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Eco-friendly process without precursor production

Cathode Active Material (CAM) Production Tech.
for Lithium-ion Battery

CALISMAITM

Proterial, Ltd.

Marketing & Sales Division

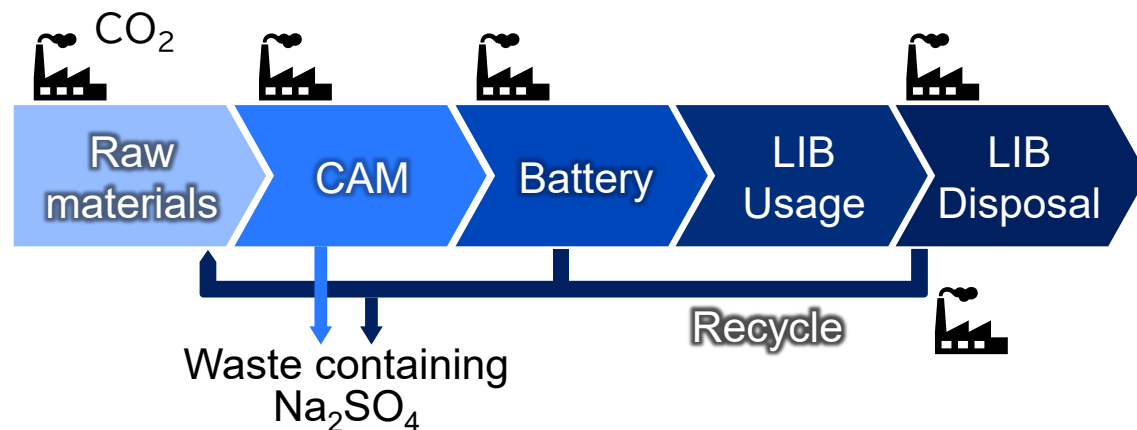
Technology Alliance Department



CAM powder (NCM) made through CALISMAITM process

CALISMAI is a registered trademark of Proterial, Ltd.
CALISMAI's logo is a trademark of Proterial, Ltd.

■ Environmental issues in the LIB life cycle



✓ CO₂ emission regulations are being strengthened

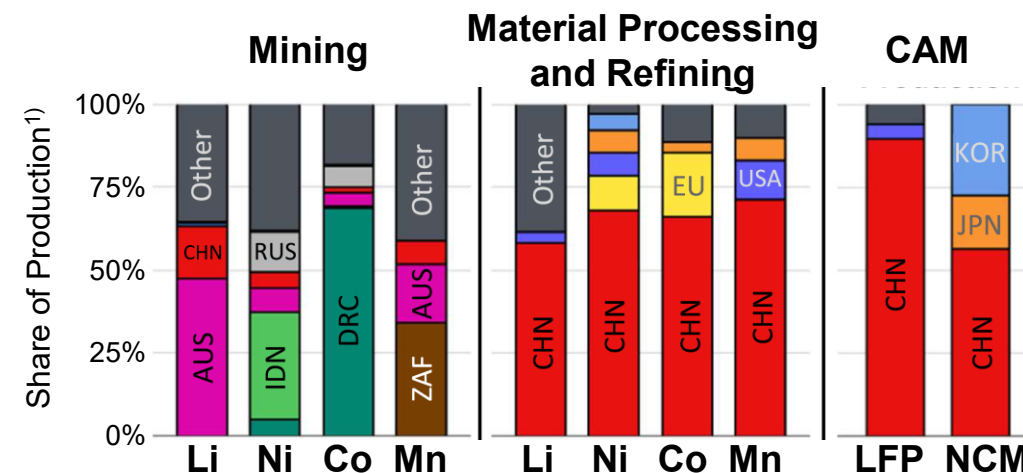
Enforcement of Europe Battery Regulation (Aug. 2023)

- Carbon Footprint reporting (Feb. 2025 –)
- Setting upper limits of Carbon Footprint (Aug. 2028 –)

✓ Emerging waste disposal challenges related to sodium sulfate (Na₂SO₄)

Court order to halt approval for river disposal of Na₂SO₄ wastewater (in Europe)

