Battery Recycling as an Enabler for Sustainability and Security of Supply

Assoc. Prof. Dr. Eva Gerold
Christian Doppler Laboratory for Advanced Recycling of Lithium-Ion Batteries
Chair of Nonferrous Metallurgy, Montanuniversität Leoben

A3PS Eco-Mobility 2026 · 12 November 2026

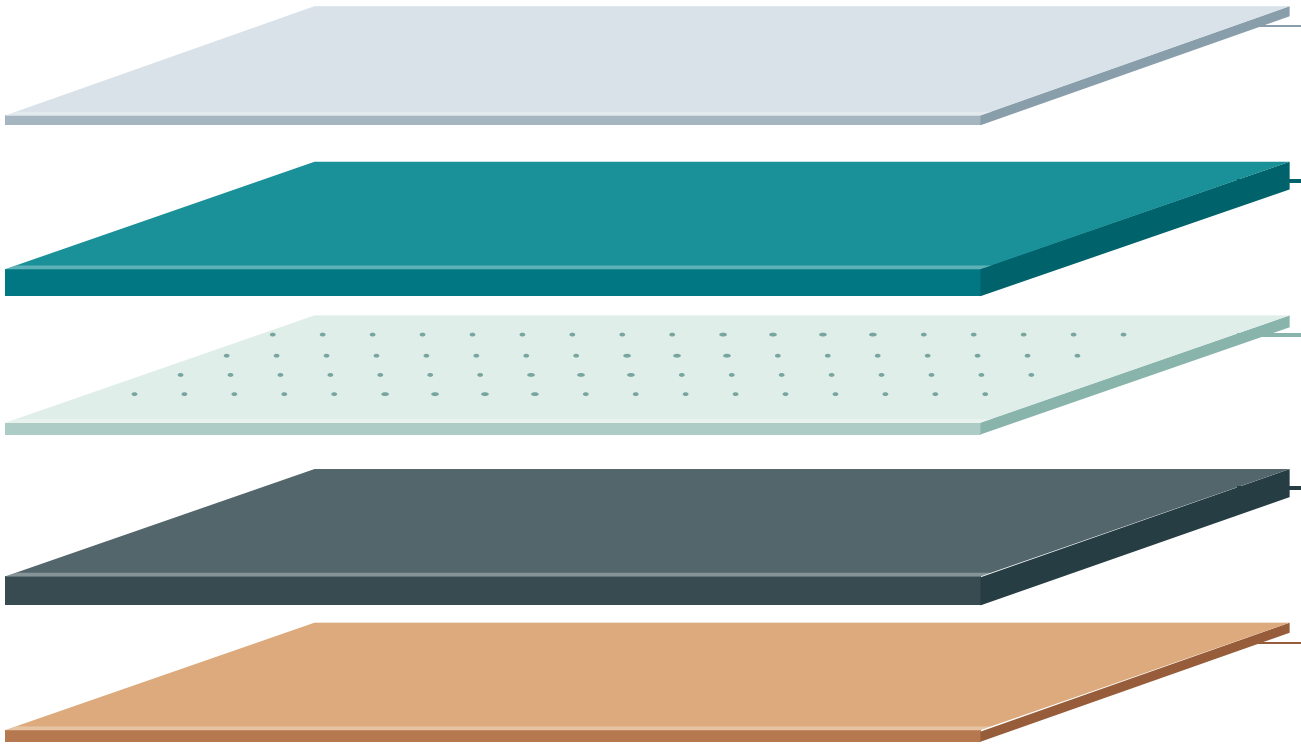
When does a used battery become a raw material?



Used battery module **Black mass and metal fractions** **Recovered materials**

Sustainability Lower environmental impacts **Security of supply** Qualified secondary materials

What is inside a lithium-ion cell?



