A STEP TOWARDS EUROPEAN AUTOMOTIVE BATTERY PRODUCTION

Project eCAIMAN

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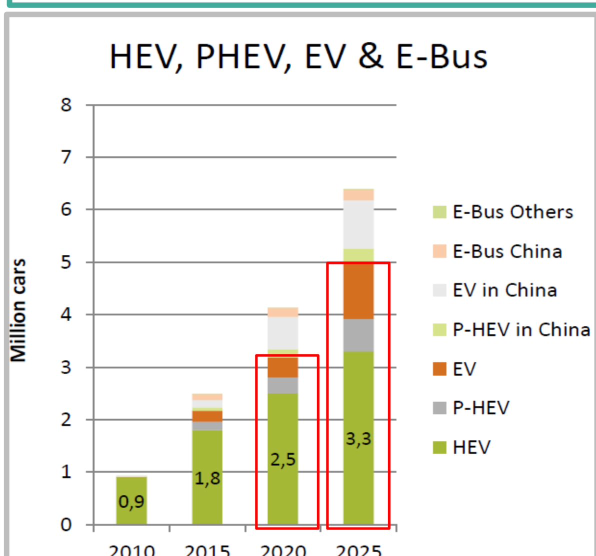
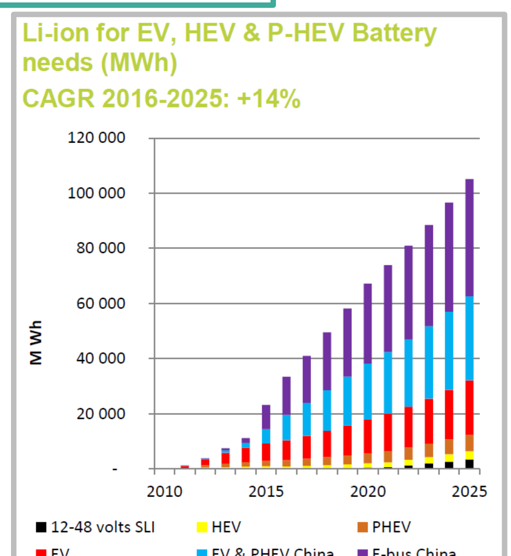
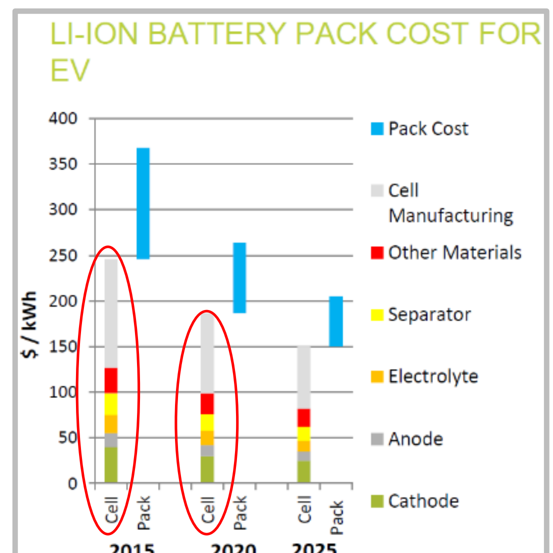
WHY CONSIDER EUROPEAN LI-ION CELL PRODUCTION?

- **Current situation**
  - Asian share of Li-ion **cell** manufacturing market >80%
  - European automotive battery production covers only one part of the value chain

- **Market development**
  - Upto 5-10% market share for electric passenger cars envisaged by 2020
  - Market penetration 20% for EVs and PHEVs by 2030
  - Cell represents >50% of module/pack level cost



