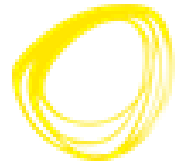




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orano

# **Electrical Vehicles lithium ion batteries advanced recycling process: from research to industrial reality**

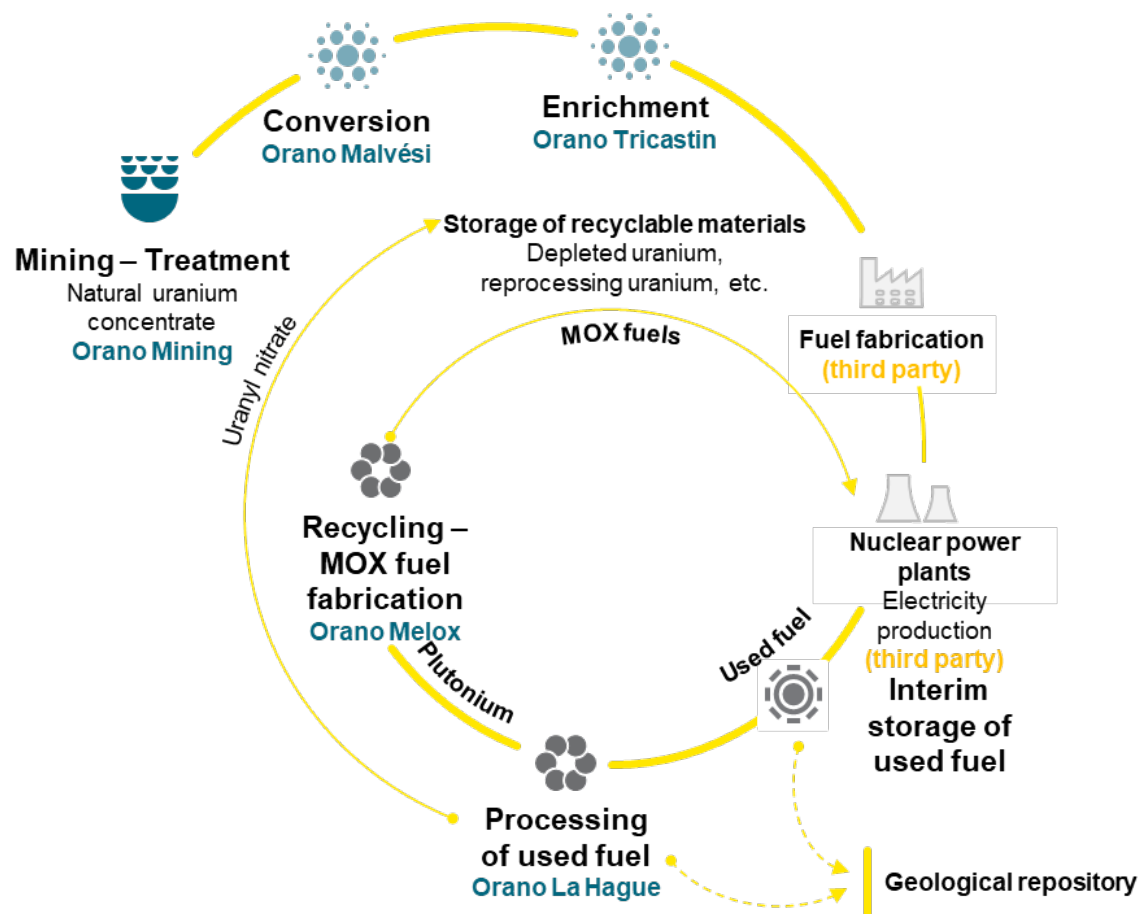
*Véronique PERES, Orano*

*Marlène CHAPUIS, CEA-Liten*



# Orano's activities are currently focused on the nuclear fuel cycle

## Fuel cycle activities



## Key Figures

- € 3.8 Bn of revenue
- € 29.9 Bn order backlog (equivalent to nearly 8 years of revenue)
- Top 3 in the world in its key activities
- 16,000 employees

# Orano is striving to expand in low carbon economy and the recycling of strategic materials for the energy transition

## Nuclear business



**Unique position in the fuel cycle**, with a background in proven technologies strengthened by a capacity for innovation



**International presence** with solid partnerships



**Resilience of business activity** with an order book corresponding to nearly 8 years of revenue



**Profitability improved thanks to an ambitious performance plan** and by refocusing on a coherent range of strategic activities



**Stronger generation of cash** thanks to a **modernized industrial base** operating at a very large scale

## New activities

- **Valorization of depleted uranium and nuclear by-products for low carbon applications**

- **High-value services for Health**

- **Recycling of strategic & complex materials**

- **Cutting-edge nuclear applications**

## Recycling of EV batteries



**An innovative solution for battery recycling**

# CEA recycling activity

## Answer the industrial needs

Develop robust , easy and low cost recycling process

In adequation with the customer specifications

(purity, recovery rate, existant process...)

