3beLiEVe: towards delivering the next generation of LMNO Li-ion battery cells and packs fit for electric vehicle applications of 2025 and beyond

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3beLiEVe at a glance

3beLiEVe responds to the European Union's Horizon 2020 LC-BAT-5-2019 call (*Research and innovation for advanced Li-ion cells (generation 3b)*) aiming at:

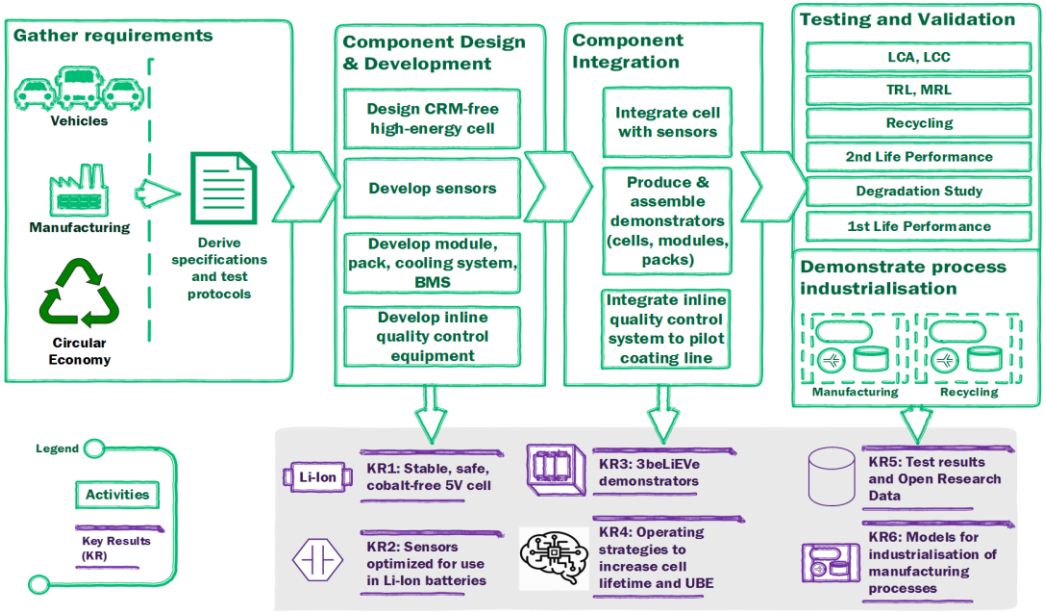
3b generation batteries with LNMO cathode, LiFSI electrolyte, and a 10-20 wt.% Si-C anode in a cell architecture capable of 750 Wh/l, 300 Wh/kg, 1.4 kW/kg, and 2,000+ deep cycles, of which 10% at 3C+;

a portfolio of internal and external sensors and an adaptive liquid cooling system managed by a smart BMS with advanced diagnostic and operational functions;

cradle to cradle approach, including cell/module/pack green manufacturing processes (modelled at gigafactory level), optical equipment for inline quality inspection, 1st and 2nd life performance and recyclability demonstration, achieving 90 €/kWh life cycle cost.

3beLiEVe at a glance

3beLiEVe is expected to run **from January 2020 to June 2023**, with a consortium of 21 European Partners under the coordination of the *AIT Austrian Institute of Technology*, with a total funding of € 10,833,760.



~250 cells of Gen. 3b, organized in 2 battery pack demonstrator of ~12 kWh each at TRL 6 and MRL 8.

3beLiEVe at a glance

3beLiEVe end-user applications (400 V / 800 V – FCA/Volvo):

FCA reference platforms (light duty passenger cars and freight vehicles)

BEV/PHEV passenger cars

A-segment | B/C-segment | D-segment | SUV




2.0 tons **BEV freight vehicles** 3.5 tons


VOLVO reference platforms (commercial vehicles)