■ Procurement issues in CAM production



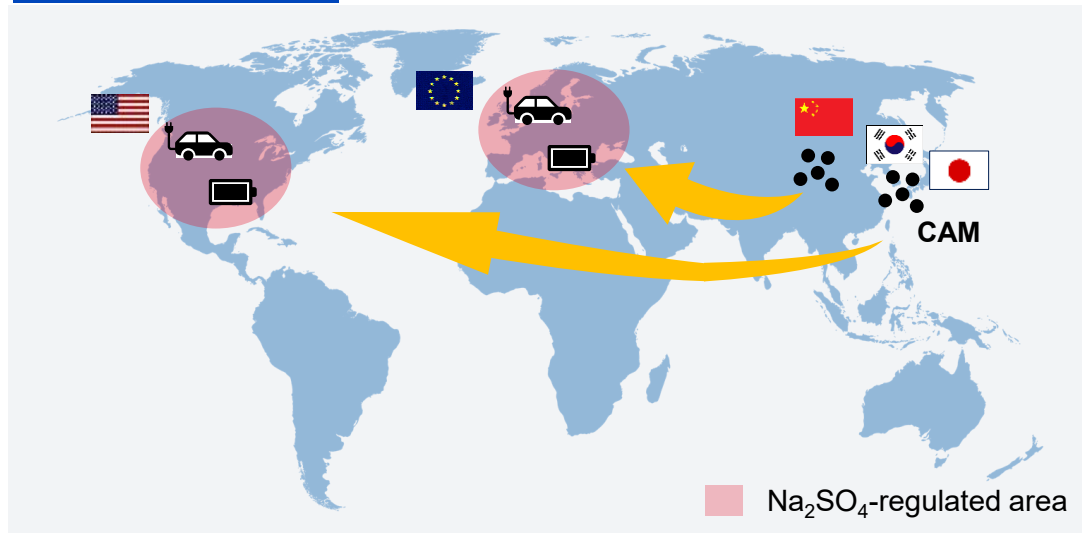
1) Anthony L. Cheng et al., "Electric vehicle battery chemistry affects supply chain disruption vulnerabilities" *nature communications* 15 (2024) 2143

- ✓ Limited choice of feedstock for producing CAM
- ✓ The geographical distribution of refined materials is dominated by China
- ✓ Strengthened export restrictions by China on battery-related materials
- ✓ Supply chain localization driven by IRA and tariffs

3 Key technical features

- ✓ Precursor-free CAM production approach
 - ✓ Using nickel metal powder as a raw material
 - ✓ Capability for direct recycling
- > Zero-waste solutions remove barriers to plant development
 - > CO₂ reduction, cost saving, avoidance of geopolitical risks
 - > Promoting a sustainable circular economy