Physico chemical  
mechanisms  
understanding

From lab ...  
to pilot scale  
demonstration (5L)

Industrial  
transfer

**Photovoltaic cells**  
Ag, Cu, Al, In



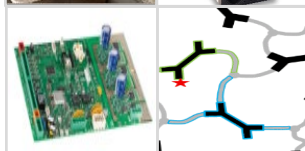
**Lithium ion Batteries**  
Transition metals, Li, Al,  
G, electrolyte

**Permanent Magnets**  
Rare Earth



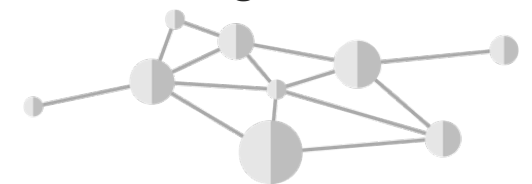
**Fuel Cells PEMFC**  
Catalysts (Pt, Co Ir),  
Nafion

**WEEE (PCB)**  
Au, Pd



**High added value polymers**  
Fiber Composites,  
thermosetting polymers

*Liten ecosystem on all  
the technologies value chain*



# A disruptive process for batteries recycling

Orano and CEA have launched since 2019 a strategic partnership with a joint lab R&D facility for the development of a new battery recycling process



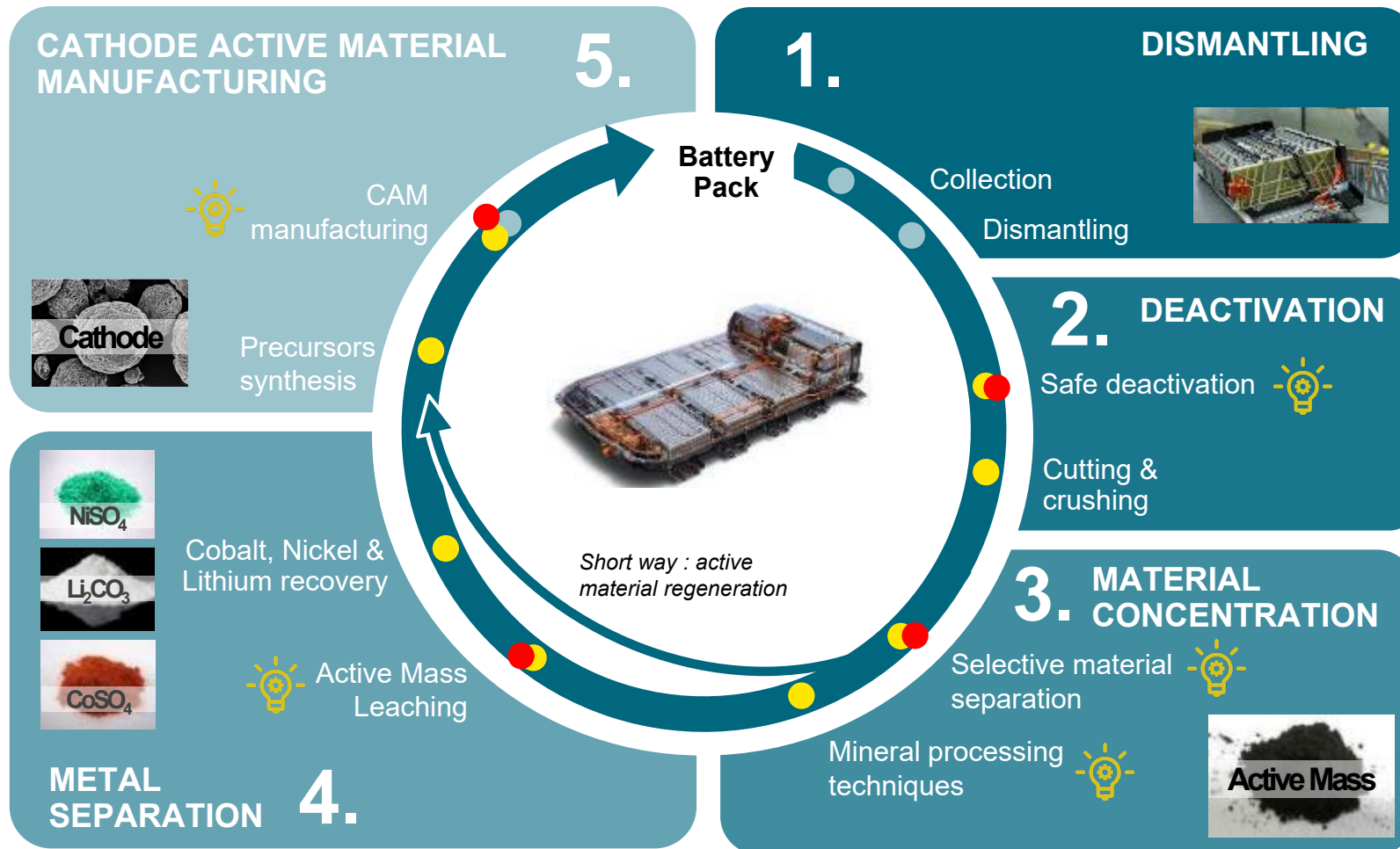
## A disruptive process for battery recycling