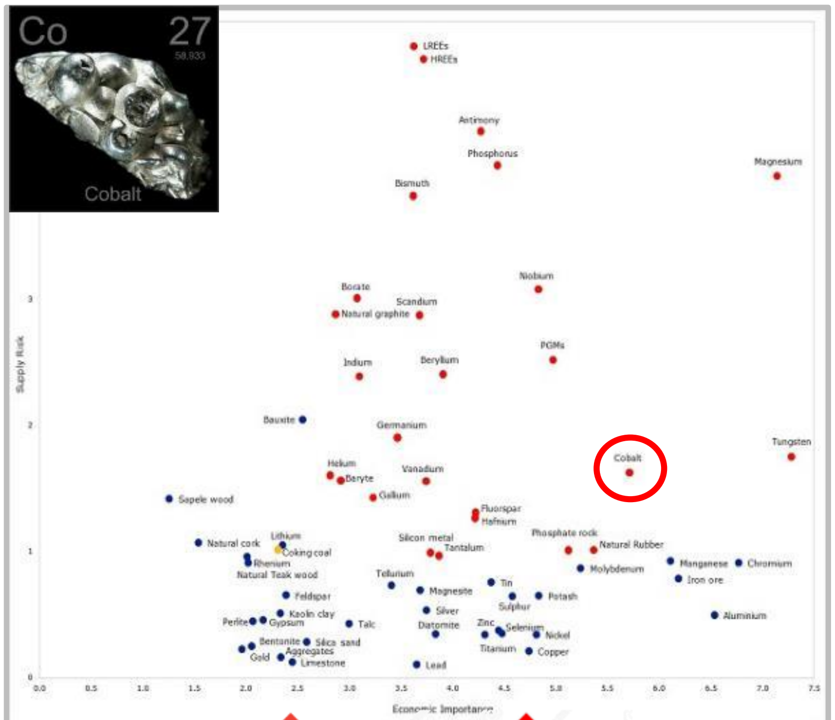


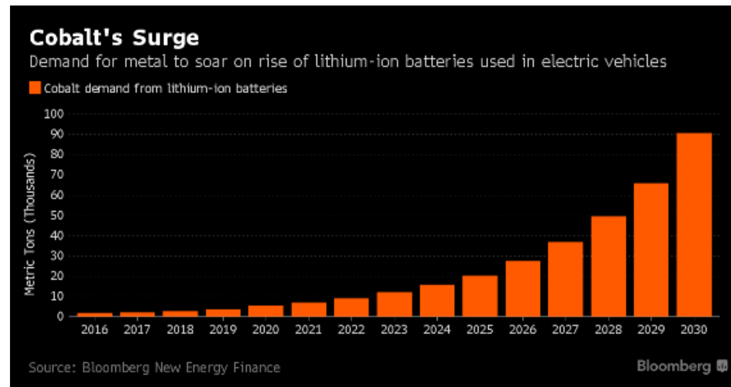


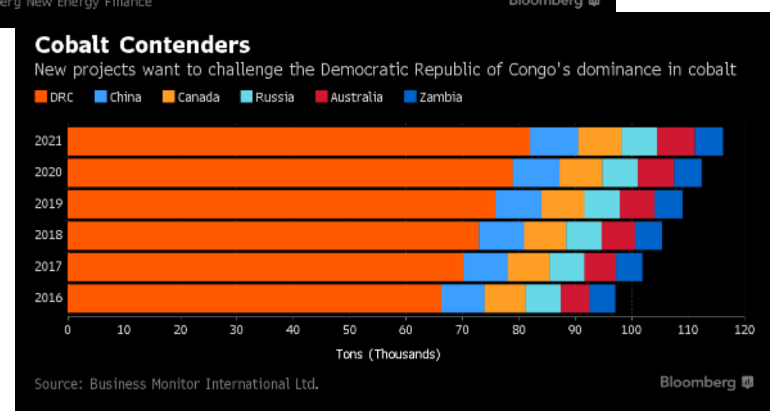
Source: Avicenne Energy 2017

WHY CONSIDER
EUROPEAN LI-ION CELL PRODUCTION?

- **Supply Chain – Cobalt as a Critical Raw Material**



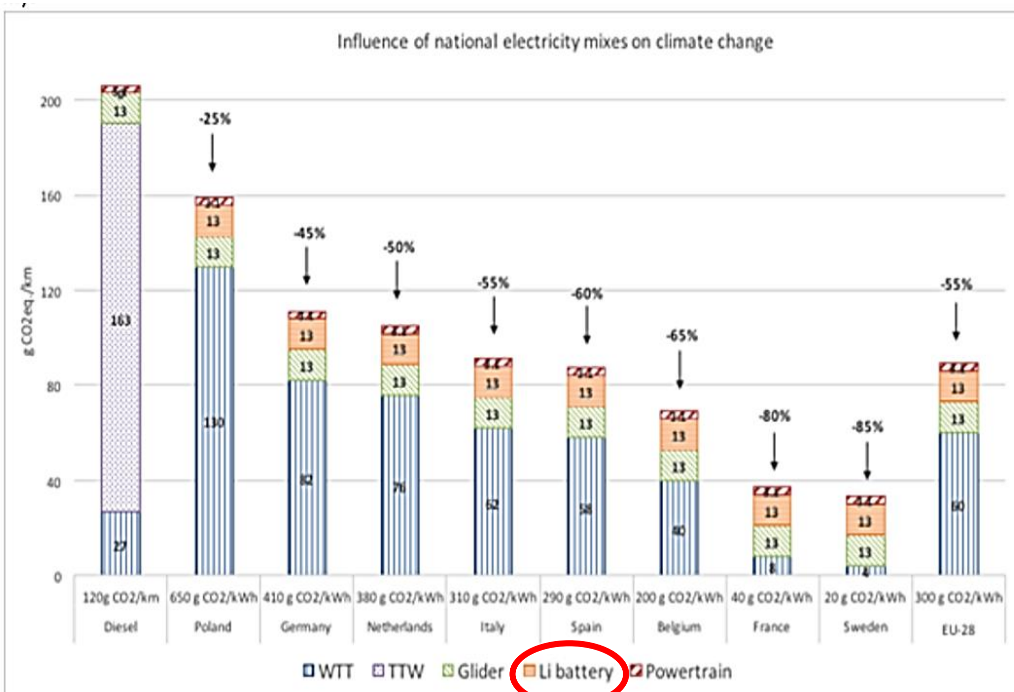




- >50% of the world cobalt production comes from Democratic Republic of Congo
- Co-compounds are highly toxic and eco-toxic.

WHY CONSIDER EUROPEAN LI-ION CELL PRODUCTION?

- Battery will be an increasingly important contribution to **xEV lifecycle emissions**
- **Electricity mix** for battery production



Source: Electric Vehicle Life Cycle Analysis and Raw Material Availability, Transport & Environment, October 2017

- **Other considerations**
  - (Small) OEM access to cells
  - Europe needs to bring a novel product (something else/new/better) than what is already there >> 5V batteries, HV electrolytes
  - Standardisation, recycling
  - „If nothing is done, European ideas will remain as R&D“

eCAIMAN

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Electrolyte, Cathode and Anode Improvements for Market-near Next-generation Lithium Ion Batteries

PROJECT OBJECTIVES

- The objective of eCAIMAN is to bring European expertise together to develop an automotive battery cell that meets the following demands:
  - energy density of 270 Wh/kg
  - cost of 200€/kWh
  - can be produced in Europe

CONSORTIUM

RTOs and academic

- AIT Austrian Institute of Technology – Tomorrow Today (Coordinator)
- cidetec energy storage
- cea
- CERTH
- RISE
- Politecnico di Torino