Current State

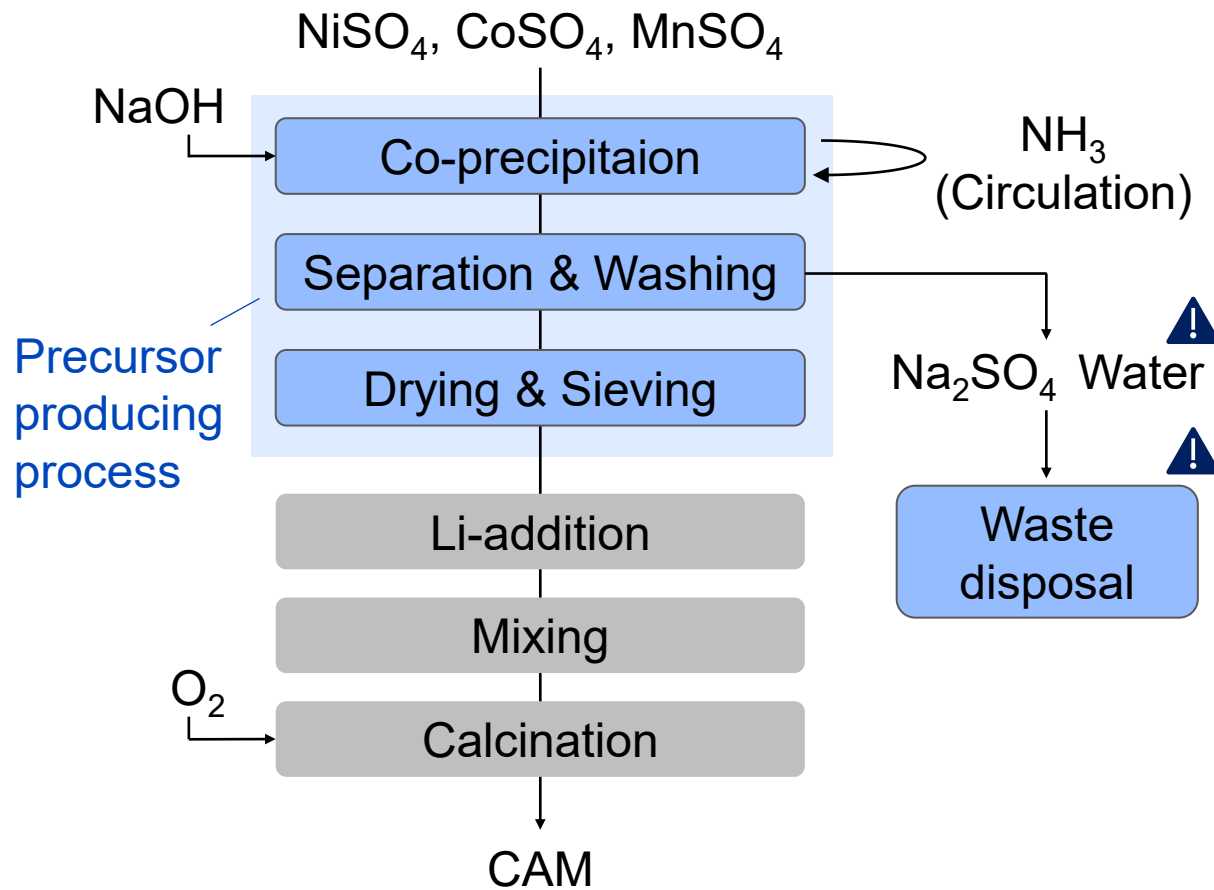


Future vision



CALISMAT® offers a new feedstock option for CAM — Ni metal powder
Zero-waste technology supporting closed ecosystem in the EU and US

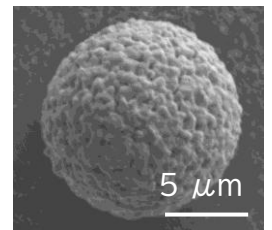
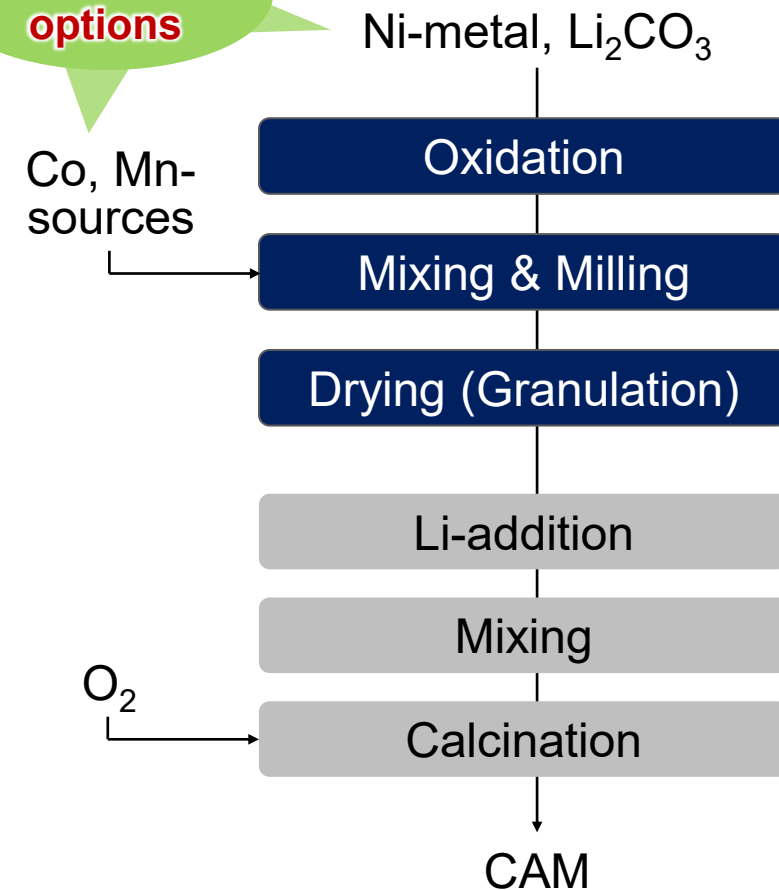
Conventional process (Co-precipitation Method)