PHEV bus

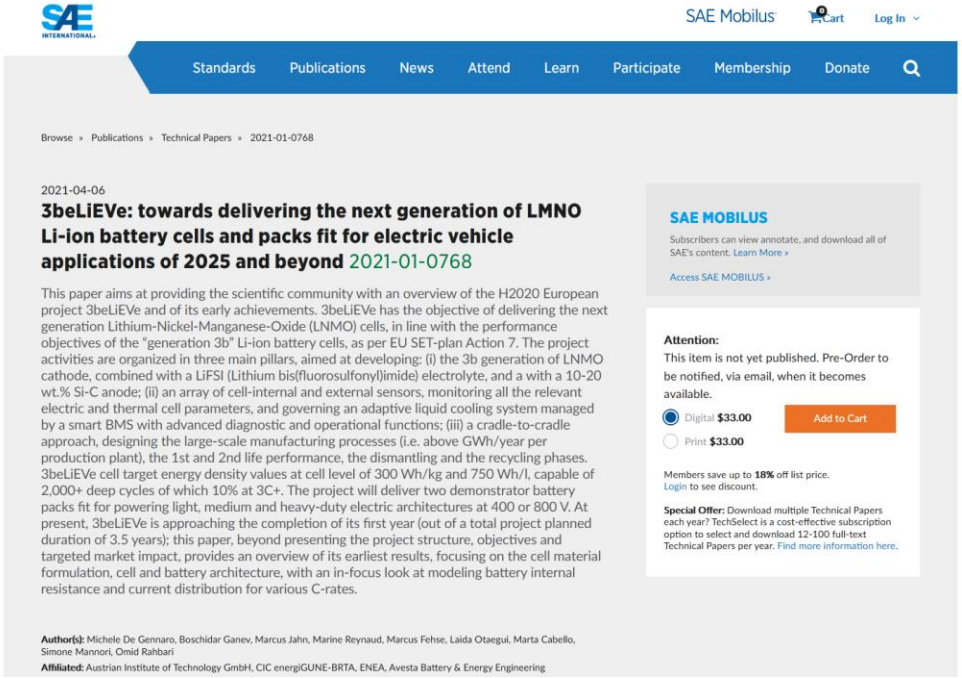
19 tons - 12 m
85 pax.


BEV truck

27 tons

3beLiEVe at a glance

3beLiEVe interim results, as per Project Month #14 (out of 42 months of total duration):



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2021-04-06

3beLiEVe: towards delivering the next generation of LMNO Li-ion battery cells and packs fit for electric vehicle applications of 2025 and beyond 2021-01-0768

This paper aims at providing the scientific community with an overview of the H2020 European project 3beLiEVe and of its early achievements. 3beLiEVe has the objective of delivering the next generation Lithium-Nickel-Manganese-Oxide (LNMO) cells, in line with the performance objectives of the "generation 3b" Li-ion battery cells, as per EU SET-plan Action 7. The project activities are organized in three main pillars, aimed at developing: (i) the 3b generation of LNMO cathode, combined with a LiFSI (Lithium bis(fluorosulfonyl)imide) electrolyte, and a with a 10-20 wt.% Si-C anode; (ii) an array of cell-internal and external sensors, monitoring all the relevant electric and thermal cell parameters, and governing an adaptive liquid cooling system managed by a smart BMS with advanced diagnostic and operational functions; (iii) a cradle-to-cradle approach, designing the large-scale manufacturing processes (i.e. above GWh/year per production plant), the 1st and 2nd life performance, the dismantling and the recycling phases. 3beLiEVe cell target energy density values at cell level of 300 Wh/kg and 750 Wh/l, capable of 2,000+ deep cycles of which 10% at 3C+. The project will deliver two demonstrator battery packs fit for powering light, medium and heavy-duty electric architectures at 400 or 800 V. At present, 3beLiEVe is approaching the completion of its first year (out of a total project planned duration of 3.5 years); this paper, beyond presenting the project structure, objectives and targeted market impact, provides an overview of its earliest results, focusing on the cell material formulation, cell and battery architecture, with an in-focus look at modeling battery internal resistance and current distribution for various C-rates.

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#1: Selection and testing of the cell active materials.

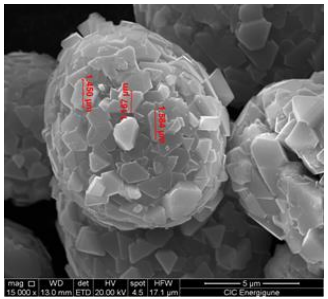
#2: Selection and arrangement of the sensors and design of the architecture of the battery pack.

