Perspectives on Lithium Iron Phosphate (LFP) Battery Recycling: Will Europe Follow China?

Dr. Tobias Elwert, CTO cylib

Table of contents

cylib – From Research to Industry: Defining European Battery Recycling by Building Europe's First LFP & NMC Recycling Plant

Company foundation
July 2022

>21,500sqm industrial facility
In CHEMPARK Dormagen

Chemistry
NMC + LFP

Water-based recycling process
Lithium-first water-based process for NCM black mass

Pilot line commissioned
In Aachen in Q3 2023

Intellectual property
6 patents filed and over 20 pending

Funding
EUR 60 mn equity + significant grants

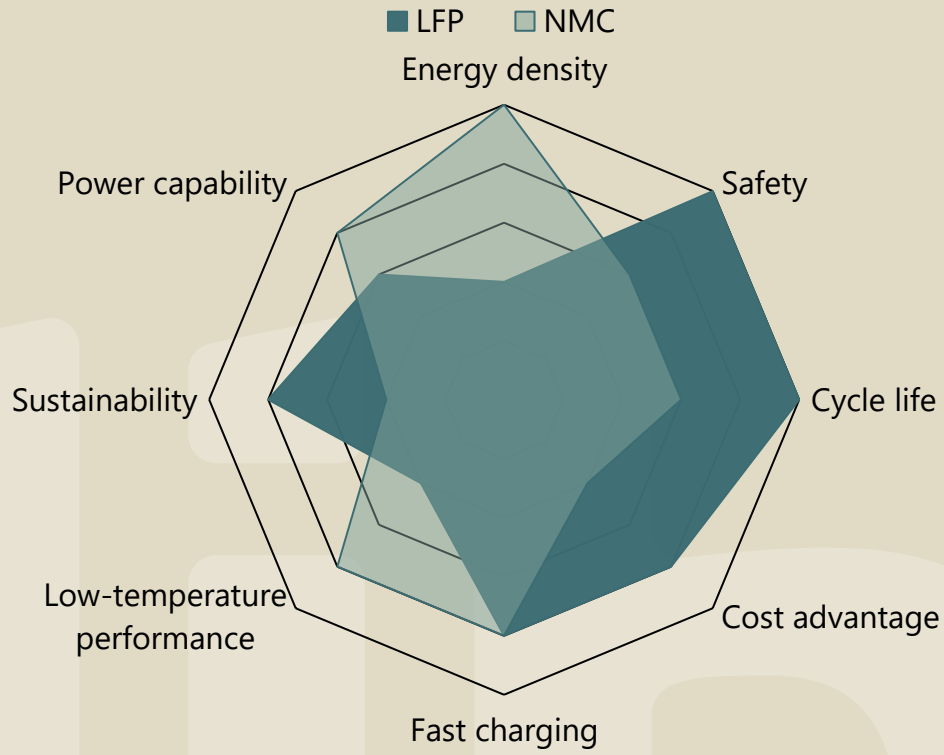
ISO certifications received
ISO 50001, ISO 14001, ISO 9001

LFP and NMC: Complementary Strengths Across Battery Applications

LFP and NMC each bring distinct advantages, shaping different performance profiles and market applications

Criteria	LFP (Lithium Iron Phosphate)	NMC (Nickel Manganese Cobalt)
Crystal Structure	Olivine	Layered oxide
Energy Density*	90-160 Wh/kg	150-300 Wh/kg
Raw Materials	Iron, phosphate, lithium	Nickel, manganese, cobalt, lithium
Raw material cost	Low	High
Cycle Life	Very good	Good
Charging Speed	Good	Good to very good
Typical Use Cases	ESS, buses, entry EVs, commercial vehicles	Premium EVs, long-range EVs, high-performance applications
Peak Performance	Moderate	Higher
Lifespan	Excellent	Good
Safety	High thermal stability	Good, but higher thermal runaway risk
Abuse Tolerance	Good	Low