- **No pyrometallurgy** in the whole process
- Process could apply to all **EV battery chemical compositions**
- Objective to get a **high purity of recycled materials**, reusable in the EV battery cycle
- All process stages include **innovation and patents**



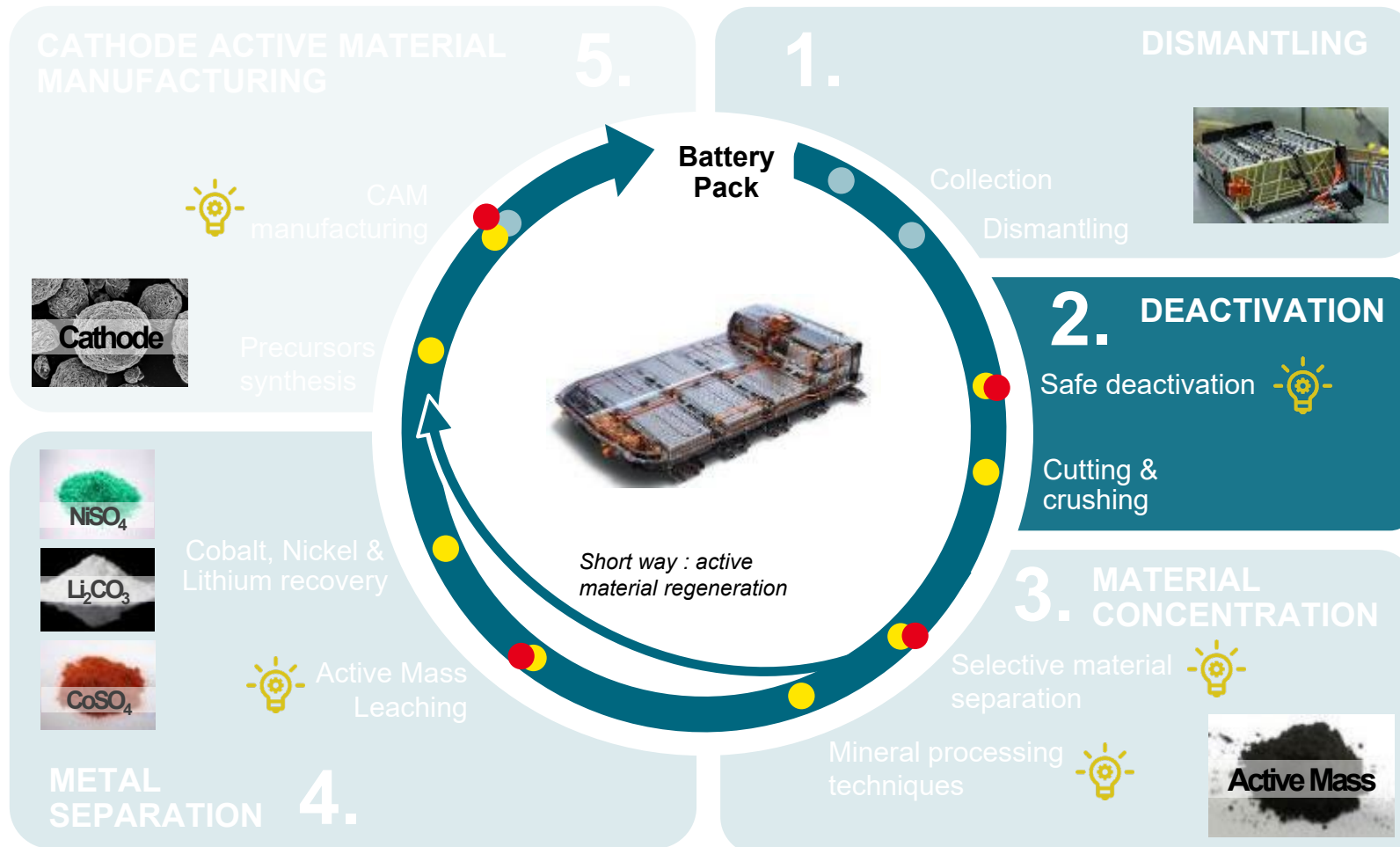
# Orano shall be integrated in the closed loop of lithium-ion battery, by developing an efficient & cost-effective recycling process