OEMs

- CRF Centro Ricerche Fiat
- Piaggio Group
- Volvo

Industrial/pilot

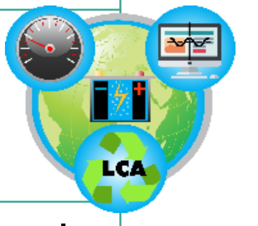
- Imerys
- Arkema
- Lithops

Dissemination, LCA

- eu|te|ma Technology Management
- thinkstep

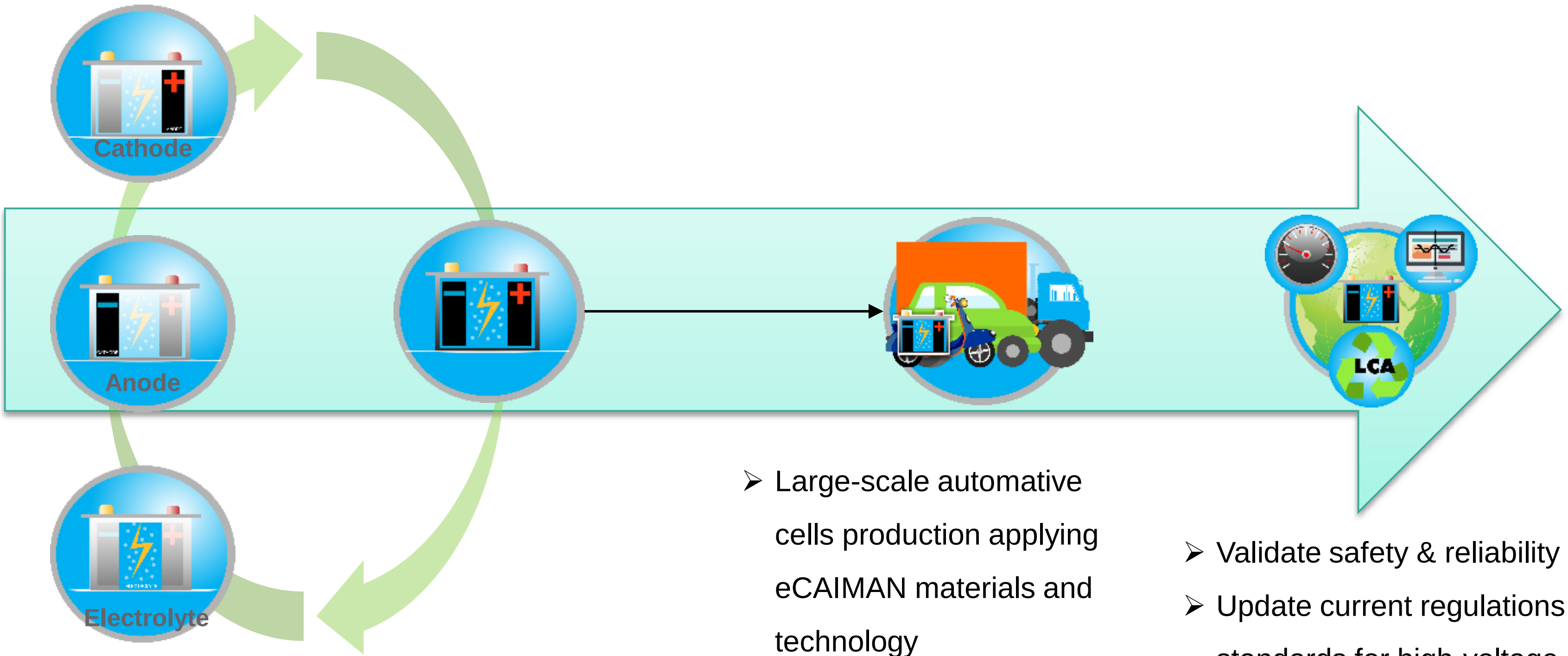
This project is co-funded by the European Union‘s Horizon 2020 program under grant agreement no. 653331

ADDRESSING USER REQUIREMENTS

User requirement	eCAIMAN
Range, cost	• Material characteristics / optimisation of the electrochemistry • Flexible module design 
Competitiveness	• Materials development from a strong European industrial base • Scale-up manufacturing on industrial scale • Investigation of vehicle integration 
Safety, reliability, Durability, recyclabiltiy	• Modeling of ageing mechanism • Greener (aqueous) chemistry • LCA 
Development of test procedures and standards	• Update current regulations and standards for high-voltage batteries • Coordination with other GV1 projects

PROJECT APPROACH

Development of Active Cell Components (WP1-3)	Cell Harmonization, Electrode Engineering (WP4)	Proof of Concept: Module Design & Peripheries (WP5)	Testing, Evaluation and LCA/LCC (WP6)



- Industrialise 5V spinel cathode material
- Industrialise high-capacity anode material
- Industrialise a stable high-voltage electrolyte

- Large-scale automative cells production applying eCAIMAN materials and technology
- Investigate integration into light, passenger and heavy duty vehicles
- BMS/electronics update for high-voltage concept

- Validate safety & reliability of the cells
- Update current regulations and standards for high-voltage batteries – aim for int'l standardization
- Assess economic/ecological aspects by LCC/LCA