Aluminium foil
Cathode current collector

Cathode coating
NMC or LFP

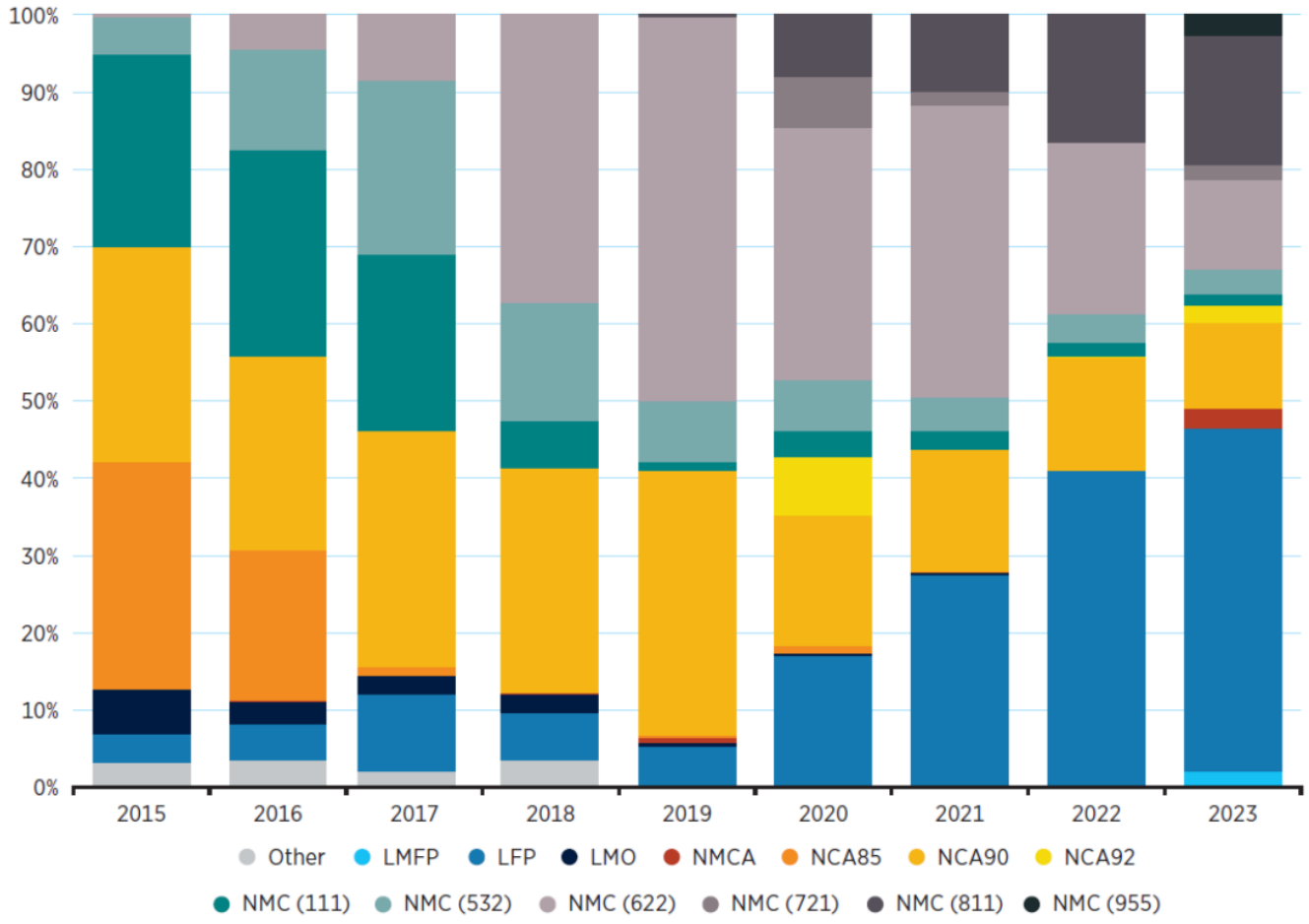
Separator
Porous membrane

Anode coating
Typically graphite

Copper foil
Anode current collector

Electrolyte Liquid electrolyte wets the pores of both electrode coatings and the separator.

How EV cathode chemistries changed



Global passenger EVs

≈44%

LFP share in 2023, up from single digits in 2015

Within NMC, the mix shifted towards higher nickel grades.