- Recycled materials **reusable** in the EV battery cycle



- A versatile process** for all chemistries : NMC, NCA, LCO, LFP
- Graphite recovery and Al, Cu and Fe removal
- High purity active mass production
- Low GHG emission

# ORANO/CEA work illustration on DEACTIVATION



- **Disruptive way to safely deactivate the module** : avoid thermal treatment, no gas generation, no explosion
- Battery discharge at **module level**
- Low-cost process with no reactive consumption

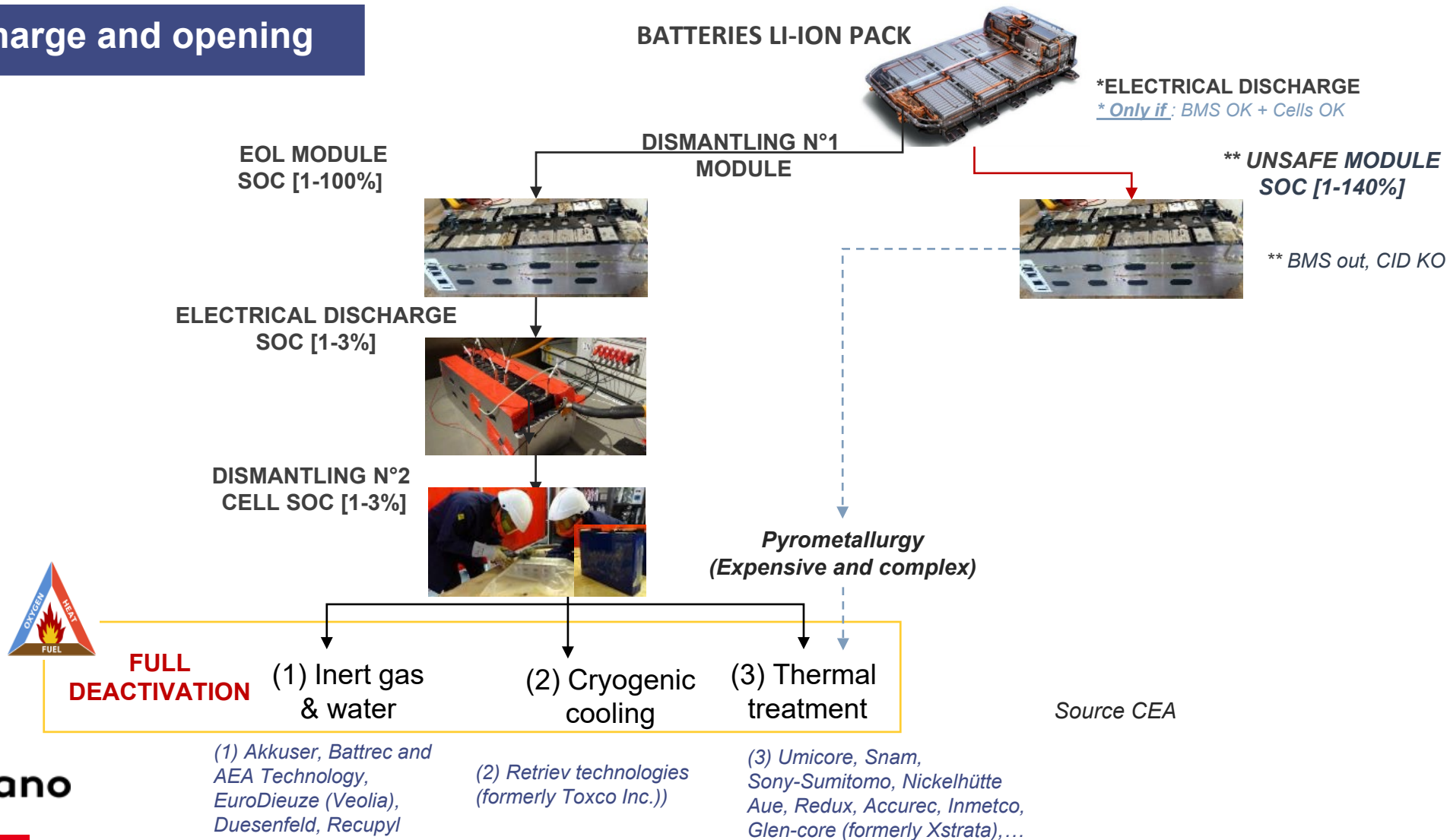


● Orano's activities ● CEA's activities ● Partners' activities ● Innovations & patents



