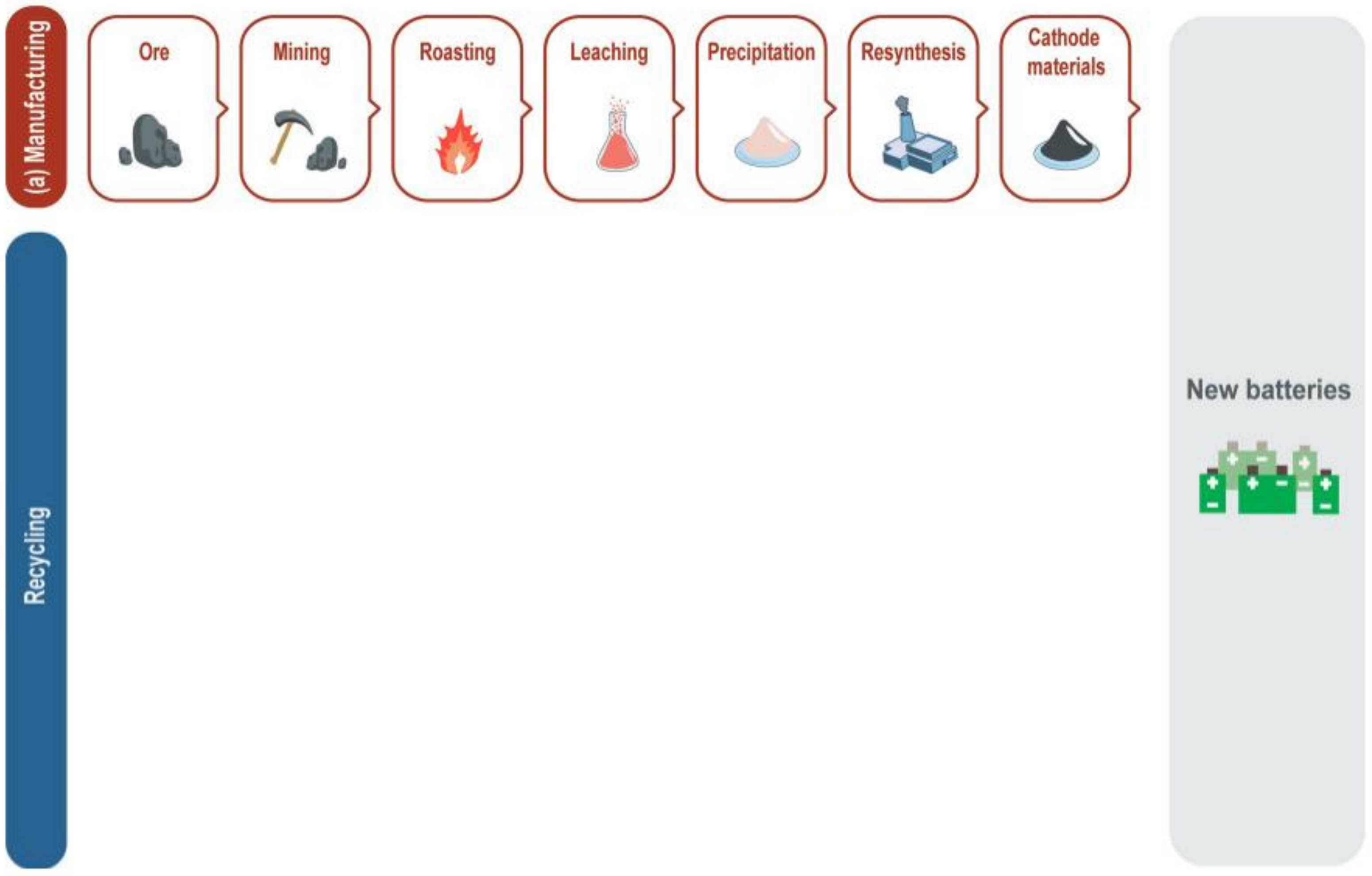
Trends in battery chemistry



Growing demand of LIBs in EVs

Investigating the U.S. battery supply chain and its impact on electric vehicle costs through 2032 - International Council on Clean Transportation (theicct.org)