NMC811 and LFP yield different recycling products

NMC811 $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$

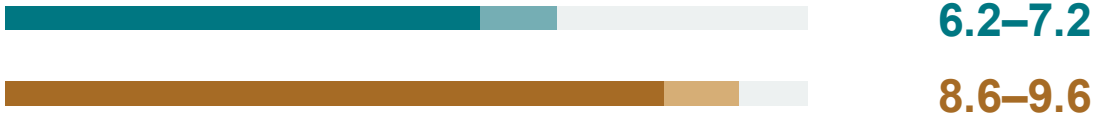
Cell price

USD/kWh



Pack mass

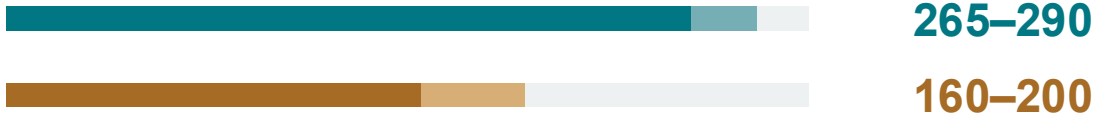
kg/kWh



LFP $LiFePO_4$

Cell energy density

Wh/kg



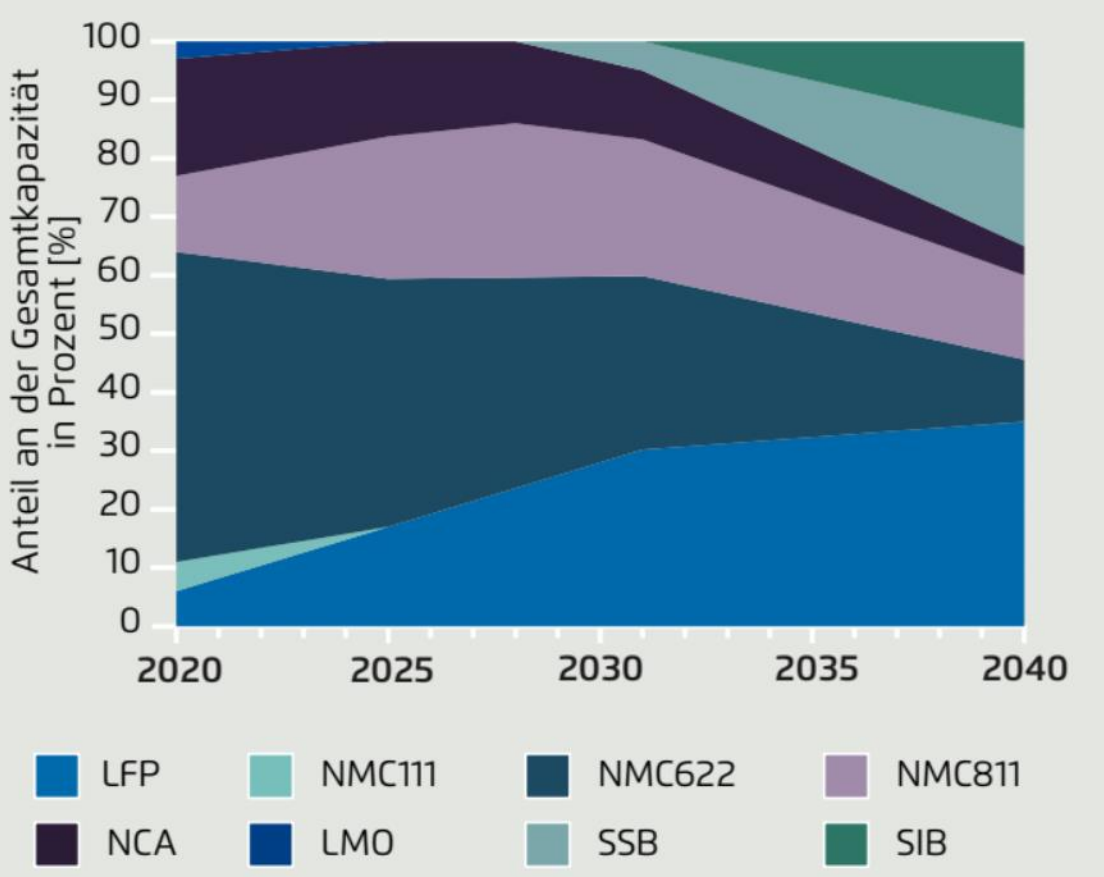
Carbon-intensive sourcing

kg CO_2e/kWh



Future cell mixes widen the range of recycling feeds

EU-27 passenger cars, capacity share (%)