# Deactivation

## Discharge and opening



Source CEA





# Deactivation

## Discharge and opening

### Safe Deactivation at module level without manual dismantling

#### ORANO/CEA Process

- Mix of spent LIB battery modules
- **Several chemistries** : LFP, NMC, NCA, LCO//G, Gsi),
- No thermal treatment (no material degradation),
- No explosion
- **Diversity of battery modules** (busbars, connector type,..)
- **Treatment of unsafe batteries** (CID KO, high reactivity,..)
- **No reactive consumption -> low cost process**

**Disruptive  
innovation**



# Deactivation

ORANO trusted the CEA  
R&D funding on the techno brick then maturation via common lab

**2019**

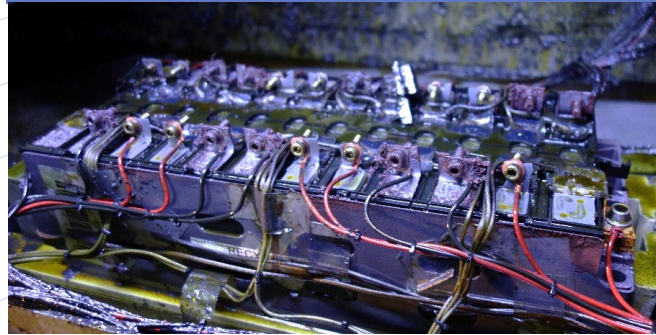
**TRL2**

**1st technical proof of concept  
of the new deactivation concept  