Mining vs recycling strategies



X. Yu, et al., Current Challenges in Efficient Lithium-Ion Batteries' Recycling: A Perspective. Global Challenges 2022

Recycling companies

Process name	Feed/Input	Capacity (tonnes/year)	Processing route	Output to battery industry	Output to other industries	Quality of recovered metal
Established LIB recycling processes						
Retriev	LIBs	4500	Mechanical pre-processing / Hydro	metal oxides (incl. CoO)	lithium carbonate (Li_2CO_3), steel, copper, aluminium, cobalt	*Recycling* – cobalt *Downcycling* – lithium, nickel, copper
Sumitomo-Sony ('sony process')	LIBs	150	Pyro / Hydro	cobalt (CoO)	cobalt-nickel-iron alloy, copper, aluminium, iron	*Recycling* – cobalt (processing required) *Downcycling* – nickel, copper *Not recovered* – lithium
SungEel HiTech	LIBs	8000	Mechanical pre-processing / Hydro	lithium salts (Li_2PO_4), cobalt (CoO), nickel, manganese	steel, copper, aluminium	*Recycling* – cobalt, lithium, nickel *Downcycling* – copper
Recupyl process	LIBs	110	Mechanical pre-processing / Hydro	lithium salts (Li_2CO_3, $LiCO_2$,Li_2PO_4, LCO/$Co(OH)_2$/Co)	steel, copper, aluminium, metal oxides (incl. nickel), carbon	*Recycling* – cobalt, lithium *Downcycling* – nickel, copper
Umicore process	LIBs (and NiMH bat.)	7000	Pyro / Hydro	cobalt (CoCl2), nickel, copper, iron	Slag containing aluminium, silicon, calcium, iron, lithium, manganese, rare earth elements	*Recycling* – cobalt (ready for $LiCoO_2$ synth.), nickel, copper *Not recovered* – lithium
GEM High-Tech	LIBs	10000	Mechanical pre-processing / Hydro	No data	No data	*Recycling* – cobalt, nickel[60]
BRUNP	LIBs	25000	Mechanical pre-processing / Hydro	No data	No data	*Recycling* – cobalt, nickel[61]
Akkuser process	LIBS	4000	Mechanical pre-processing	Pre-processing only	cobalt, carbon, copper, iron	*Recycling* – further processing required through hydromet process

Dominish et al. (2021). Reducing new mining for electric vehicle battery metals: responsible sourcing through demand reduction strategies and recycling. Institute for Sustainable Futures, University of Technology Sydney.

Primary sources vs recycling

Process	Advantages	Disadvantages	Cost	Technological Feasibility	Energy Consumption	GHG Emissions	Water Consumption	Pollutants Generation
Brine Extraction	Lower energy requirement; Low-cost extraction; Abundant in South America (e.g., Salar de Atacama)	Long evaporation time; Vulnerable to climate; Low lithium recovery efficiency	Low to moderate	Mature (but region-specific feasibility)	30,000-36000 MJ/tonne Li_2CO_3	2.7-3.1 tonne CO_2/tonne Li_2CO_3	Very high (~31-50 m^3/tonne Li_2CO_3	Brine depletion; ecosystem disruption
Hard Rock (Spodumene)	High lithium content (~1–2%); Shorter processing time; Less climate dependent	High energy use for calcination; More costly than brine; Mining impacts	High (mining + thermal processing)	Mature (used globally, e.g., Australia)	218,000MJ/tonne Li_2CO_3	20.4 tonne CO_2e/tonne spodumene	High (~77 m^3 tonne Li_2CO_3)	Tailings, dust, chemical residues
Pyrometallurgy	Simple and scalable; Can treat mixed batteries; Existing infrastructure	High energy demand: Lithium lost in slag; Toxic gas and slag production	High	Mature (commercially applied)	110 MJ/kg battery (CED)	8.81 kg CO_2-eq/kg (GWP)	Low	SOx, NOx, CO_2, hazardous slag
Hydrometallurgy	High recovery (Li,Co,Ni); Lower energy and GHGs; Selective extraction possible	Requires chemical reagents; Generates wastewater; Multi-step process	Moderate (reagent-dependent)	Mature (lab to industrial scale)	66.87 MJ/kg battery (CED)	3.04 kg CO_2-eq/kg (GWP)	Moderate	Acidic effluent, heavy metal contamination