LFP share of global black mass

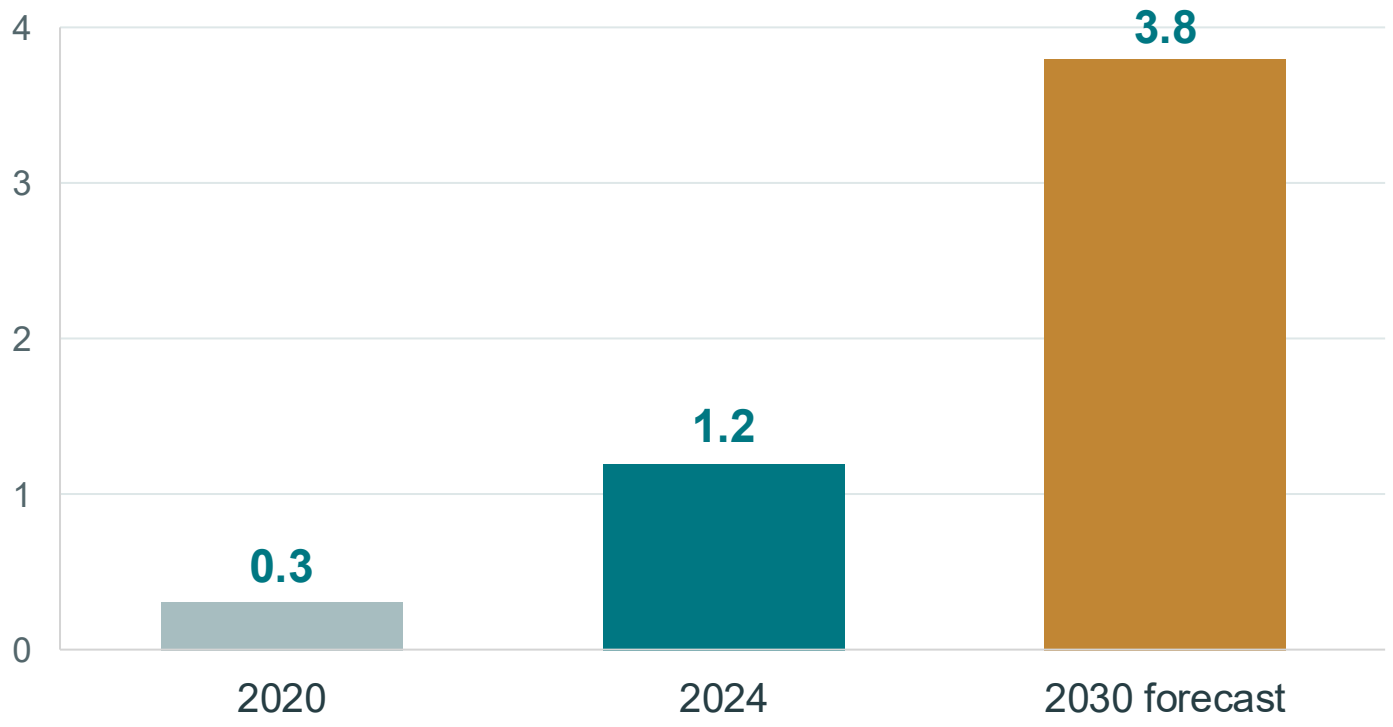
26% to 32%

2024 estimate to 2034 forecast

LMFP adds manganese to phosphate feeds. Solid-state and sodium-ion systems can require different treatment.