at CEA lab**

**Patents Pending** 💡

**2020**

Technology Maturation  
on cells and modules



*Batterie abusive testing lab*

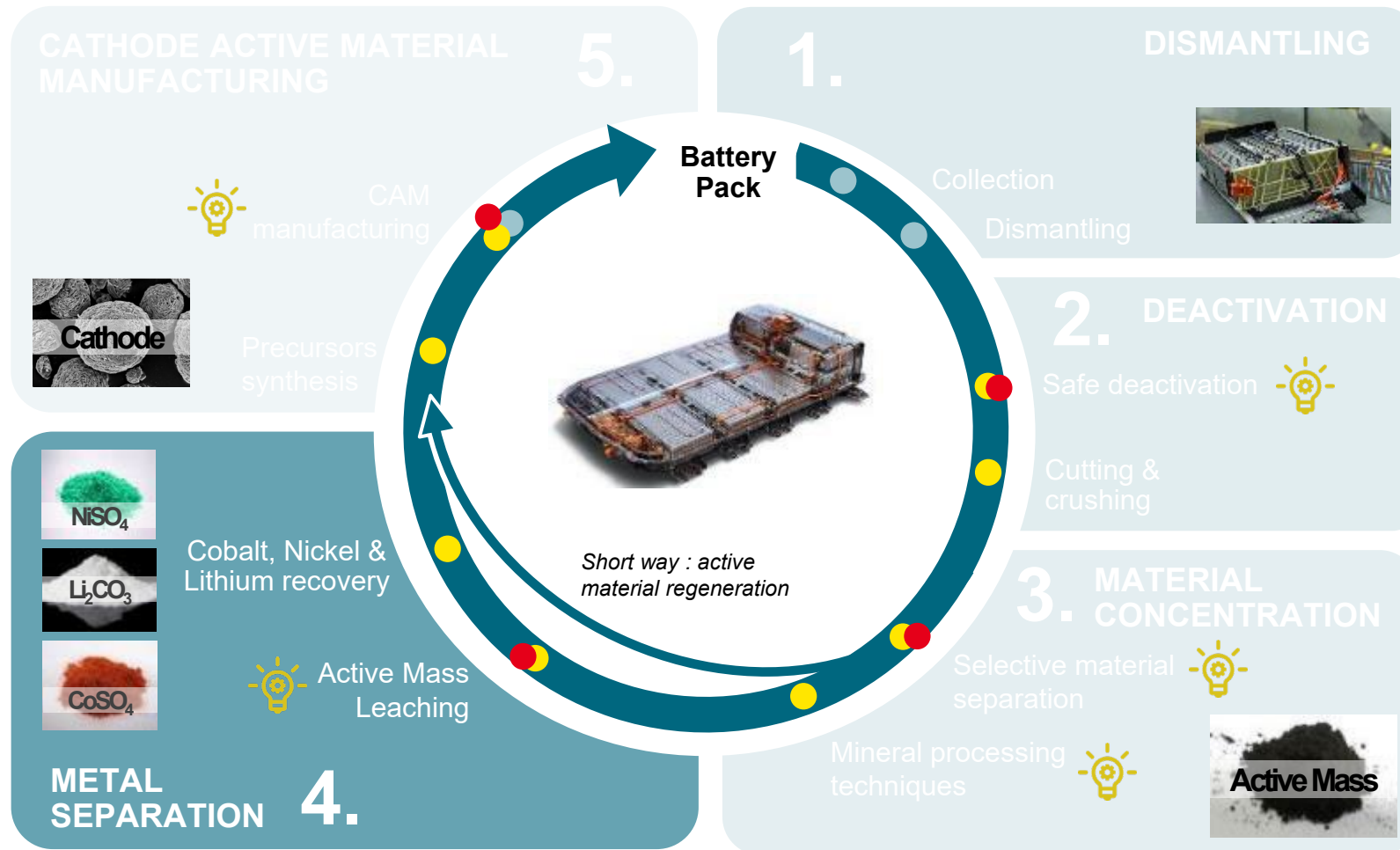
**2022**

**2023**

Technology Transfer  
on ORANO pilots  
CIME (Bessines, France)



# ORANO/CEA work illustration on HYDROMETALLURGY



- High recovery rate process
- Recovery of battery grade salts
- A full hydrometallurgical process



● Orano's activities   ● CEA's activities   ● Partners' activities   ● Innovations & patents



# Hydrometallurgy for the metals recovery



**Hydrometallurgy: core business, existing pilots**



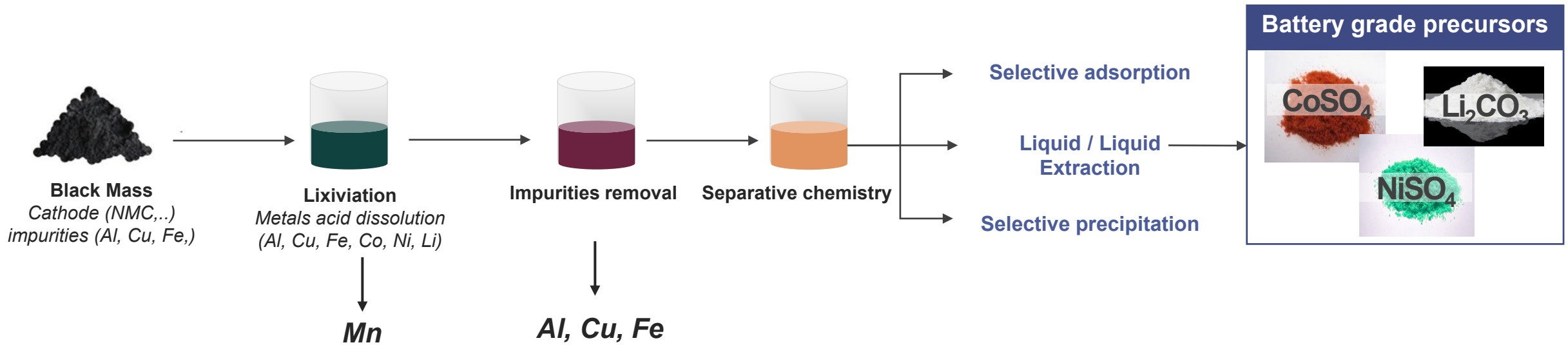
## Contribution

- **Reduce separation costs**
- **Understanding of physical-chemical mechanisms for process optimization**