Note: GWP: Global warming potential, CED: Cumulative energy demand

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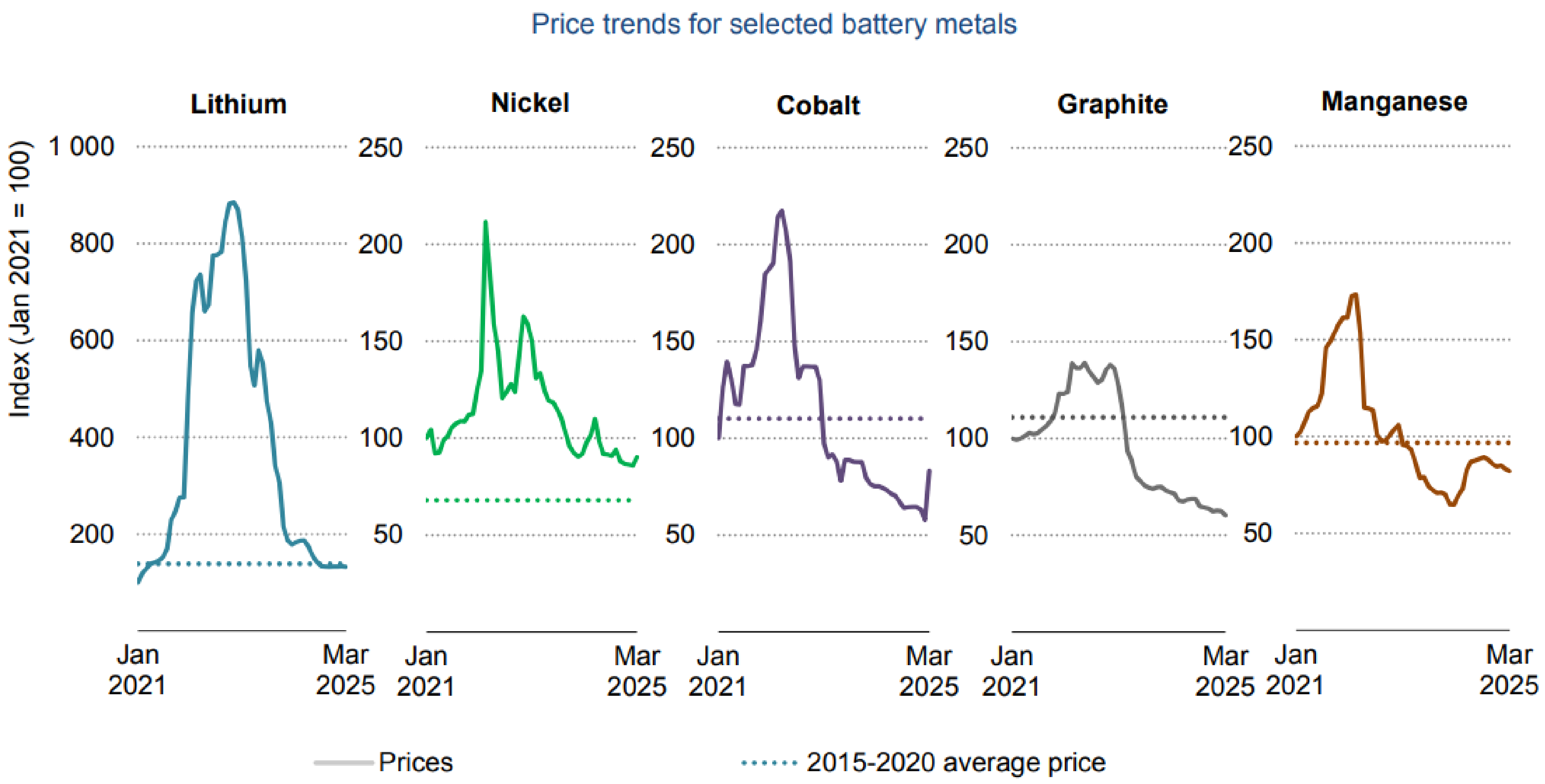
Price development