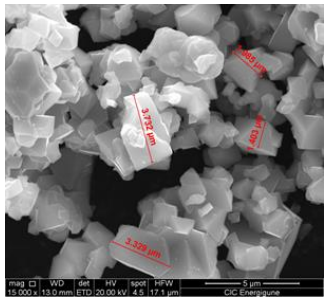
#1: Selection and testing of the active cells materials

Positive electrode material

- High voltage, Co-free LNMO spinel
- Three candidates pre-selected
- Material properties thoroughly characterized
  - TM ordered and disordered
  - Highly pure >99% spinel
  - Ni-deficient
  - Micrometer scale particles

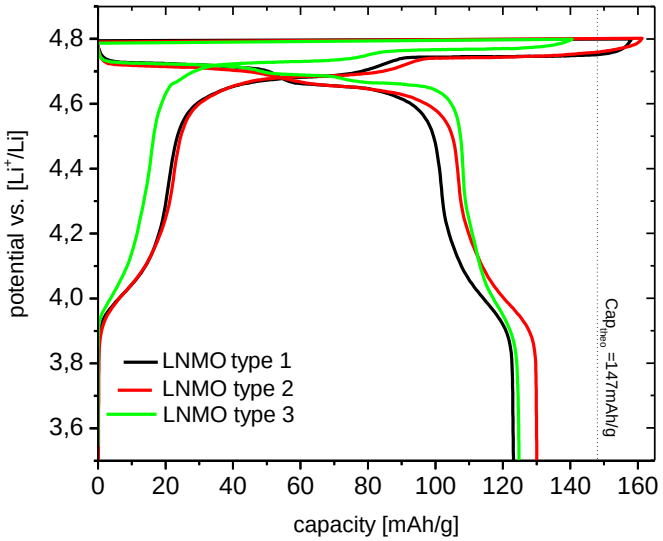
Property	Type #1	Type #2	Type #3	Technique
Phase	spinel, predominantly disordered (*Fd-3m*)	spinel, predominantly disordered (*Fd-3m*)	spinel, predominantly ordered ($P4_332$)	(S)XRD, RS, NMR, NPD, TEM
Impurities	LiNiO	LiNiO	below detection limit	(S)XRD, NMR, NPD
Crystal size	165 nm	310 nm	294 nm	XRD
Morphology	Spherical particles, homogeneous, Φ 10µm	particles 3µm, strong agglomeration	Spherical particles, homogeneous, Φ 8 µm	SEM, Particle sizer
Stoichiometry	Ni/Li: 0,47(1), Mn/Li: 1,53(2)	Ni/Li: 0,47(1), Mn/Li: 1,57(3)	Ni/Li: 0,41(1); Mn/Li: 1,59(3)	ICP, NPD

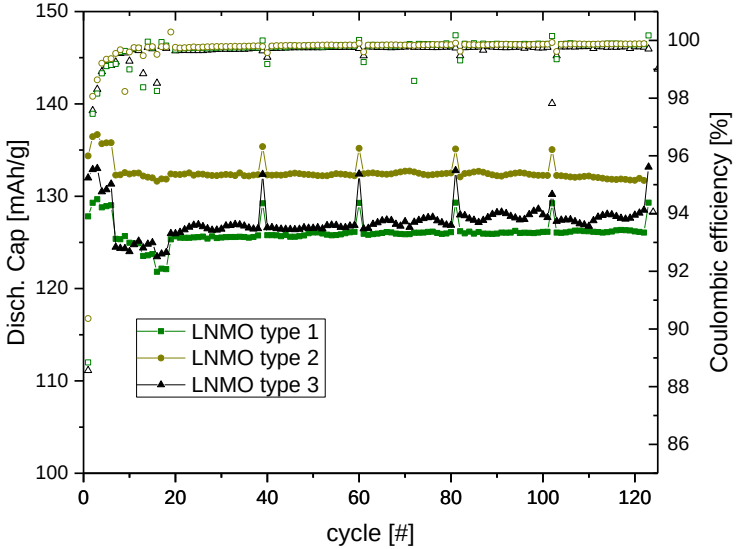




#1: Selection and testing of the active cells materials

Electrochemical characterization in half-coin cells: initial reversible capacities: ~134mAh/g high rate capability: 126mAh/g @ 3C, excellent capacity retention: >99,5% (100 cycles @1C)