*Cell level

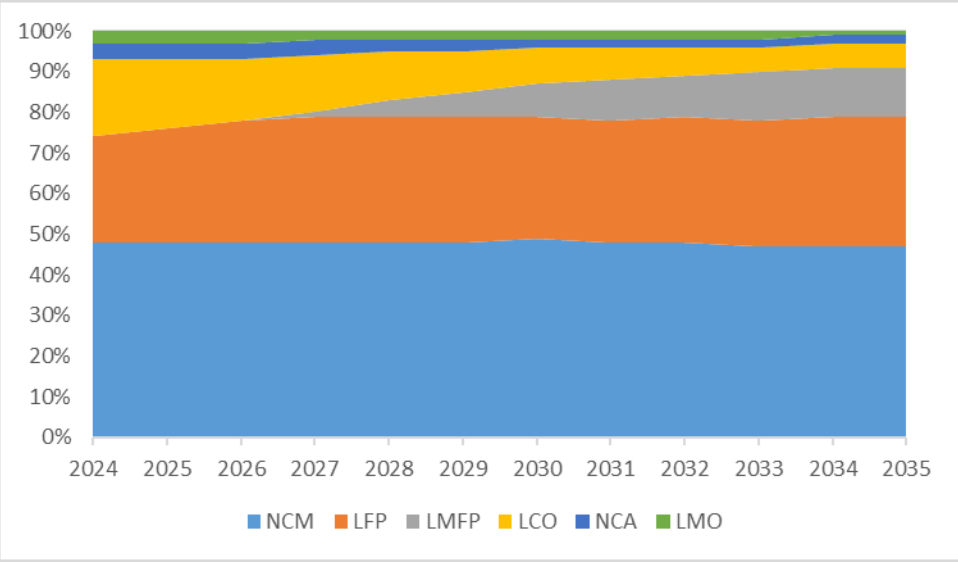


LFP offers **better safety**, **lifetime**, and **cost**, while **NMC** delivers **higher energy density** and **better low-temperature performance**.

LFP Continues to Expand Its Market Role Globally and in Europe

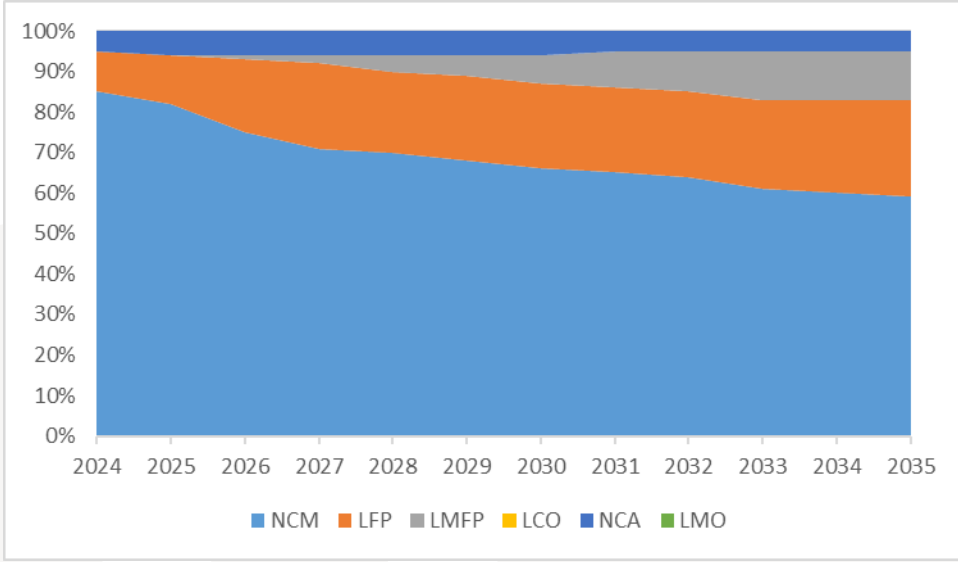
Until 2035, LFP is expected to strengthen its position in global batteries and European EVs, while NCM remains the leading chemistry overall

Global battery chemistry (w/ ESS, EV, CE, etc) mix forecast*



LFP is expected to **strengthen its global position through 2035**, driven by **growing adoption** in **ESS** and **mass-market mobility**, while NCM remains the largest chemistry overall.

European EV battery chemistry mix forecast*



LFP is expected to **steadily grow** its **market share in Europe** in the **EV sector** through 2035, reflecting its rising importance as **a cost-effective and safe battery chemistry**, while NCM remains the leading chemistry overall.