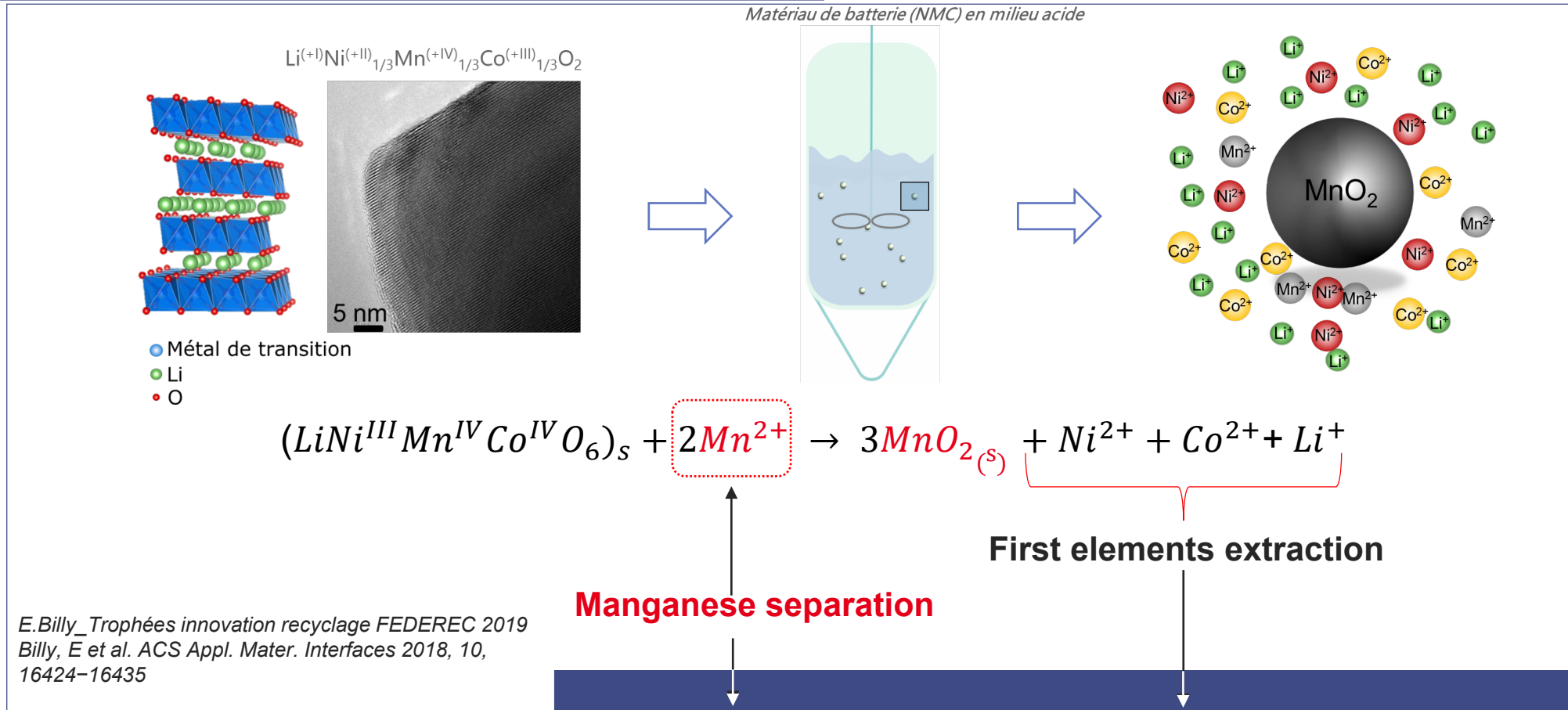
# Hydrometallurgy for the metals recovery

Main challenges is to reduce separation costs to obtain battery grade precursors



# Hydrometallurgy

From lab research to industrial application...



E.Billy\_Trophées innovation recyclage FEDEREC 2019  
 Billy, E et al. ACS Appl. Mater. Interfaces 2018, 10,  
 16424–16435

Combine 2 complex and environmentally expensive steps

# Hydrometallurgy

Implementation of a disruptive recycling process

**40%**

*Effluents reduction*

**35%**

*Steps numbers  
reduction*

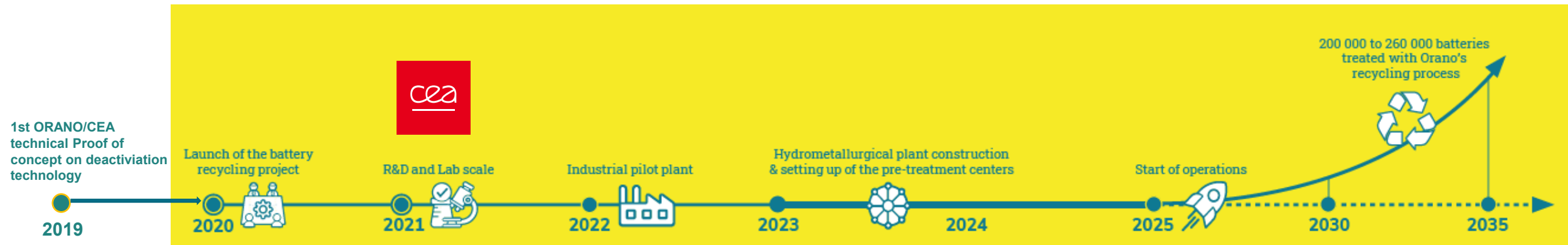
**40%**

*Chemical reagent  
quantity reduction*



# With CEA Support, Orano is on track to enter the EV battery recycling business by 2025 with a roadmap from lab to large scale industrial plant