Battery demand grows before batteries return

Global battery demand, TWh



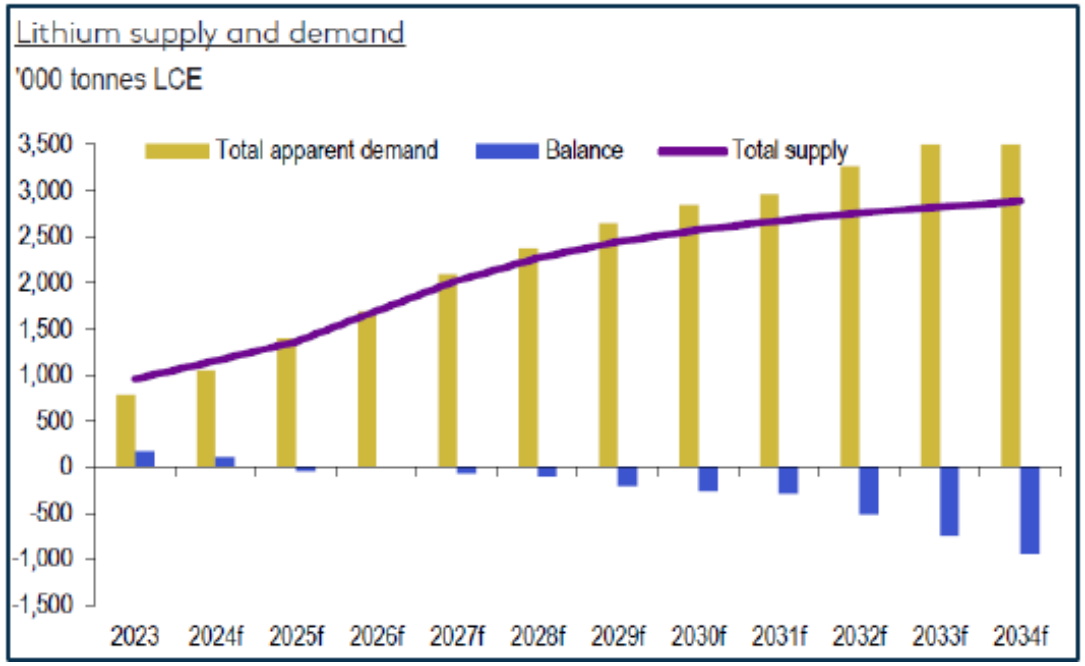
≈3×

2024 to 2030 in this forecast

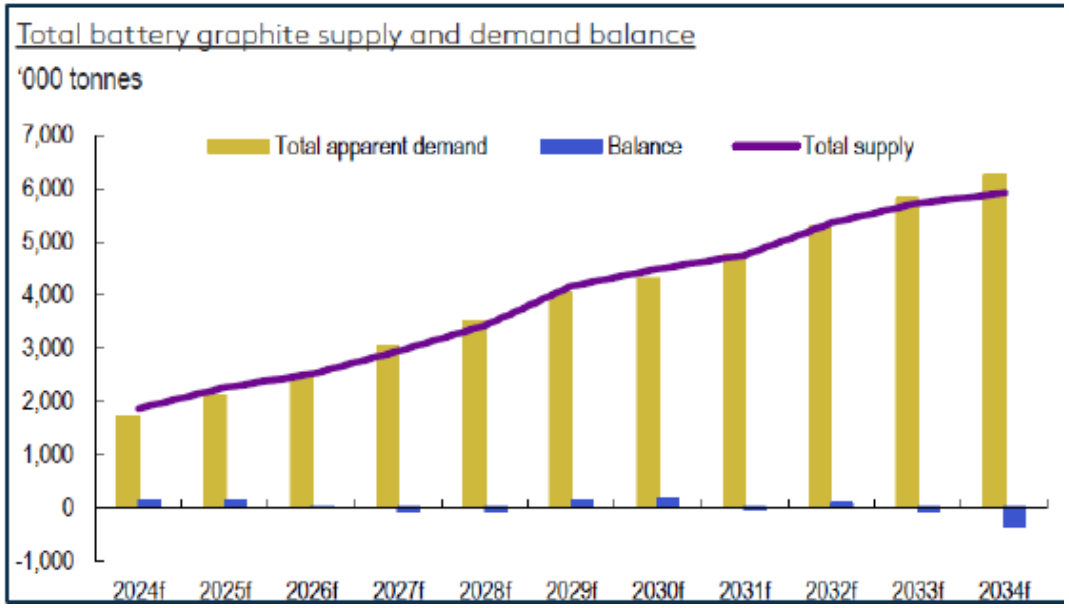
EVs lead demand. Stationary storage and consumer applications add to it.

How cell chemistry changes material demand

Lithium supply and demand



Battery graphite supply and demand



The NMC-to-LFP balance also shifts demand for nickel, cobalt and manganese.

Secondary supply follows battery retirement

Near term

Manufacturing scrap and early battery retirements

Years in service

Longer battery life keeps materials in use for longer

After 2035

The IEA projects a rapid rise in retired EV battery volumes

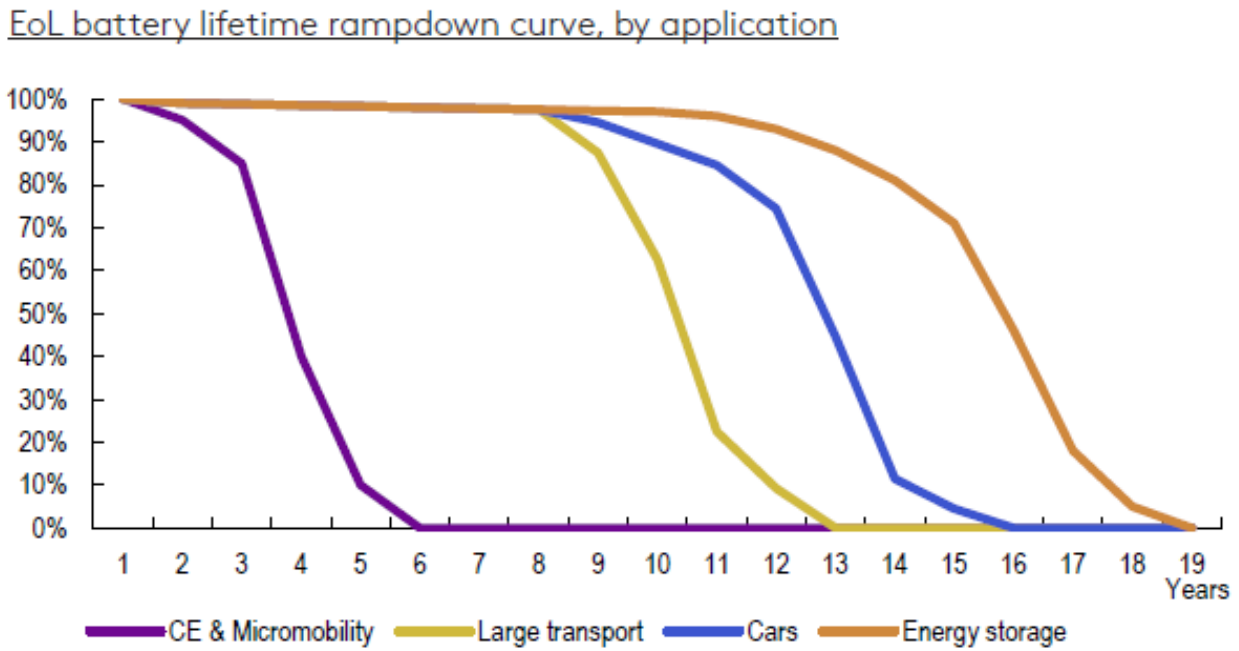
Capacity planning Align plant capacity with when feedstock will be available and secure supply contracts.