* (based on GWh), data provided by Fastmarkets | ESS: Energy Storage System, EV: Electric Vehicle. CE: Consumer Electronics

China’s LFP Leadership is Structural, Integrated, and Scaled

Integrated supply chains, large-scale manufacturing, and an established recycling ecosystem underpin China’s leadership in LFP

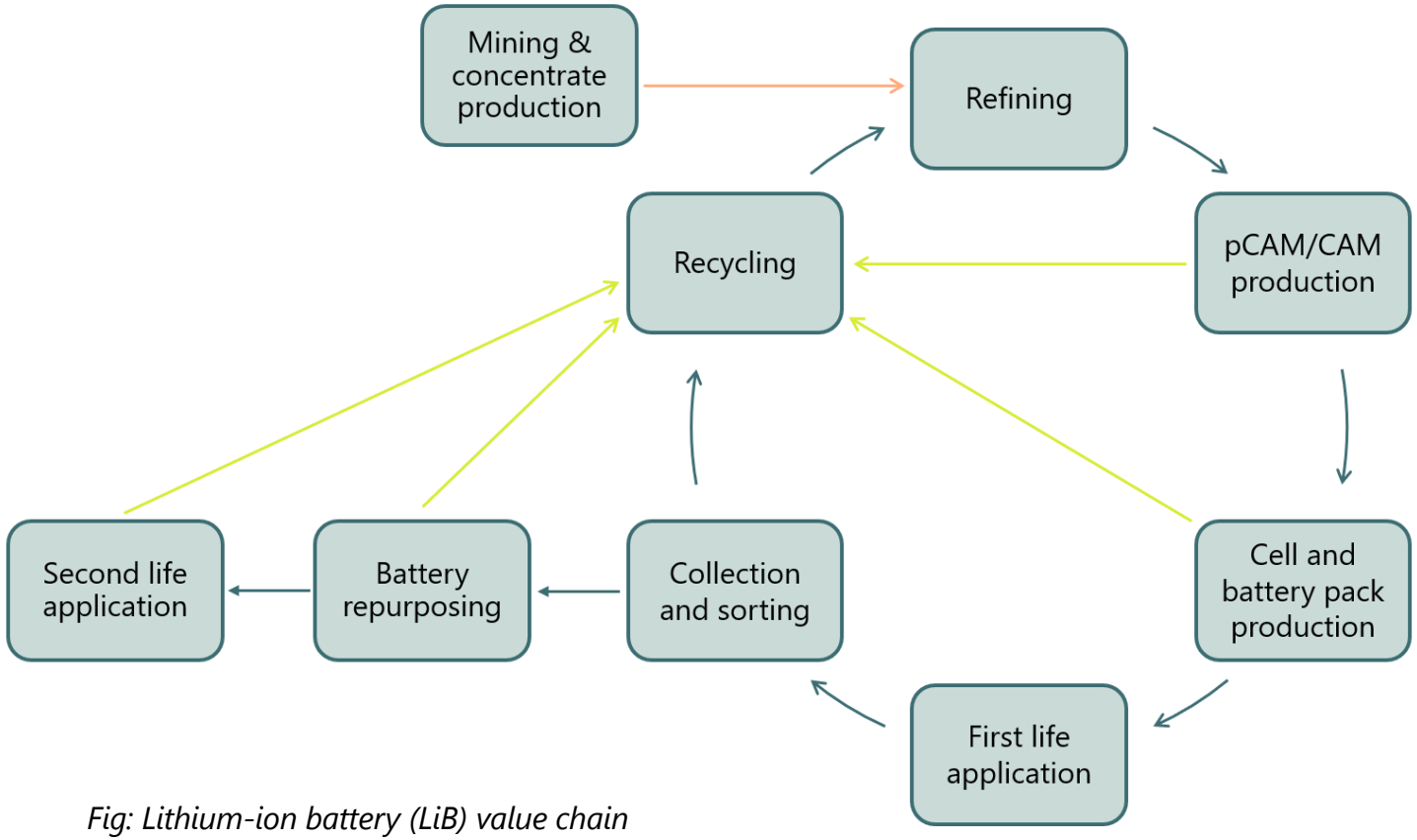


Fig: Lithium-ion battery (LiB) value chain

End-to-end leadership
China spans the full LFP value chain—from refining and phosphate chemistry to cathode materials, cell production, pack assembly, and recycling.