Wide range
options

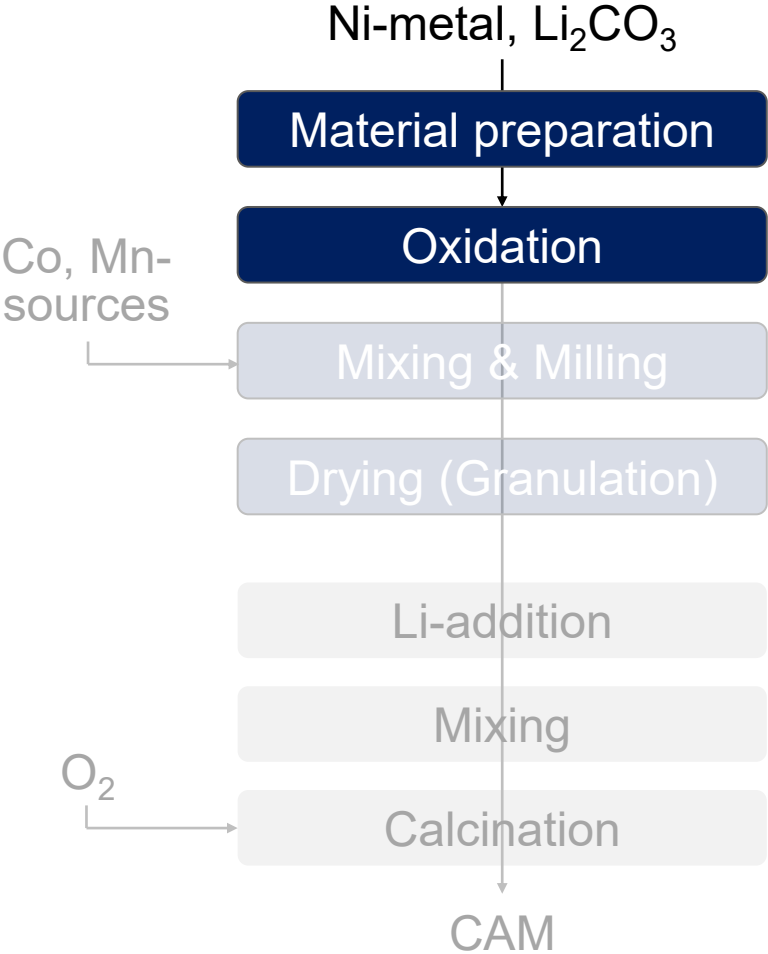
CALISMAI™

Reduce CO₂
emissions

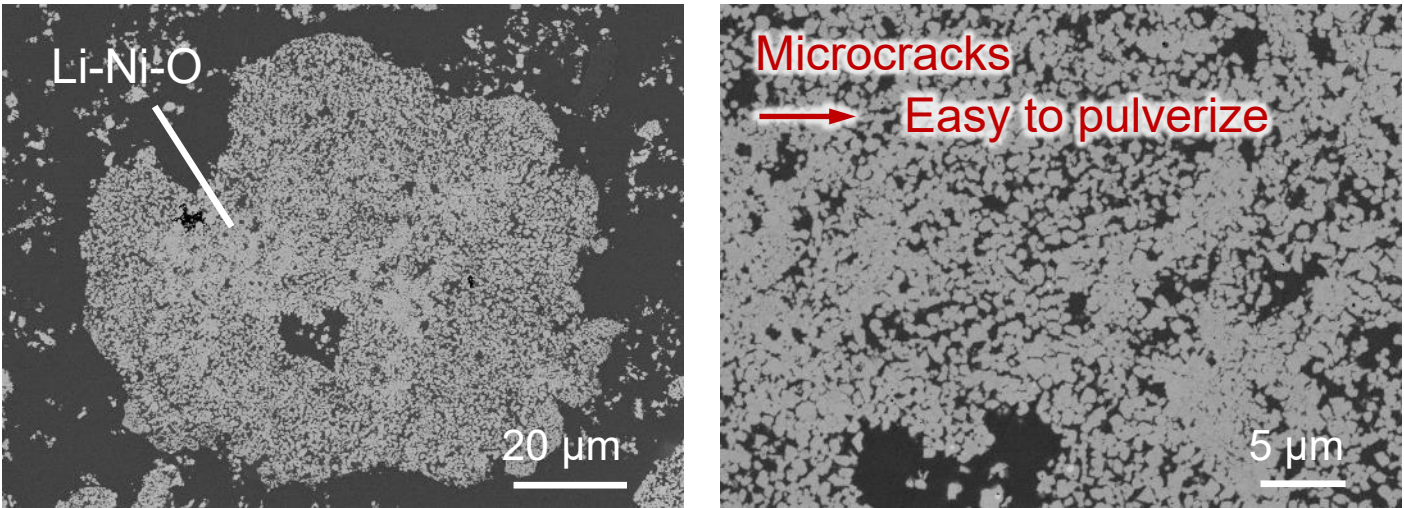


Patented oxidation-assisted Ni pulverization process is a key technology that enables uniform CAM production with commercial-level electrochemical performance

Ni oxidation process (Patented)



Cross-Section SEM images



SEM images of sample calcinated with Li₂CO₃.