CATHODE: CHEMISTRY SELECTION

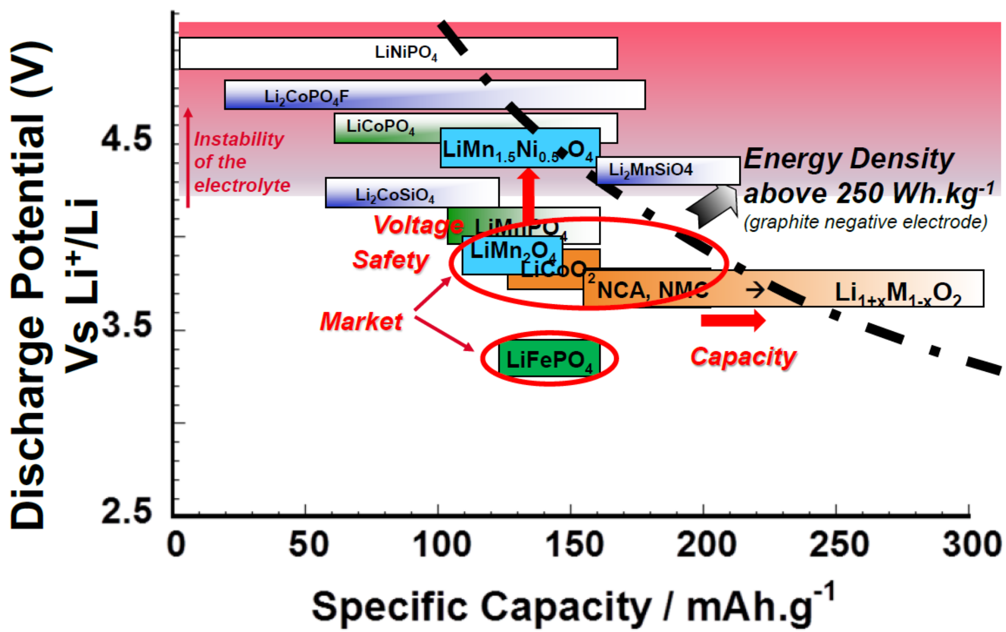
$LiMn_{1.5}Ni_{0.5}O_4$ (**LMNO**) is **promising positive electrode** material for high-energy density Lithium ion batteries:

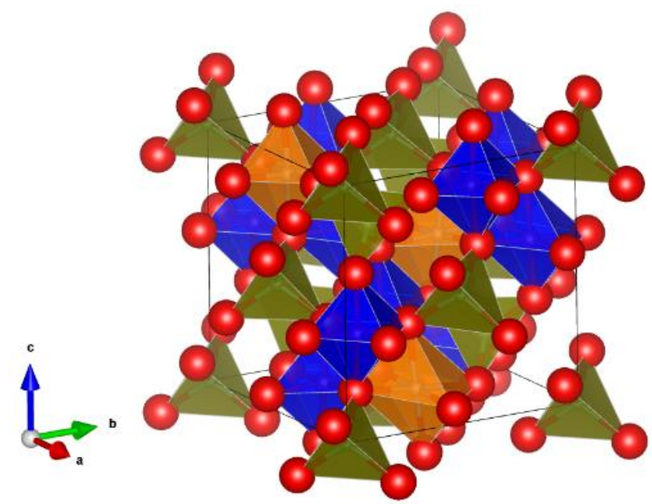
- **Cobalt free**
- 3D lithium-ion diffusion paths
- High operating voltage of 4.8 V
- Theoretical capacity of 147 mAh/g
- Theoretical energy density 700 Wh/kg

<u>**Drawbacks**</u>:

High operating voltage of $LiMn_{1.5}Ni_{0.5}O_4$

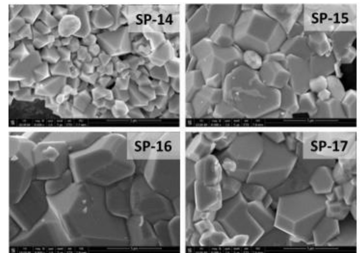
- challenges the electrochemical stability of the electrolyte (gas formation)
- induces interfacial side reactions
- irreversible capacity loss
- poor cycling performance
- safety issues

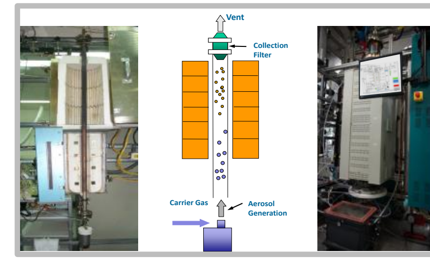




Ordered structure of LMNO: the green tetrahedra, blue and orange octahedra indicate respectively the LiO_4, NiO_6 , and MnO_6 polyhedra.

CATHODE





Characterisation

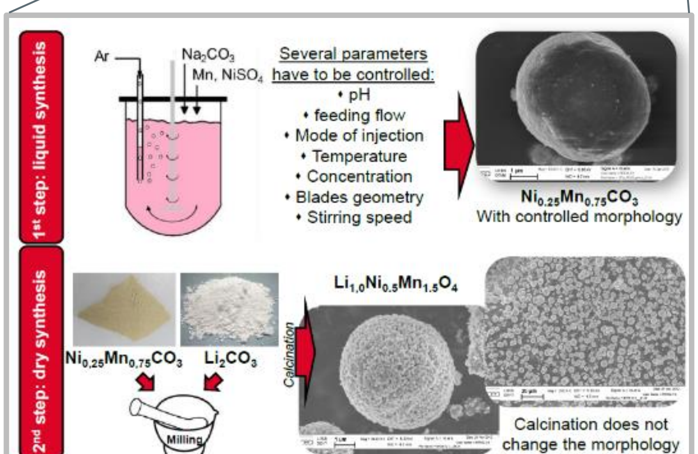
(Raw materials) → Synthesis → Structure Modification → Surface Treatment → Upscaling