More battery scrap, with a different chemistry mix

Global end-of-life battery scrap

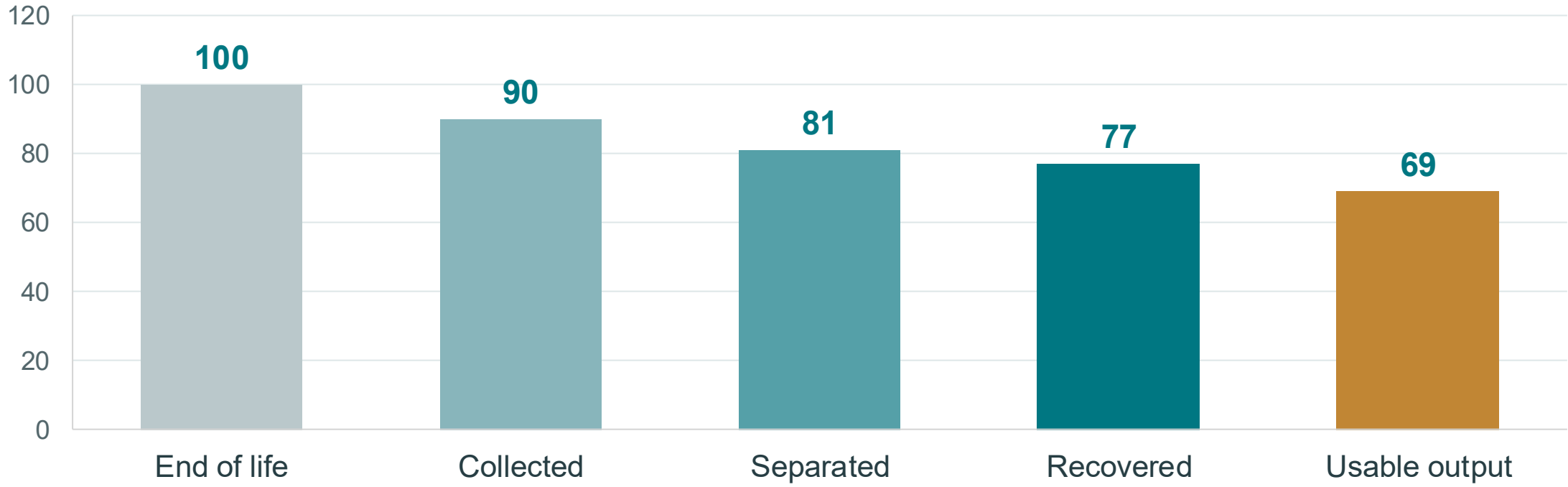
Thousand tonnes per year

Chemistry	2024 est.	2034 forecast
NMC	147	≈1,400
LFP	79	941
LMFP	7	337
LCO	56	162
NCA	13	48



In this scenario, LFP scrap rises from 79,000 to 941,000 tonnes per year, nearly twelvefold.

Losses accumulate across the recycling chain



90% collection × 90% separation × 95% recovery × 90% usable output ≈ 69%

Rounded cumulative values. Assumptions shown above are stage efficiencies.

EU requirements span recovery and new batteries

Recycling efficiency

Share of lithium-based battery input mass

By 31 Dec 2025

65%

of battery input mass

By 31 Dec 2030

70%

of battery input mass

Material recovery

Share of each element in the recycling input

By 31 Dec 2027

Li 50%

Co, Cu and Ni 90% each

By 31 Dec 2031

Li 80%

Co, Cu and Ni 95% each

Recycled content

Share of each element in the active materials of new EV batteries

From 18 Aug 2031

Li 6%

Co 16% / Ni 6%

From 18 Aug 2036

Li 12%

Co 26% / Ni 15%

Product information EV battery passport from February 2027. Carbon footprint under Article 7.