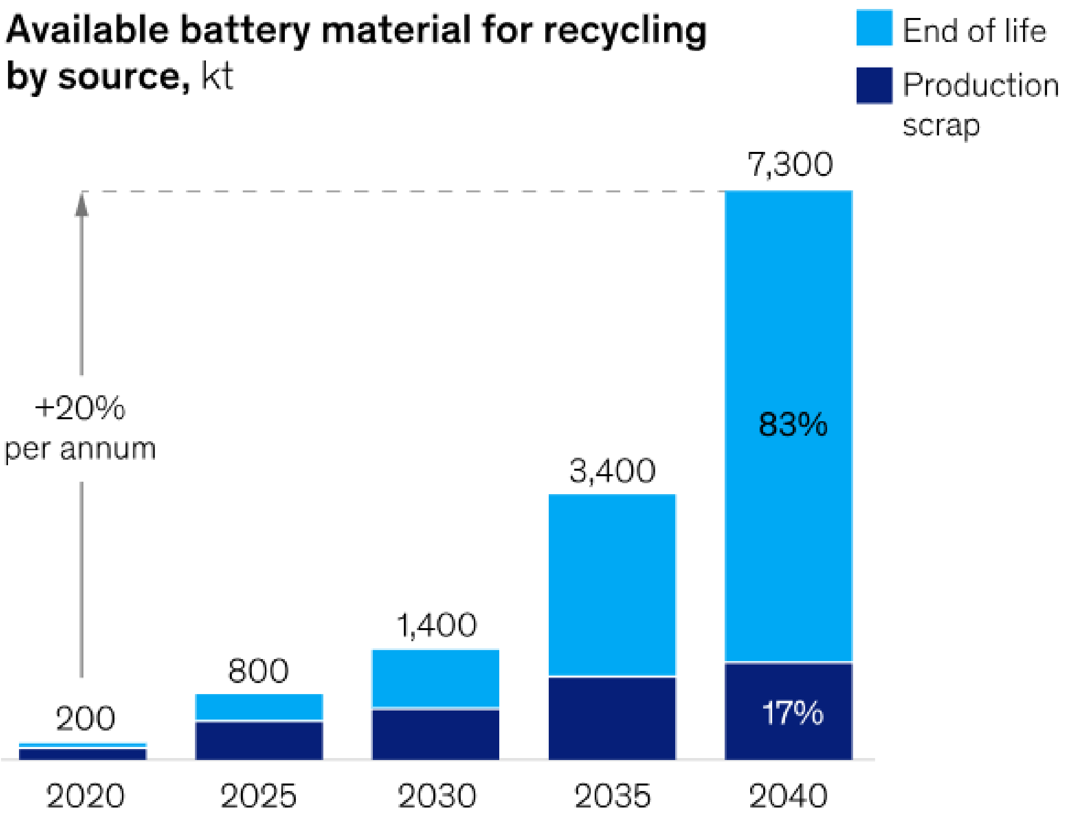
Prices for battery metals continued to decline in 2024 amid growing supply, with the exception of manganese