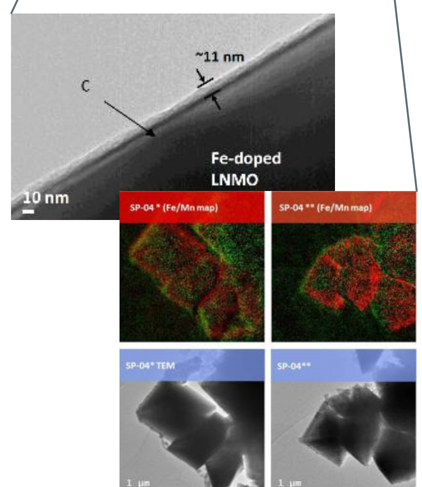
Synthesis
- 9 synthesis strategies
- Three selected

Structure Modification
- 5 dopants
- Two selected

Surface Treatment
- 12 coating approaches
- One selected

Upscaling
- From lab scale to pilot scale
- Pouch cells





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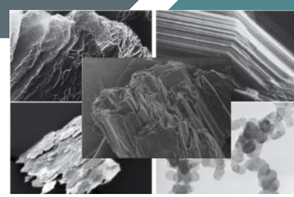
ANODE

Modified synthetic graphite to be processed with acqueous biners

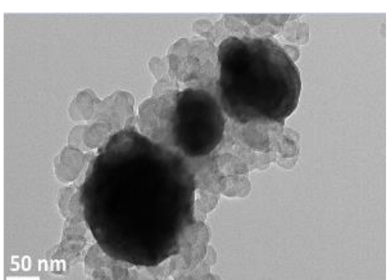
Commercial graphite → Project: Advanced Graphite → Upscaling



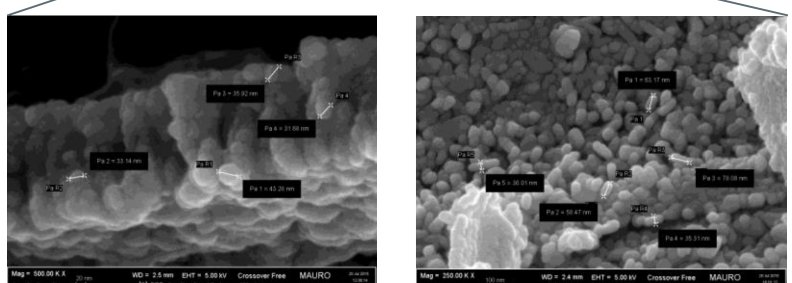
~100 pouch cells → Module

SnO2 as alternative anode

Increase conductivity of commercial samples → Production of pure and doped nanoparticles → Proof of concept at lab scale



SnO_2: carbon black
3:1



Left: FESEM image of pure SnO_2
Right: FESEM image of SnO_2 doped with Cu

Coin cells
1-2 pouch cells

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ELECTROLYTE: OBJECTIVES

To improve the performance of high voltage lithium ion batteries in developing tailored coumponds for new and/or improved electrolyte formulations

Main issues : degradation of standard electrolytes at high potentials

Description

Reference electrolyte : 3EC/7EMC 1M $LiPF_6$ +2% FEC

1) Optimisation by substituting additives or salts
2) Development of tailored electrolytes from alternative solvents to carbonates

⇨ Electrochemical evaluation in coin cells and post-mortem analysis

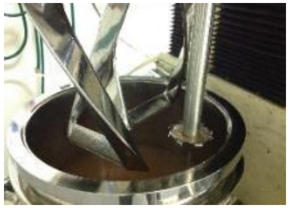
Solvents → Additives → Salts → Upscaling

Major challenges

- Low electrochemical stability of carbonates
- High production of gas under functioning conditions
- the transition metal ion (Mn^{2+}, Ni^{2+}) dissolution for spinel cathodes like $LiNi_{0.5}Mn_{1.5}O_4$

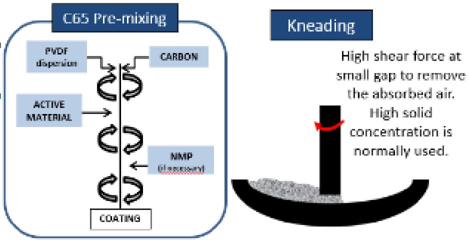
CELL HARMONIZATION

- **Goal: optimize electrochemical performance on full cell level**
- **Inactive components:** Binders, conductive additives, separators, current collectors,…



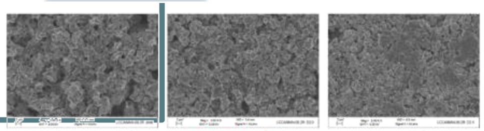
Electrode formulations

- **Components selection** and **manufacturability assessment**



Slurry and electrode engineering

- Optimization of slurry rheology via **formulation**;
- **Mixing strategies** for homogeneous slurry;
- **Drying** conditions & optimum **densification**;
- Evaluation of PVdF kynar blend;
- Slurry **coating scale-up assessment**



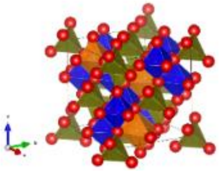
As coated 1.0g/cc | Cal. 2.0g/cc | Cal. 2.5g/cc

Reaction mechanisms at surface/interface

- Degradation mechanisms
- Analysis on swollen cells
- Coated-LNMO characterization

Modelling

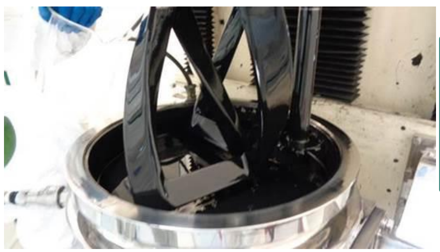
- LNMO electronic structure & DOS by DFT+U started to assess effect of dopants