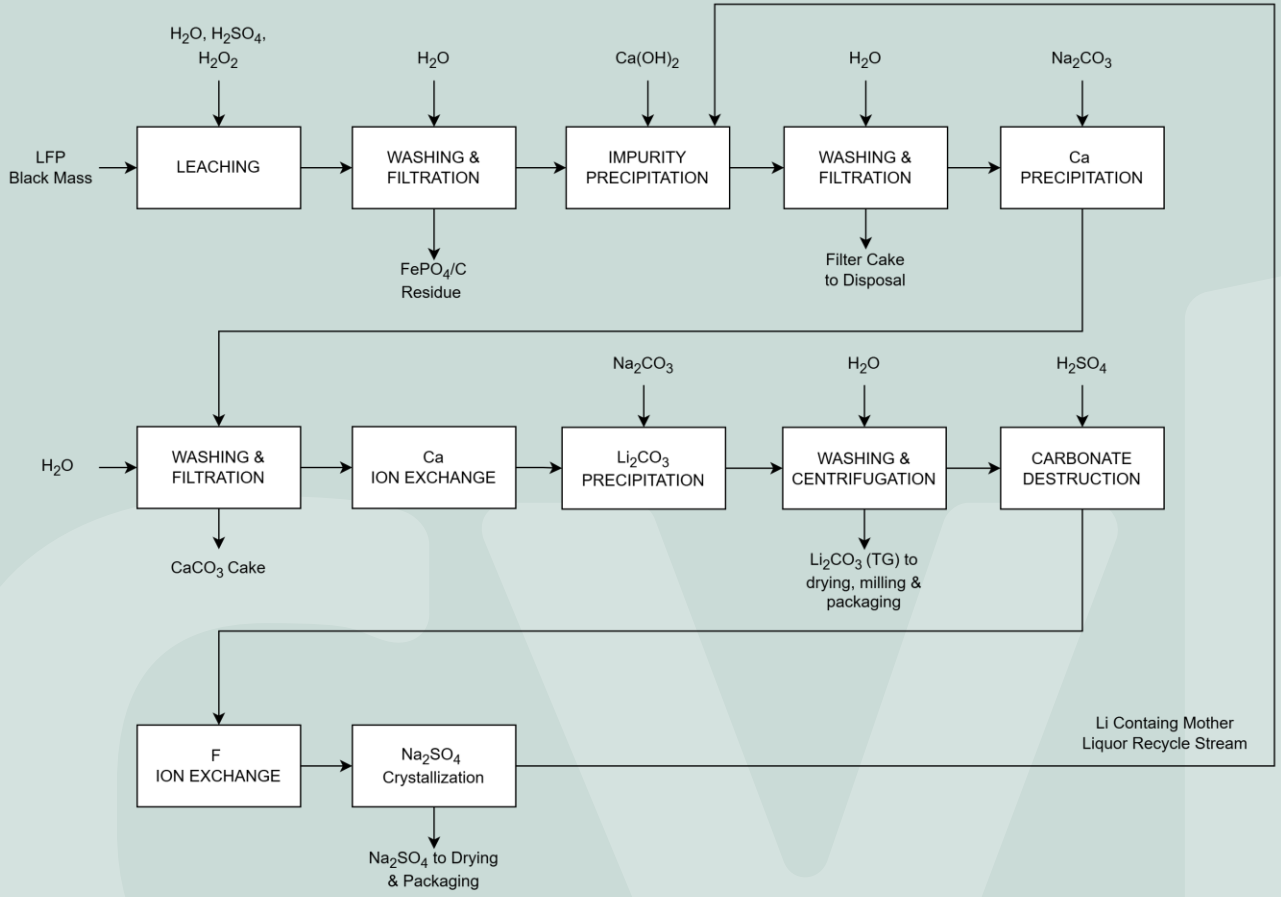
Scale, cost, and manufacturing advantage
A strong chemical/metallurgical base, integrated supply chains, large domestic EV/bus/ESS demand, and leading cell capacity drive low-cost, high-volume LFP output and ongoing cost-performance gains.

Recycling as a strategic pillar
China’s established recycling ecosystem enables material recovery, strengthens supply security, and supports long-term LFP circularity.

LFP Recycling Route 1: Selective Lithium Recovery

A selective leaching route focused on high lithium recovery with iron phosphate and graphite remaining in the leach residue

$$2\,LiFePO_4 + H_2SO_4 + H_2O_2 \rightarrow 2\,Li^+ + SO_4^{2-} + 2\,FePO_4 + 2\,H_2O$$