Recycling routes deliver different products

Spent cells and electrode fractions

Pyrometallurgy
Smelting

→ **Ni/Co-bearing alloy or matte**
Track Li in slag or dust

Hydrometallurgy
Leaching and solution purification

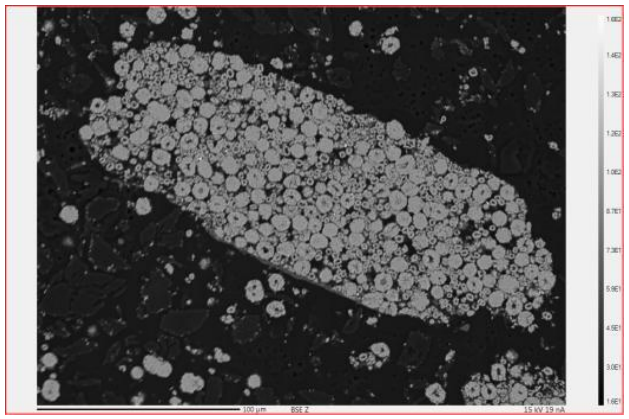
→ **Purified salts or precursors**
Track co-dissolved impurities and leach residue

Direct recycling
Separation and regeneration

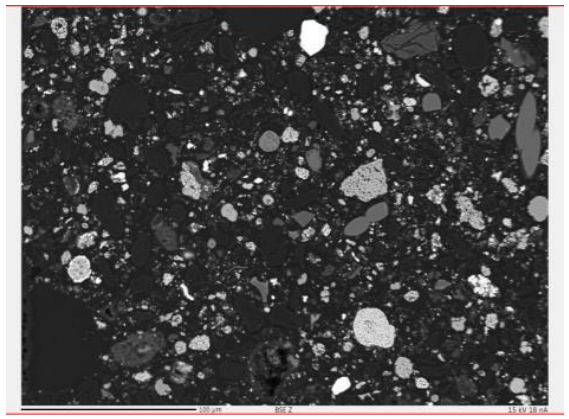
→ **Regenerated active material**
Verify phase purity and electrochemical performance

Industrial flowsheets can combine operations from these route families.