CELLS: MANUFACTURING

- **Example: some steps in the cell manufacturing process**

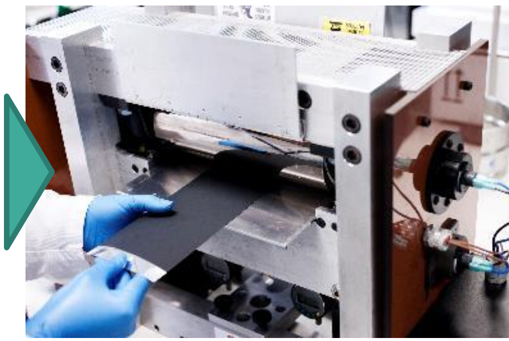
(non-exhaustive)



Slurry preparation

Electrode coating - cathode

Electrode coating - rolls



Calendaring

(Cell assembly, electrolyte filling…)

Pouch cell - welding

Pouch cell

Upscaling parameters identified

CELLS: PROTOTYPES

- **Pouch cells** to be integrated in modules for automotive battery packages

10Ah baseline cell at the beginning of the project with commercial LMNO and electrolyte.

Cell1 (C01L09) after 1 month

Cell2 (C01L10) after 1 month

10 Ah Ecaiman cells with improved materials.

MODULE DESIGN: HARMONIZING OEM REQUIREMENTS

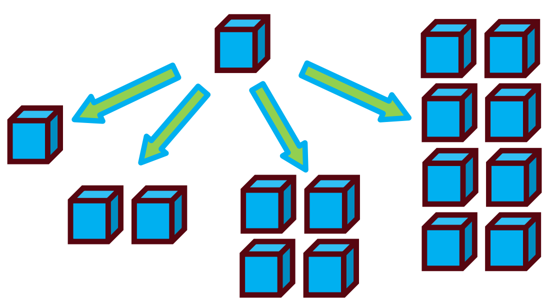
- One of the most challenging aspects has been balancing the technical specifications in order to meet the (very different) needs of every OEM

PIAGGIO

CRF CENTRO RICERCHE FIAT

VOLVO

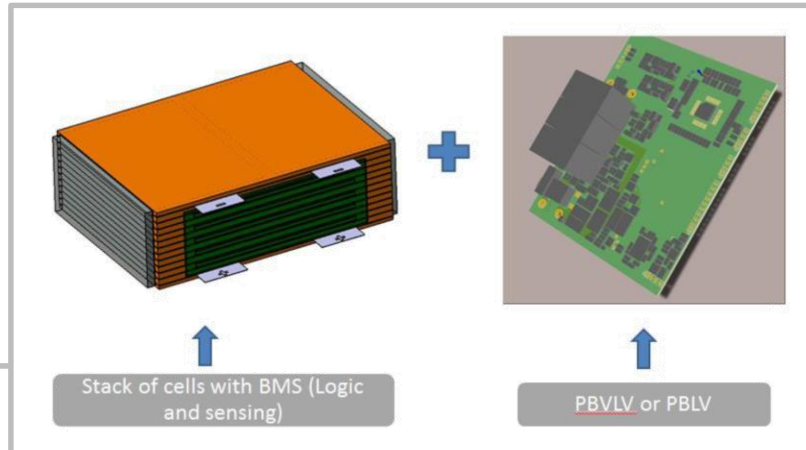
❑ Compact dimensions	❑ Performance	❑ High power
❑ High volumetric energy density	❑ Good range	❑ Robustness
❑ Very low voltage	❑ Battery pack layout	❑ High energy

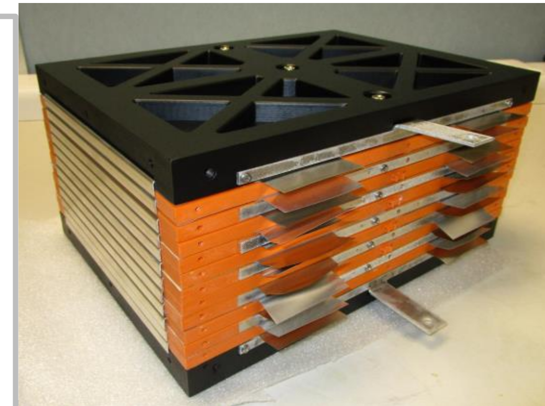


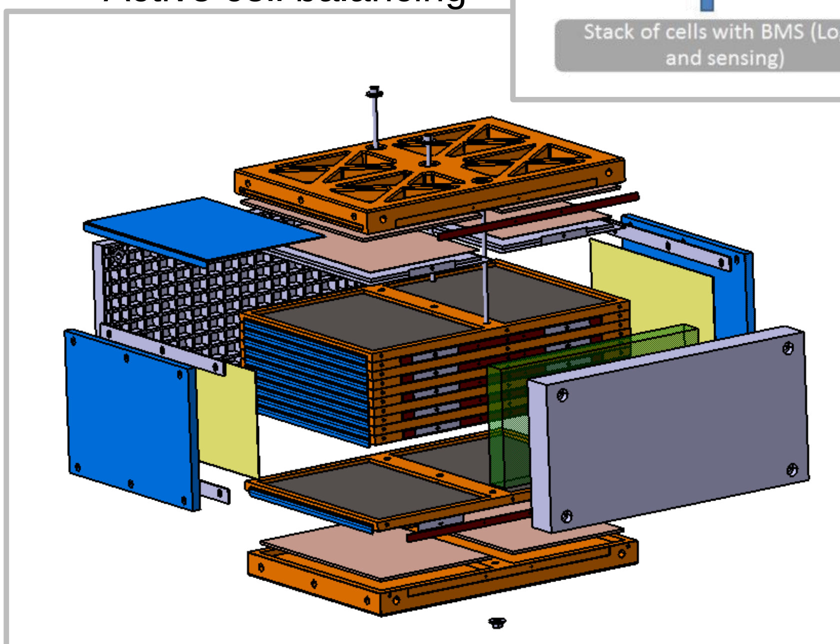
The final idea has been to design a unique battery module that can be used in **series/parallel configuration** to get complete battery pack