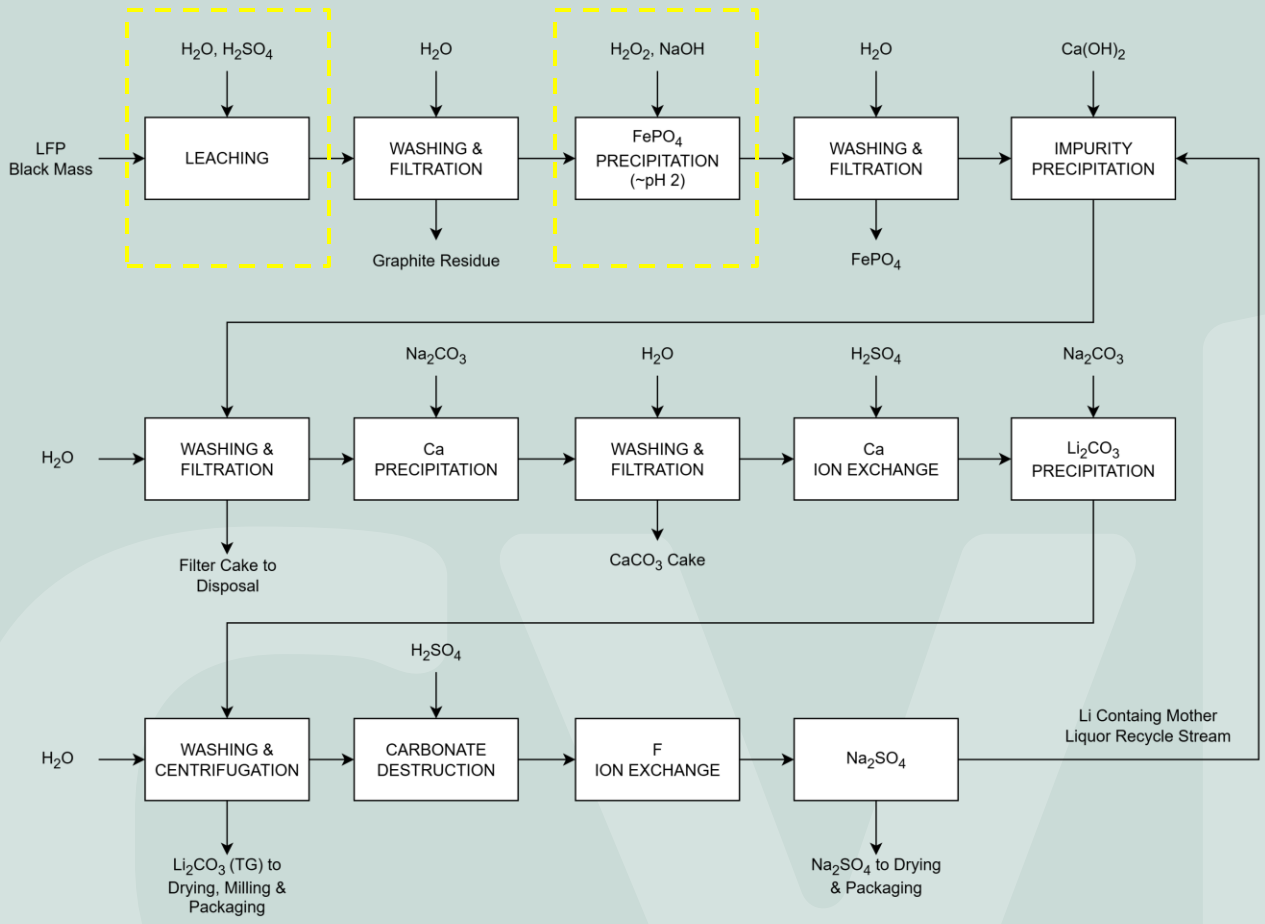


- **Lithium-first leaching:** Lithium is selectively leached from LFP black mass using acid and an oxidizing agent.
- **Separation:** The process yields a lithium-rich solution and an iron phosphate/graphite residue.
- **Recovery:** Lithium is purified and precipitated as lithium carbonate and sodium sulphate is sent to crystallization.
- **Yield:** Lithium recovery of 90-95% is possible with thorough washing.
- **Residue:** The remaining residue (10 tonne of wet residue per tonne of LCE) is either stockpiled or sold for low-prices (~10 €/tonne or ~800 RMB/tonne) back into the value chain.