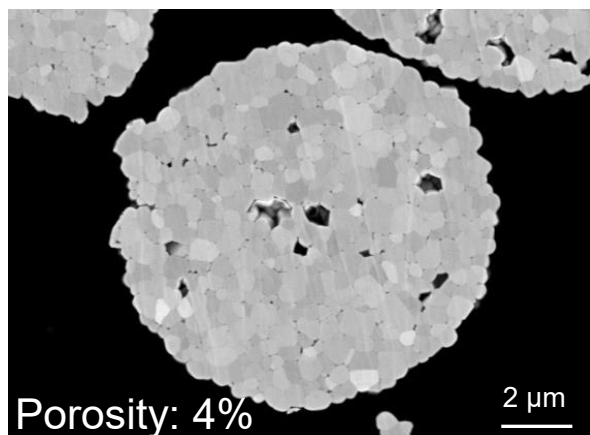
Electrochemical Performance (NCM811)

	CALISMAT	Commercial CAM
Discharge Capacity [Ah/kg]	192–205 (ave. 198)	198
Coulombic Efficiency [%]	86–92 (ave. 87)	89

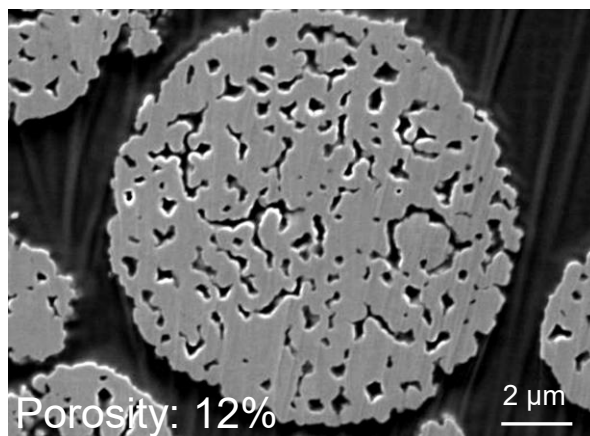
Applicable to single and poly-crystalline NCMs with wide composition range, and enables morphology control based on performance requirements