 IEA: Global Critical Minerals Outlook 2025

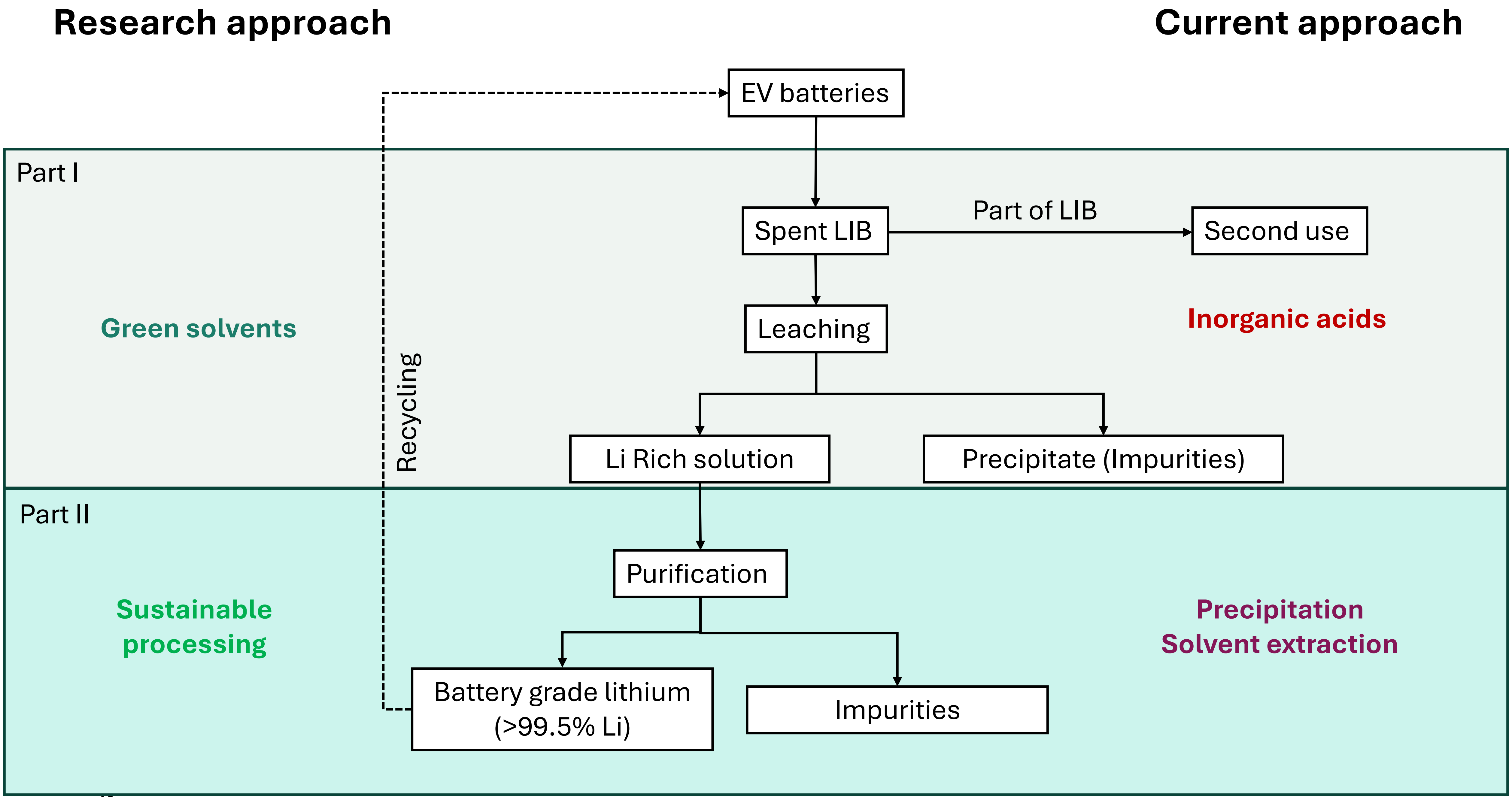
Recycling cost

USD



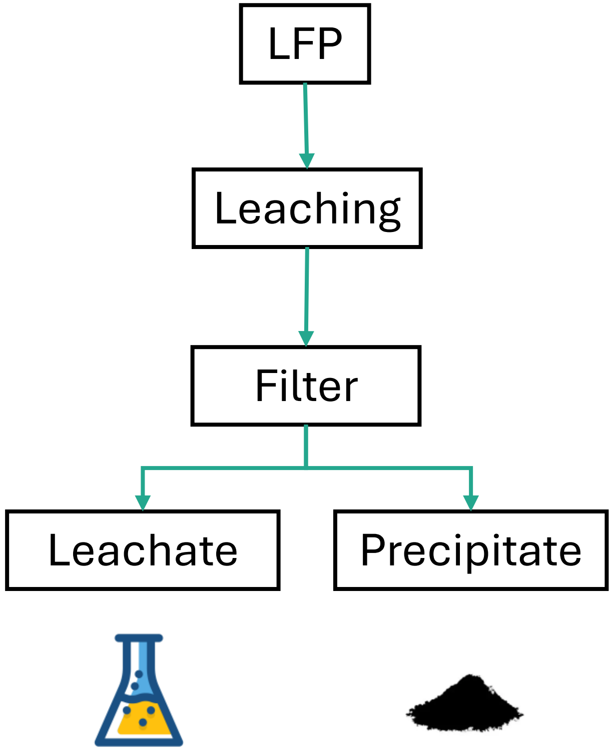
[1]Values represent an average across all battery types.