## Roadmap:



***ORANO/CEA's collaboration accelerates the project***





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**Thank you for your  
attention**

*Véronique PERES, Orano  
Marlène CHAPUIS, CEA-Liten*

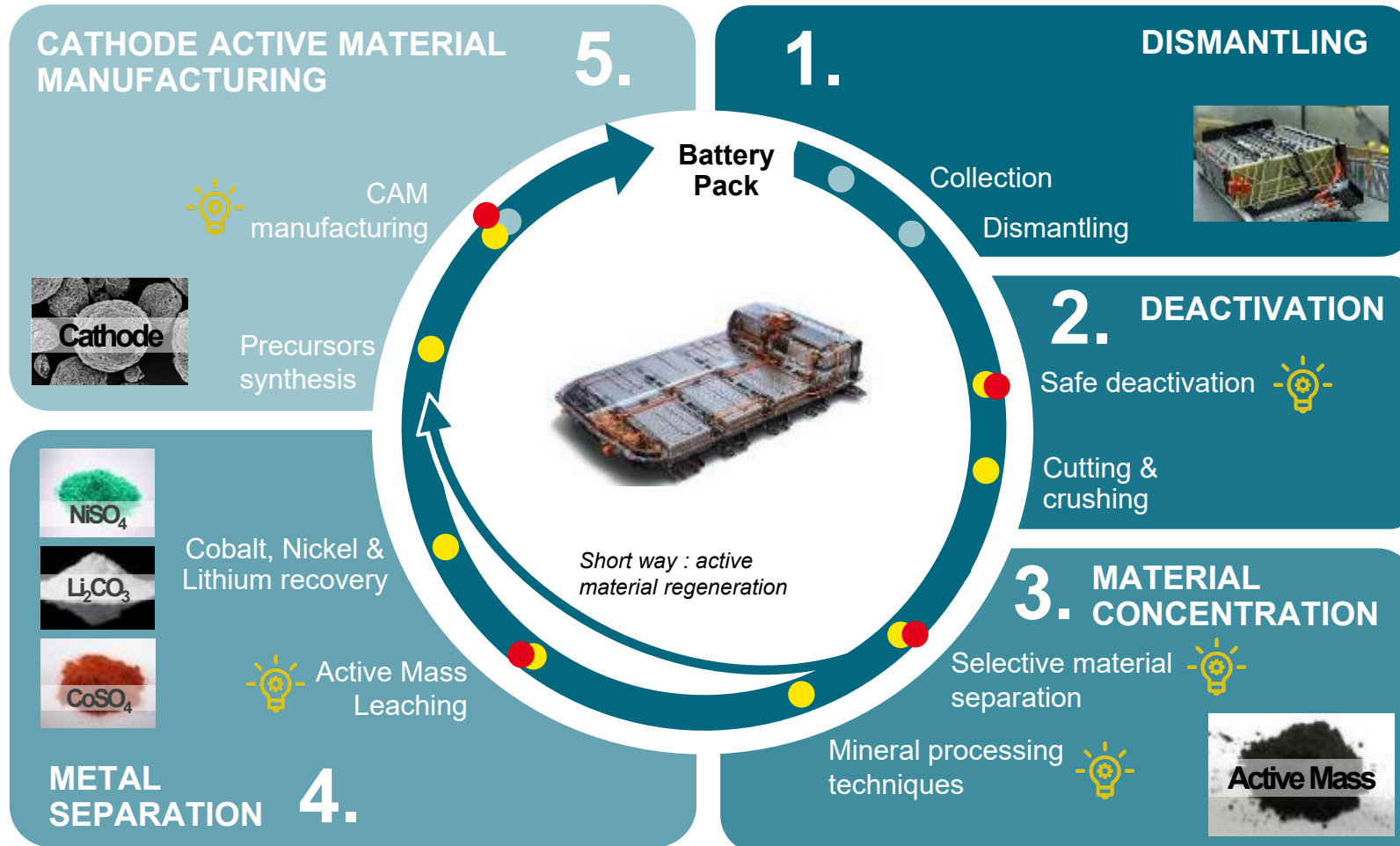


# Orano shall be integrated in the closed loop of lithium-ion battery, by developing an efficient & cost-effective recycling process



- Recycled materials **reusable** in the EV battery cycle
- Enable to comply with **circular economy** and EU objectives

- High recovery rate** process
- Recovery of **battery grade salts**
- A full **hydrometallurgical** process



- Disruptive way to safely** deactivate the module : avoid thermal treatment, no gas generation, no explosion
- Battery discharge at **module level**
- Low-cost process with no reactive consumption
- A versatile process** for all chemistries : NMC, NCA, LCO, LFP
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