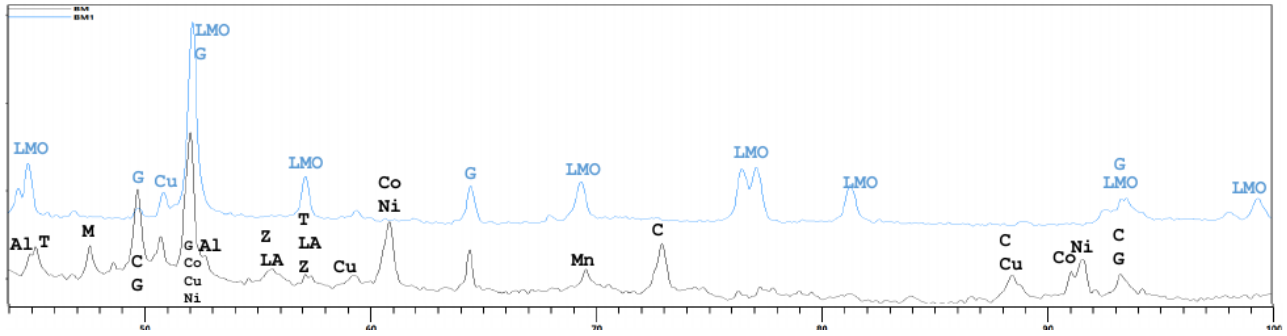
Black mass as intermediate product



Non-pyrolysed



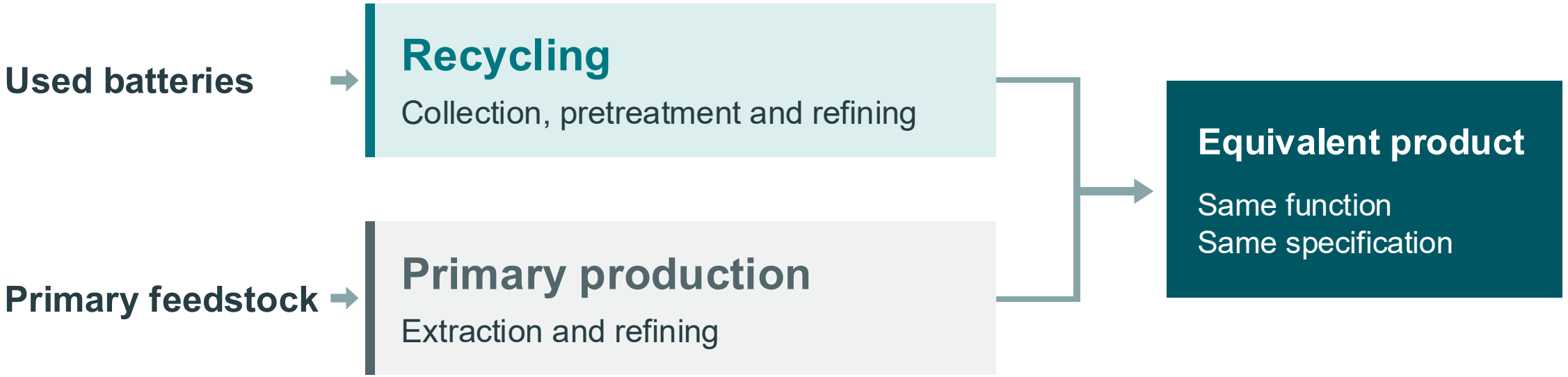
Pyrolysed



XRD traces Pyrolysed (black) Non-pyrolysed (blue)

Constituent	Content (wt%)
Main components	
Ni + Co + Mn	25–35
Li	2.5–4.5
Graphite	≈30
Silicon	0–5
Inorganic impurities	
Al	1–5
Cu	1–5
Fe	0.02–3
Fluorine	2–4
Other halogens	0–0.2
P	0.05–2
Trace metals	0.00X–0.X
Organic impurities	
TOC (total organic carbon)	0–10

Environmental impacts across the full route



Compare the full routes Use consistent boundaries and include energy, chemicals, water treatment and residues.

A high recovery yield can coexist with high processing burdens

Priorities for the next stage of battery recycling

01

Research

Close element balances.
Improve selectivity and control impurities.

02

Industrial validation

Test representative feeds.
Qualify products and define residue treatment.

03

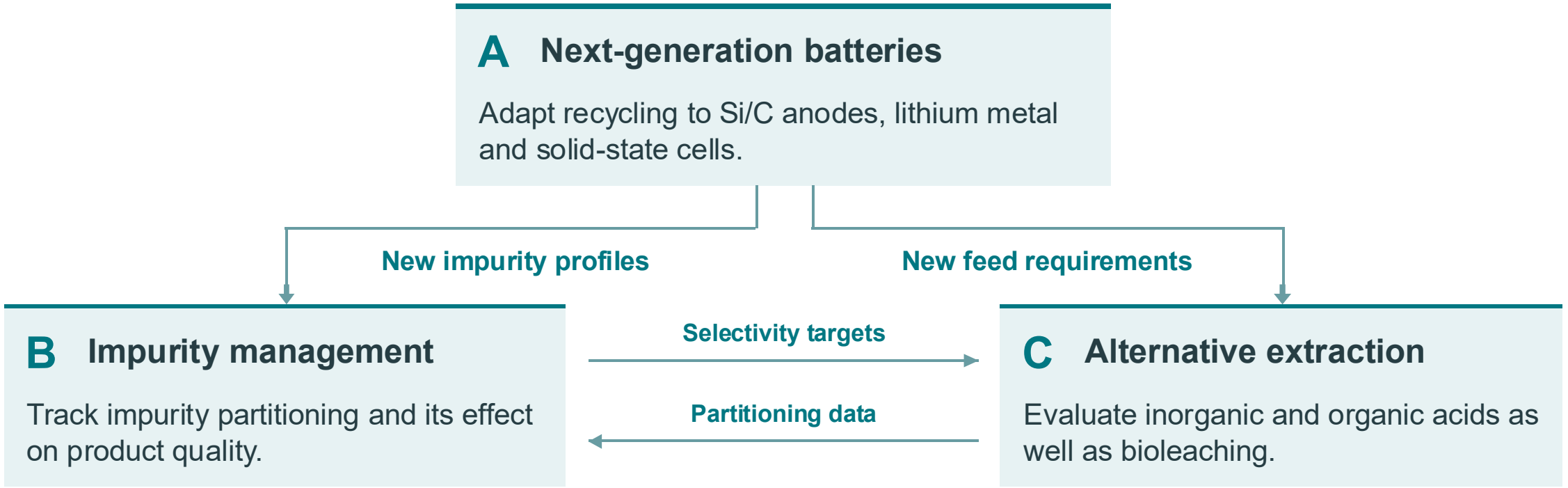
Scale-up

Secure feedstock and offtake.
Verify realistic plant utilization.

Demonstrate performance across the complete material loop

Our Christian Doppler Laboratory

Advanced Recycling of Lithium-Ion Batteries



Shared goal **Recover critical materials at a quality that allows them to return to battery production.**

Thank you for listening!

Assoc. Prof. Dr. Eva Gerold
Christian Doppler Laboratory for Advanced Recycling of Lithium-Ion Batteries
Chair of Nonferrous Metallurgy,
Montanuniversität Leoben

Move mountains