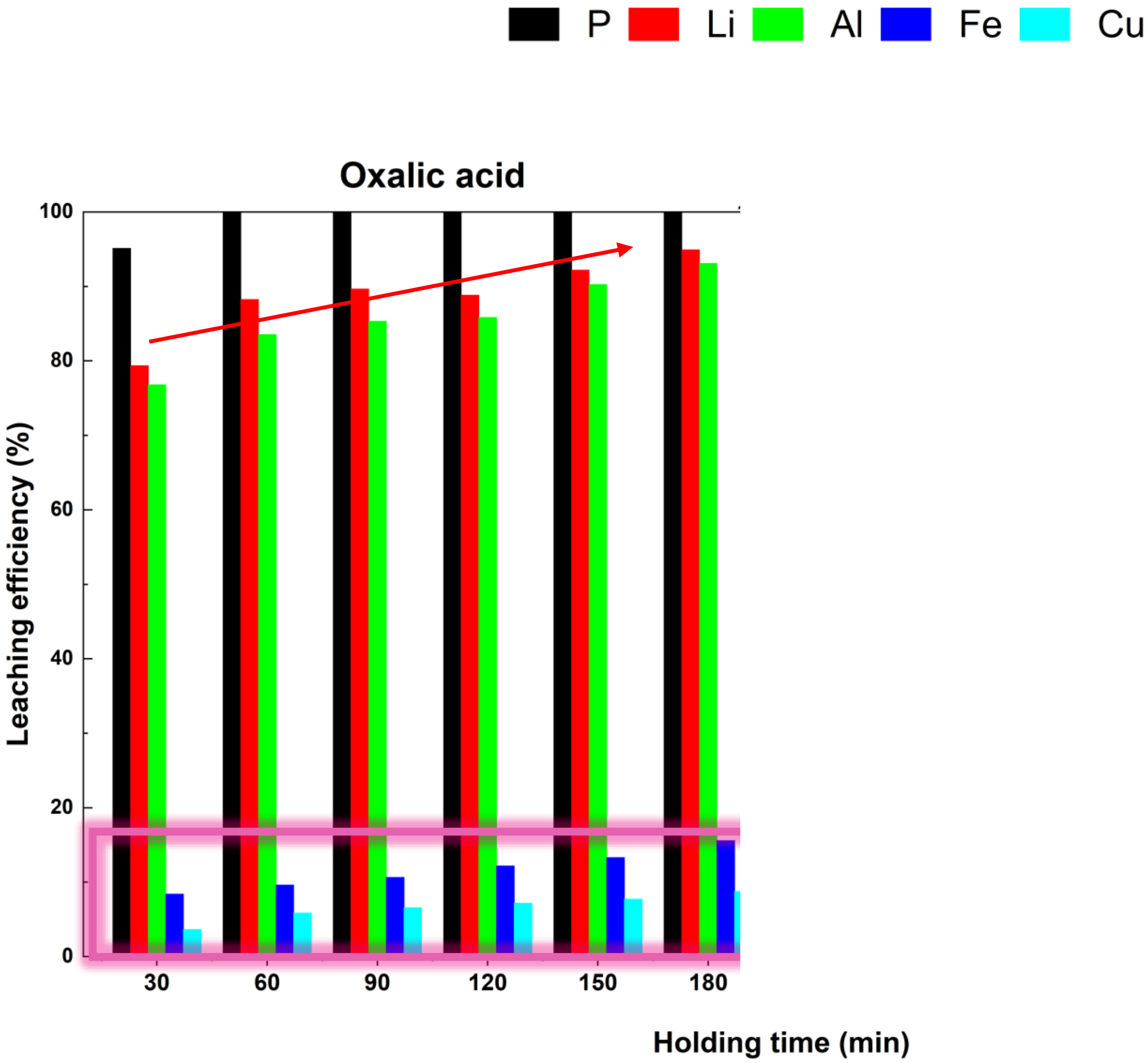
McKinsey & Company: Battery 2030: Resilient, sustainable, and circular