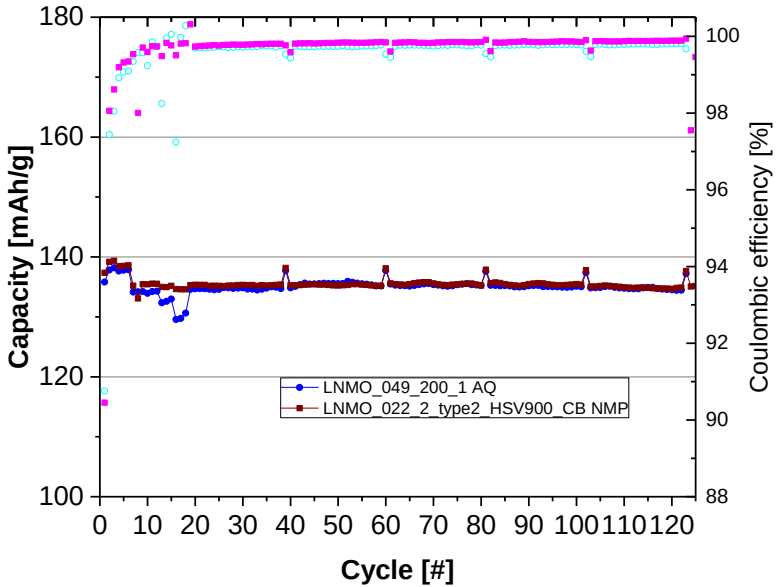




#1: Selection and testing of the active cells materials

Aqueous processing and electrochemical characterization analogous to NMP based:

- Electrochemical signature not affected by solvent
- Similar reversible capacity values obtained
- Equally stable capacity retention



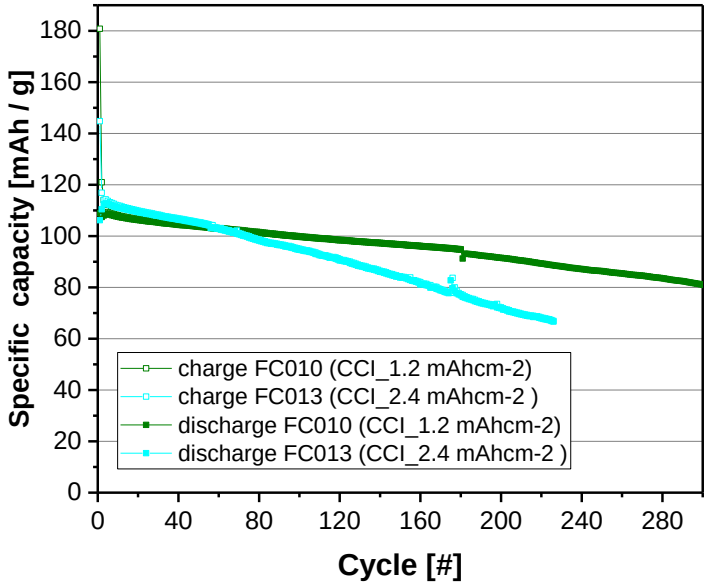
#1: Selection and testing of the active cells materials

Full cell test:

- LNMO//Carbon full cells using specifically designed high voltage electrolyte
  - Initial reversible capacity almost 120mAh/g
  - Capacity fading, 80% SOC after 200 cycles
  - Accelerated fading for higher loading

Next step of 3beLiEVe:

- Determine the cause of capacity fading
- Probe stable electrolyte
- Adjust electrochemical cell parameters to minimize capacity fade



#2: Selection and arrangement of the sensors and design of the architecture of the battery pack

Battery pack design drivers:

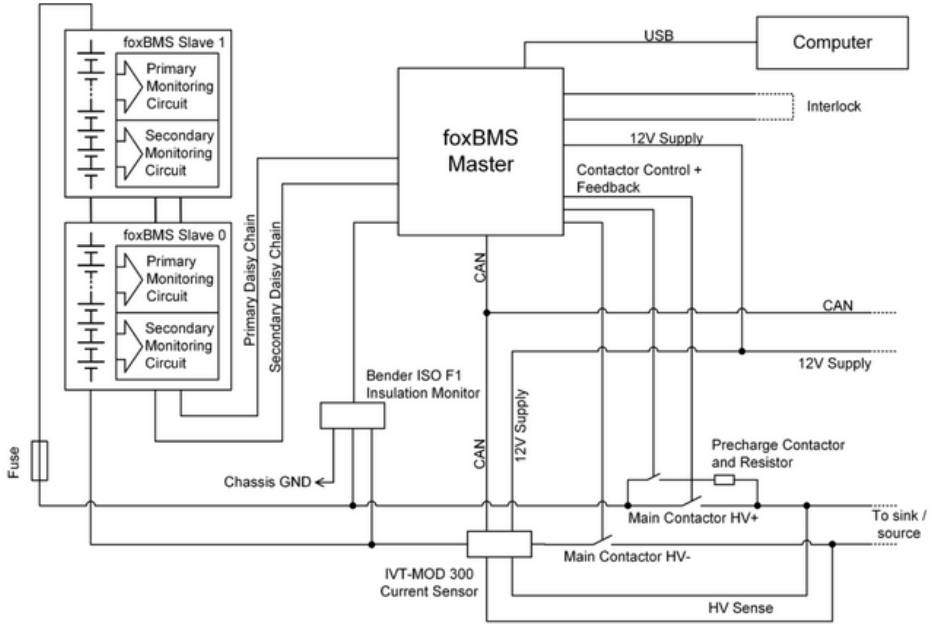
1. the two packs need to reach one-fourth of the targeted nominal voltage (i.e. pack #1 is expected to reach 100 V and while pack #2 is expected to reach 200 V). This allows for four packs to be arranged in series to reach the final desired voltage, while variable capacities can be reached by parallelizing the packs, depending on the applications;
2. both packs need to share the same cell and module design, a key element to drive down the manufacturing costs;
3. each module has a dedicated “sensors package” that matches the serial/parallel arrangement of the cells. The sensor package is designed maximizing redundancy and measurement diversification.

#2: Selection and arrangement of the sensors and design of the architecture of the battery pack

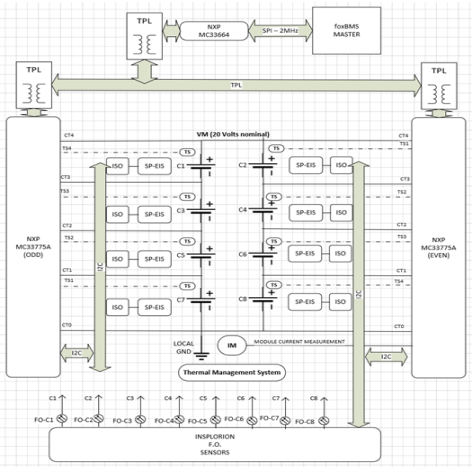
Selected cell and sensors:

- **30 Ah pouch cell format** equipped with:
    - **MC 33775A (external)**: single-chip solution under development by NXP, capable of measuring the individual voltage of a string of cell in series (from 4 to 14) and up to up to eight temperature points.
    - **Insplorion opto-electronic sensor (internal)**: physical sensor is an optical fiber designed to be sensible to the Li-ion concentration, from which one can compute the State of Charge (SoC) and State of Health (SoH).
    - **SENSIPLUS chip (external)**: real-time measurements of the internal impedance of the individual cell by using lock-in technique for SoC and SoH, plus DC voltage of the cell, temperature and mechanical strain.