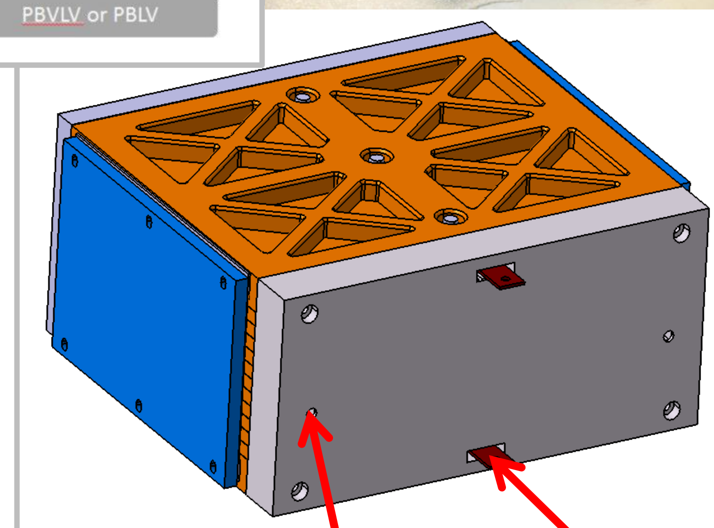
MODULE DESIGN

- 24 cells – 12s2p
- Air or water cooling
- Exchangeable power board for low/very low voltage
- Active cell balancing







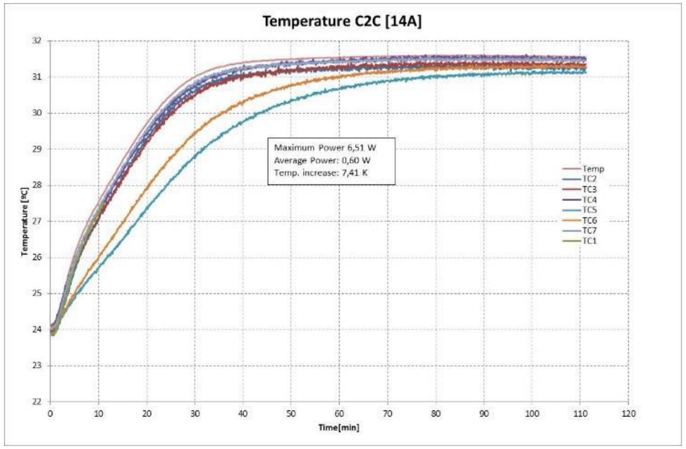


Terminal busbar

BMS+PB fixing plane

TESTING: OBJECTIVES

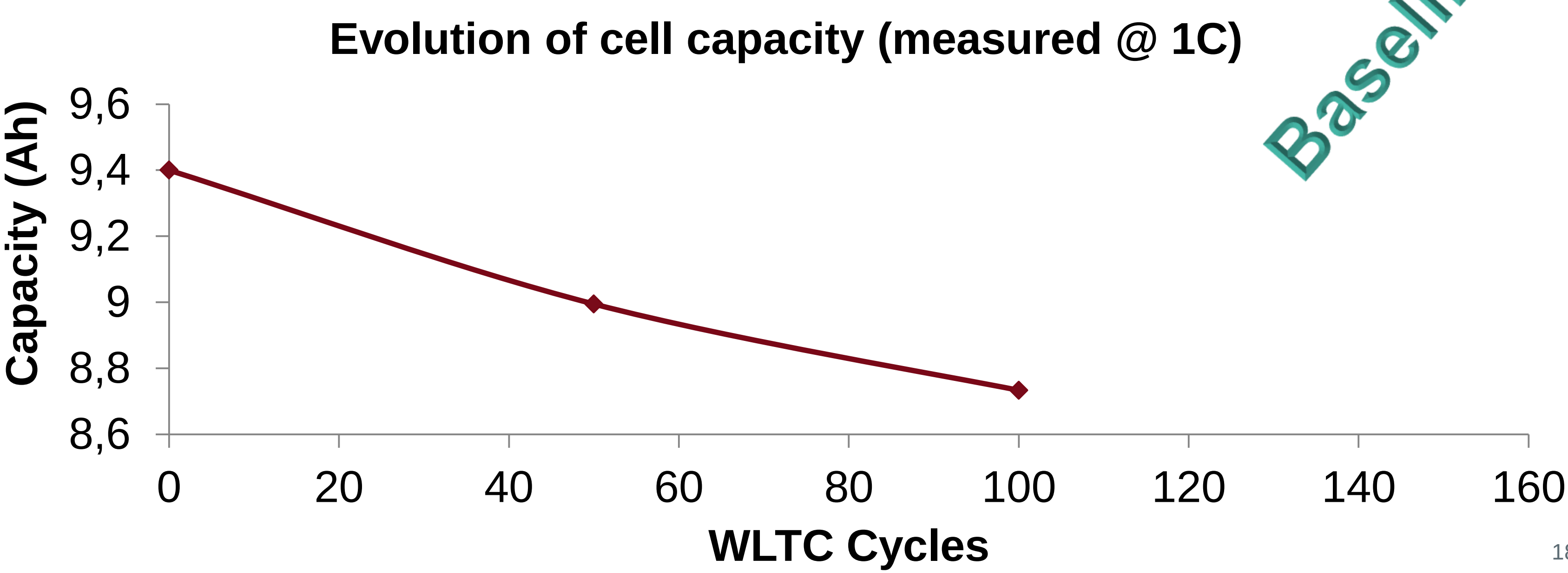
- Test single cells as well as modules with BMS
- Update current testing procedures to meet high energy/high voltage requirements
- Benchmark the new cells
- Investigate lifetime behaviour
- Better understanding of ageing effects based on electro-thermal simulation
- Evaluate safety behaviour
- Build realistic models for future integration of the pack and supporting BMS
- Improve economic and environmental aspects by LCC/LCA and materials roadmap