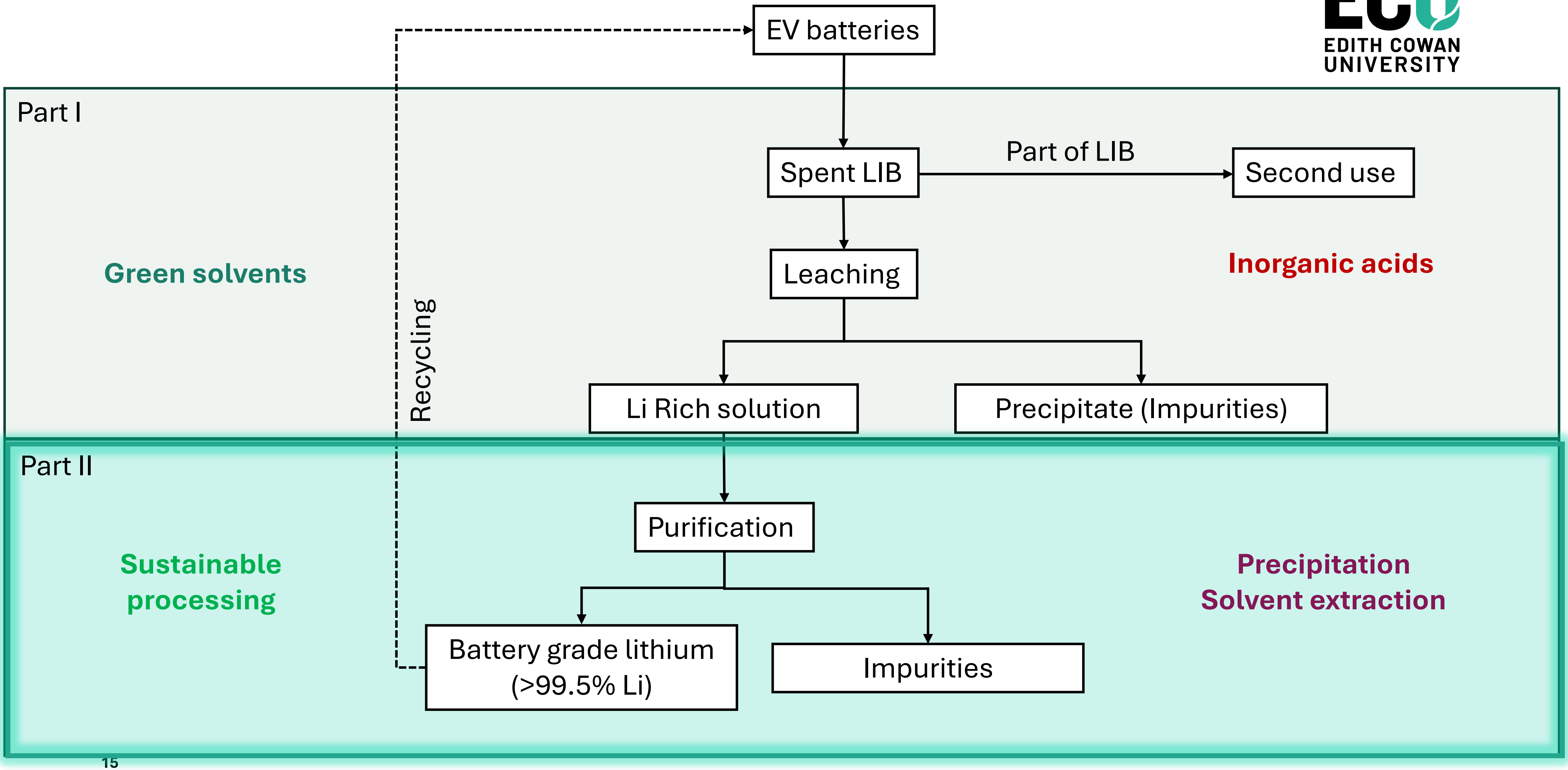
Research approach
Current approach
EV batteries
Part I
Spent LIB
Part of LIB
Second use
Green solvents
Leaching
Inorganic acids
Recycling
Li Rich solution
Precipitate (Impurities)
Part II
Purification
Sustainable processing
Precipitation
Solvent extraction
Battery grade lithium (>99.5% Li)
Impurities

Organic acid leaching





Research approach **Current approach**



Recycling: Key to sustainable energy transition

Future Perspectives

Encourage users to recycle instead of discarding batteries

Provide clear regulations and guidelines for recyclers, and engage the public in the recycling journey

Design batteries that are easy to disassemble and made with less toxic materials and green technologies

Adopt green recycling methods that are safe for both people and the environment

Du, K., Ang, E.H., Wu, X. and Liu, Y. (2022), Progresses in Sustainable Recycling Technology of Spent Lithium-Ion Batteries. Energy Environ. Mater., 5: 1012-1036

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Thank you

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