LFP Recycling Route 2: Full Dissolution and Iron Phosphate Recovery

A broader recovery concept designed to capture both lithium and iron phosphate, albeit with increased process complexity

$$2\,LiFePO_4 + 3\,H_2SO_4 \rightarrow 2\,Li^+ + 2\,Fe^{2+} + 3\,SO_4^{2-} + 6\,H^+ + 2\,PO_4^{3-}$$



- **Full dissolution:** LFP black mass is fully dissolved in sulfuric acid.
- **Graphite separation:** Graphite is removed from the leach solution by solid-liquid separation.
- **Fe/P recovery:** Iron and phosphate are precipitated as iron phosphate precursor after oxidation and pH adjustment.
- **Li recovery:** After impurity removal, lithium is precipitated, and sodium sulfate is sent to crystallization.

Compared to Route 1:

- More complex and less mature ↓
- Slightly lower lithium yield ↓
- Economics driven mainly by lithium prices –
- Difficulty in $FePO_4$ precursor qualification ↓

ALTA 2026

cylib

Key Challenges for Building an LFP Battery Recycling Industry in Europe

Why is Europe not yet structurally positioned for large-scale, competitive LFP recycling?

Europe lacks a comprehensive battery strategy

No long-term, comprehensive strategy which incentivizes sufficient investments in the battery value chain

Limited offtake options

Local routes into CAM/pCAM and cell manufacturing are still underdeveloped

Europe has higher cost base than Asia

Higher energy, labour, and permitting costs weaken competitiveness, especially at smaller scale

Legacy focus has been on NMC

Early recycling efforts focused on higher-value nickel-rich batteries

Distinct recycling model

LFP recycling is feasible, but depends on scale, process efficiency, and market integration

Need for a stronger local value chain

Europe still lacks an integrated value chain from refining to battery recycling including primary production

cylib

What Needs to Be Done in the EU to Scale LFP Battery Recycling

Key Enablers for Scaling LFP Recycling in Europe ✓

Raw material strategy

Besides development of European deposits, investments in deposits and mines outside Europe should be considered including countries with higher risk profiles.

Clear and stable regulation

The EU needs predictable regulation, faster permitting, and clarity on waste, transport, targets, and primary raw materials

Targeted financial support

Early-stage LFP recycling may need subsidies, risk-sharing, and investment support to offset Europe's higher cost base and accelerate scale-up

Smart process flowsheets

Recycling routes must be tailored to LFP, with a focus on efficiency, recovery value, energy use, and downstream integration

Stronger value chain integration

Recycling should be more closely linked with refining, CAM/pCAM, cell manufacturing, and battery producers to build closed-loop pathways

Industrial coordination and scale-up

Europe needs coordinated action across industry and policymakers to scale up and improve competitiveness

Why cylib Still Sees a Strong Opportunity

The current market is challenging, but several structural trends support long-term value creation ✓

Growing market need

Growing battery volumes in Europe will drive long-term demand for local recycling capacity

Introduction of new waste codes from Nov 2026

New waste code will classify LiB wastes as hazardous waste including LFP waste

Political support is moving in the right direction

Battery recycling is gaining relevance within Europe’s broader agenda on strategic autonomy, circularity, and clean-tech industrial policy

Current overcapacity is unlikely to persist

Global recycling overcapacity is unlikely to last as volumes, regulation, and regionalization evolve

Technology barriers are manageable

Technology catch-up is challenging, but manageable with strong process know-how and industrial execution

cylib's Contribution to Building the Solution

A differentiated approach combining commitment, process design, and execution speed ✓

Early commitment to LFP

cylib is among the first recyclers to commit to LFP, positioning early around a rapidly growing chemistry

Funding secured for scale-up

cylib secured grant support to de-risk development and accelerate industrial implementation

Integrated and cost-efficient process design

cylib has developed an integrated flowsheet, with improved process efficiency & best-in-class recovery rates, costs and emissions record

Holistic approach across the recycling chain

cylib applies a full-chain view of LFP recycling, combining operational learnings from China with European requirements

Fast execution and industrial agility

cylib pairs technology development with rapid execution to keep pace in a fast-evolving market

cylib: Shaping Holistic Battery Recycling Solutions for LFP and NMC

Innovative and scalable recycling approach for Europe's evolving battery landscape

LFP is gaining strategic importance

Future recycling systems in Europe will need to address both chemistries

Europe still lacks structural readiness

Infrastructure, integration, and market conditions remain underdeveloped.

The need for local recycling solutions is growing

Competitive advantage will depend on process design, industrial integration, and execution

cylib is building an innovative response

With early LFP commitment, integrated process development, secured support, and fast implementation

cylib's approach is relevant for both LFP and NMC

Positioning cylib as an innovative battery recycler supporting Europe's circular battery future