■ Controllability of Morphology

Lower porosity
for high energy density

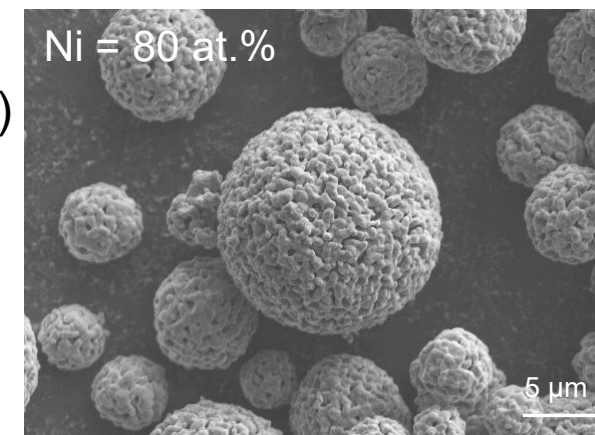


Higher porosity
for high charging rate

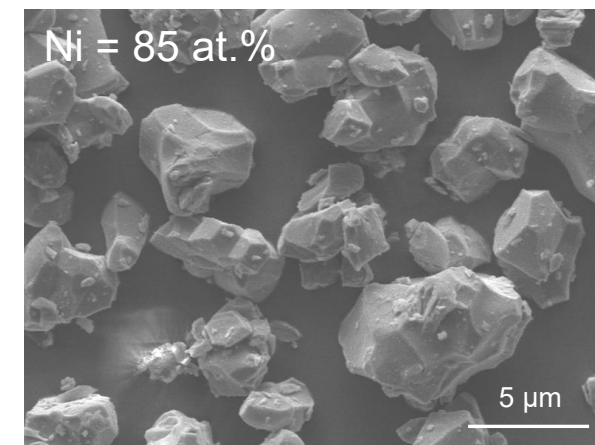


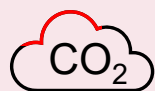
■ Adaption for wide range types of NCMs

Poly crystal NCM
(high-Ni: Ni = 80–92 at.%)



Single crystal NCM
(high Ni)





**Footprint
reduction**

36%



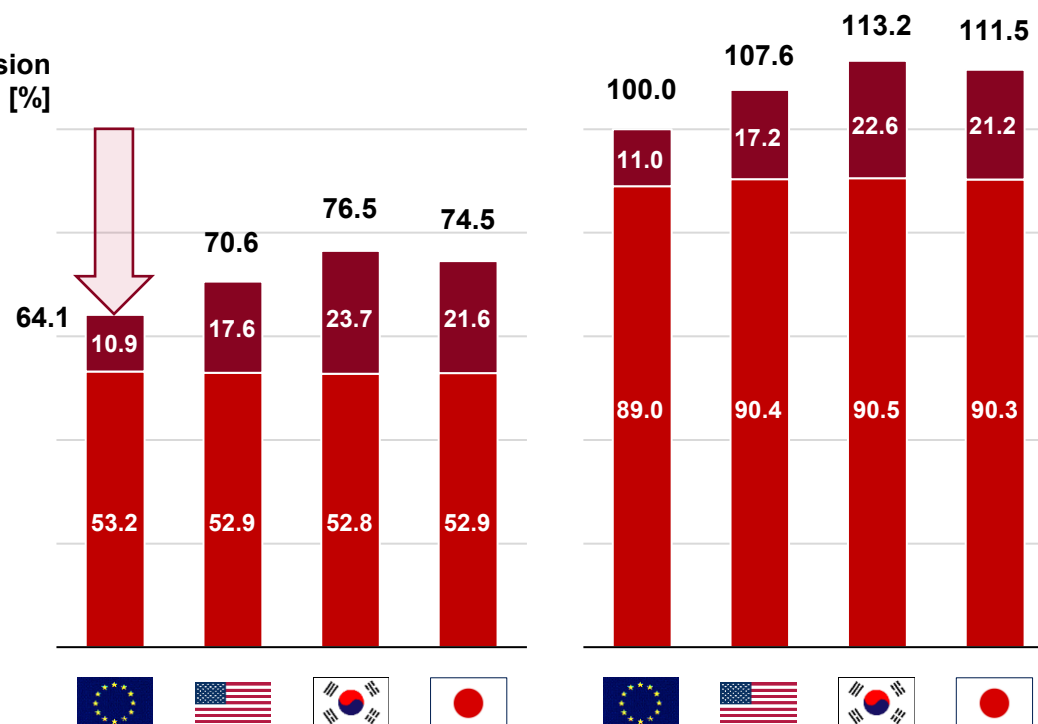
**Cost
reduction**

6% + added value

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Co-precipitation

CO₂ emission
[%]