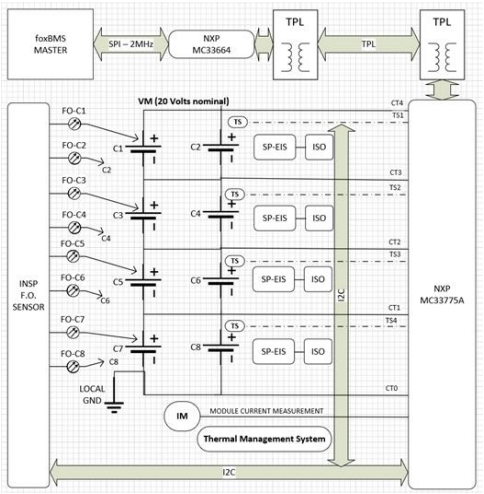
Selected BMS (foxBMS – master/slave architecture):



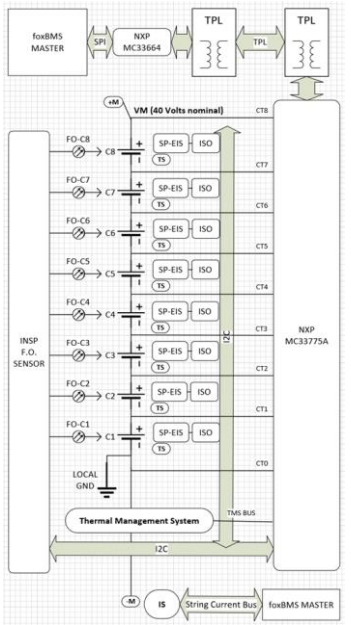
#2: Selection and arrangement of the sensors and design of the architecture of the battery pack



2 × 4S-1P module design
(candidate #1)



4S-2P module design
(candidate #2)

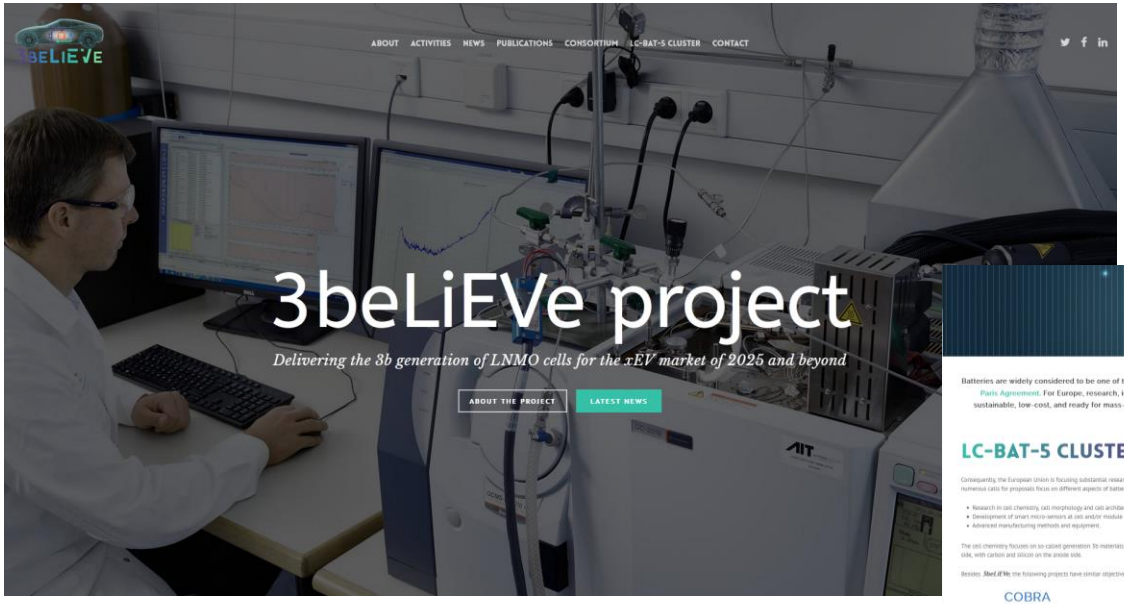


8S module design
(candidate #3)

3beLiEVe choice

3beLiEVe website and contacts

www.3believe.eu



Consortium Information

Consortium: **21 organizations | 10 countries** | 2 vehicle OEMs | 5 RTOs | 1 university | 4 SMEs | 9 large enterprises

Speaker Information

- Michele DE GENNARO
- Senior Scientist @ the Austrian Institute of Technology (Vienna, AT)
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Thank you for your attention

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