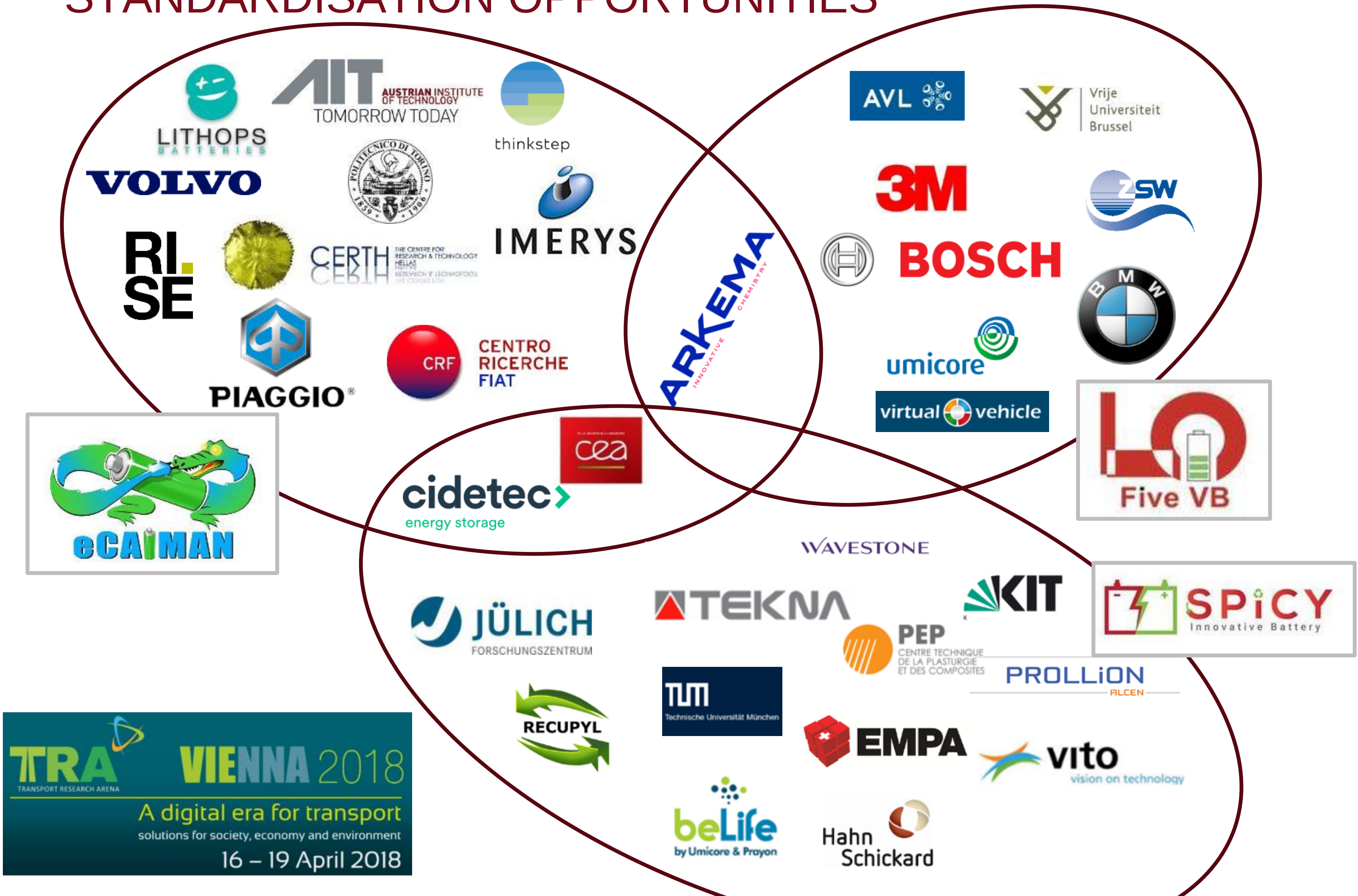
TESTING: EVOLUTION OF CELL PERFORMANCES

WLTC Cycles	Capacity (Ah)	W_{ed} (Wh)	ρ_{edw} (Wh/Kg)	ρ_{edv} (Wh/l)
0	9.4	41.3	91.1	192.8
50	9.0	38.5	85.0	179.9
100	8.7	37.6	82.9	175.5
150	Running	Running	Running	Running

Baseline cells



STANDARDISATION OPPORTUNITIES



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SUMMARY & OUTLOOK

- **Industrial opportunities, supply chain, ecological and policy considerations** for xEV cell production in Europe
- **eCAIMAN is one example** of EU co-funded H2020 projects to stimulate European automotive battery production
- Development of cell chemistry through to module and testing
- **5V prototype cell built**
- Final results pending

- **Challenges**
  - Large number of process parameters to control and harmonize
  - Materials optimization and compatibility (cell harmonization)
  - Scale-up laboratory → pilot
  - Manufacturability (equipment constraints)
  - Meeting automotive requirements energy density ←→ power density, cycle life, safety
- **Commercialisation**
  - 5V cells not commercially available yet; expected in mid-2020s.

THANK YOU FOR YOUR ATTENTION

www.ecaiman.eu

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