Raw materials

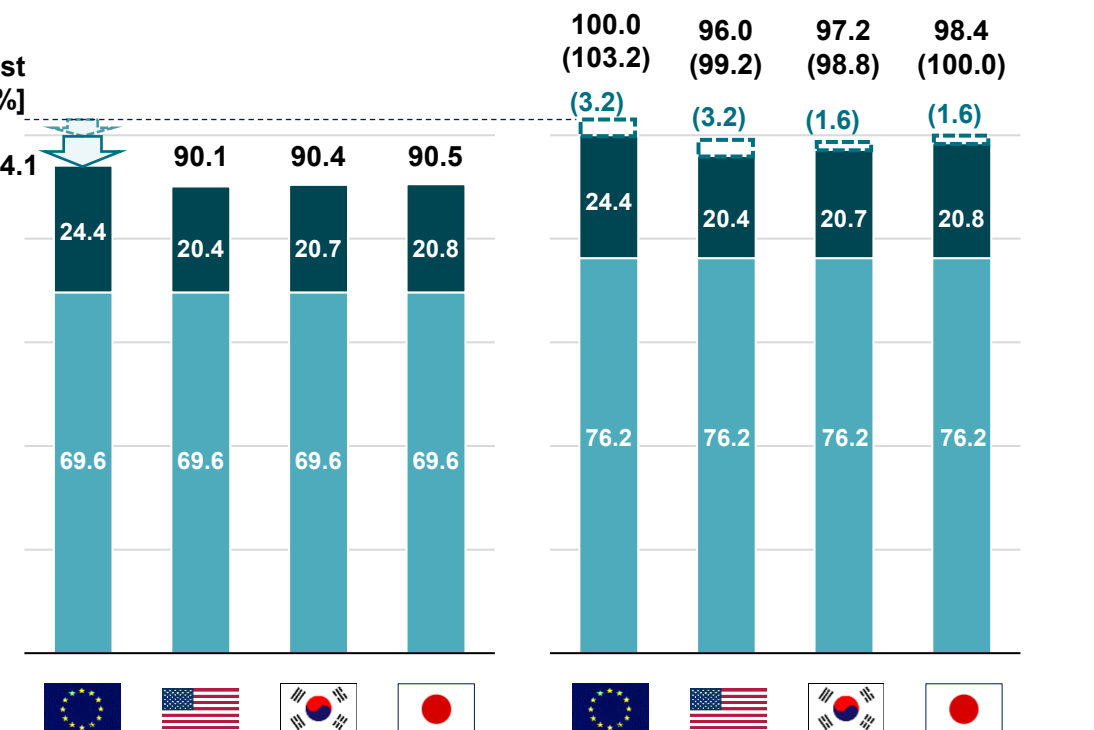
Energy
+ Direct process emissions

ecoinvent

CALISMAT

Co-precipitation

CAM cost
[%]



Raw materials

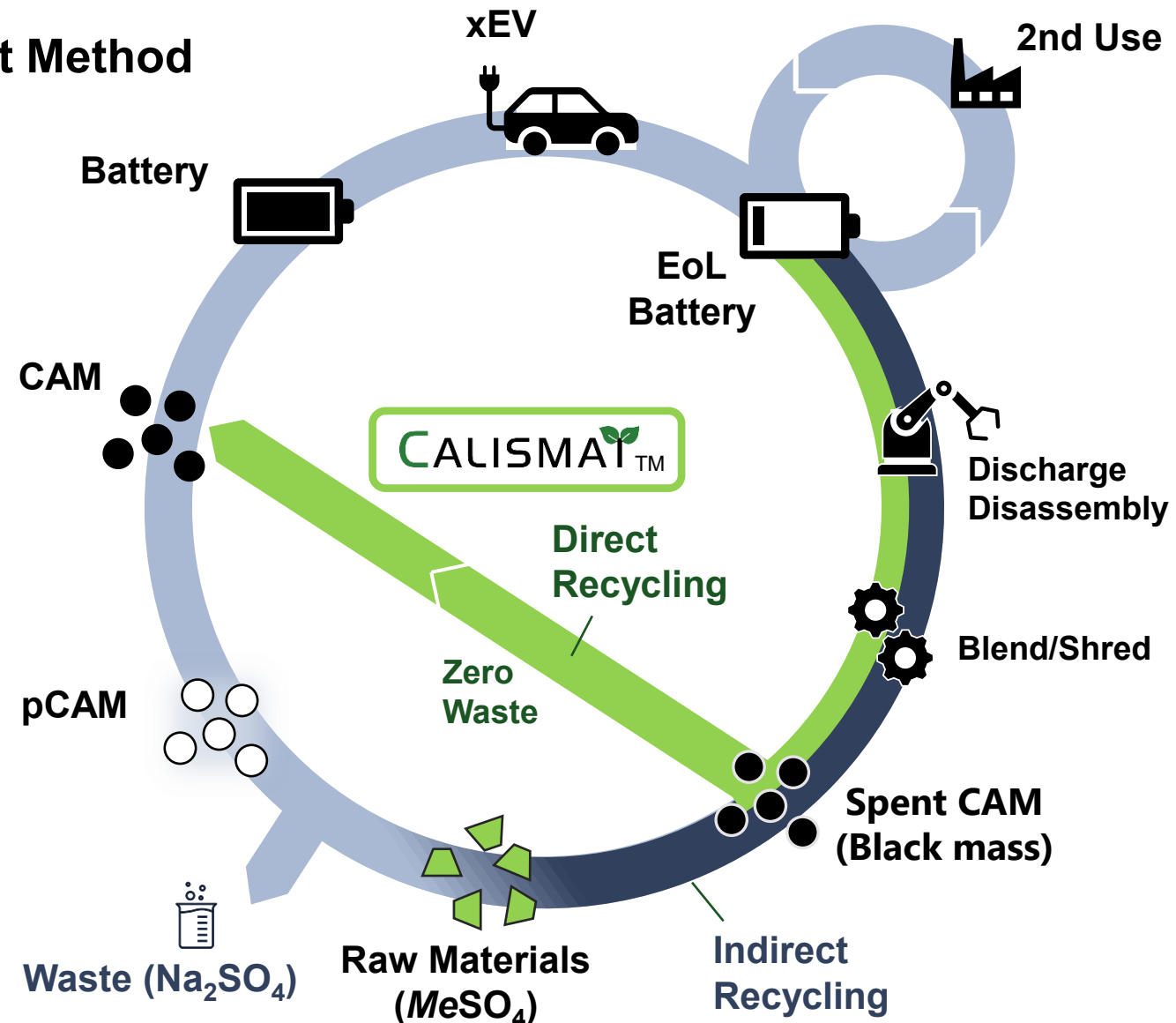
Depreciation
+ Energy + Labor + Other

Wastewater treatment
+ Na₂SO₄ disposal (EU, US)

1. The composition is NCM811, and raw material prices were estimated based on SMM data (January 2025), while CO₂ emissions were calculated using ecoinvent.
2. CAM cost was normalized to 100, assuming production in Europe via co-precipitation method at a scale of 1,000 tons/month.
3. CO₂ emissions were also normalized to 100, based on production in Europe using the co-precipitation method.

■ Advantages of applying CALISMAT® to “Direct Recycling” Compared to the Indirect Method

- ✓ Fewer process steps and lower cost
- ✓ Zero waste with minimal environmental impact
- ✓ Capable of establishing closed ecosystems in each region
- ✓ Modifying the composition through powder metallurgy process
- ✓ Recycling spent CAM without separating by compositions and crystal morphology
- ✓ We're exploring partners to co-develop a direct recycling supply chain



Summary — Key benefits on applying CALISMAT® **PROTERIAL**

We contribute to the sustainable society by providing “CALISMAT®” as a solution for CAM, battery and xEV manufacturers.

■ Key benefits compared to co-precipitation process

- ✓ **Precursor (pCAM)-free CAM production technology** using our unique powder metallurgy process
 - **Zero emissions of sulfate waste** — removing a barrier to new factory construction
 - Water consumption during CAM production is reduced by over 85%
- ✓ **Wide variety of raw material options, including water-insoluble ones for CAM production**
 - **Reduces CO₂ emissions by 36%²⁾ and costs by 6%³⁾**
 - **A supply chain independent of China** is expected to be established
- ✓ **Capability for direct recycling** without separating by compositions
- ✓ **Compact manufacturing line reduces investment scale**
- ✓ **Electrochemical properties are equivalent to those of conventional methods**



**Na₂SO₄
free**



**Footprint
reduction
36%**



**Cost
reduction
6%**



**Reduce
procurement
risk**

(Evaluated by **FEV**
CONSULTING)

2) The validated values represent the proportion in the entire CAM production process including raw materials.

3) Based on raw material prices from early 2025

PROTERIAL
