Gain Insight on Research Goals:

A Look at the New CBI Technical Roadmap and Technical Program

Dr. Begüm Bozkaya // Senior Technical Manager // Consortium for Battery Innovation

21ABC, 5 September 2025, Kota Kinabalu, Malaysia

CONSORTIUM FOR BATTERY INNOVATION

Journey of Technical Projects

CBI's Technical Roadmap
with KPIs for various applications

Requests for Proposals (RFPs)
addressing KPIs

Review
of the proposals by CBI's Technical Committee

Selection
of highest-scored proposals for funding

Monitoring
of projects' progress by CBI through regular meetings and updates to keep Members informed of research

Final results
are made available to Members

Technical expertise
provided by CBI to Members to help them understand how to utilise research results

Outcomes
are used by Members to improve batteries in the market

New Technical Roadmap 2025

Technical roadmap will:

- guide our future RFPs and all projects in the technical program
- be used as a steering document as we speak to stakeholders
- be technical resource for our members and the lead industry.

The information on the roadmap is generated from:

- membership discussions and interviews
- end users
- market reports, government and non-profit reports (Avicenne, KPMG, US DOE, PNNL, etc.).

New roadmap focuses on:

- Auxiliary and ESS applications – high priority
- other applications like industrial, motive power and e-bikes – priority 2
- new market reports and technical projects.

Auxiliary Applications

CBI Technical Roadmap (draft version) and Technical Program

Types of Auxiliary Batteries and New Terms

Three different categories according to IEC 60095-8

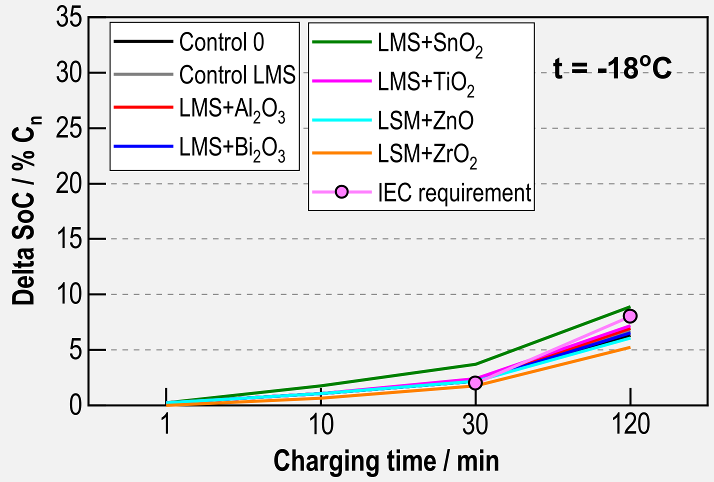
- 12V central storage (main) battery – Category 1
  → most functions of modern automotive batteries except engine starting
- 12V back up battery – Category 2
  → voltage stabilization and emergency power (safety relevant)
- 12V auxiliary batteries in start/stop and microhybrids – Category 3
  → voltage stabilization during engine start (not safety relevant)

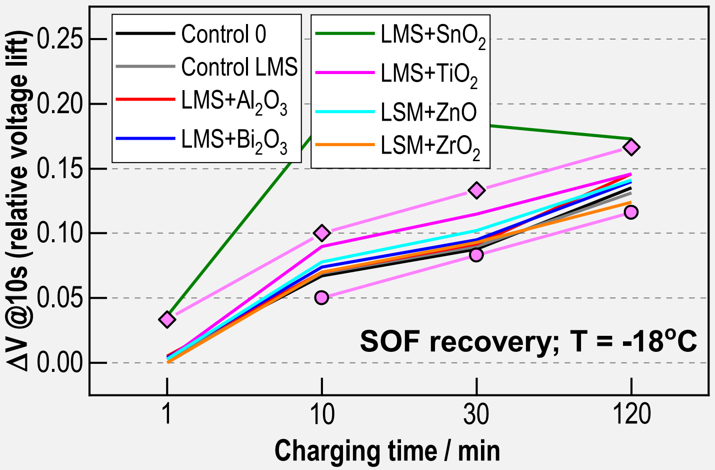
Charge recovery (CR)

- CR determines restoration of power (state-of-function) and energy (state-of-charge)
- CR is measured on a time scale of minutes to hours compared to DCA (recuperation events lasting seconds)

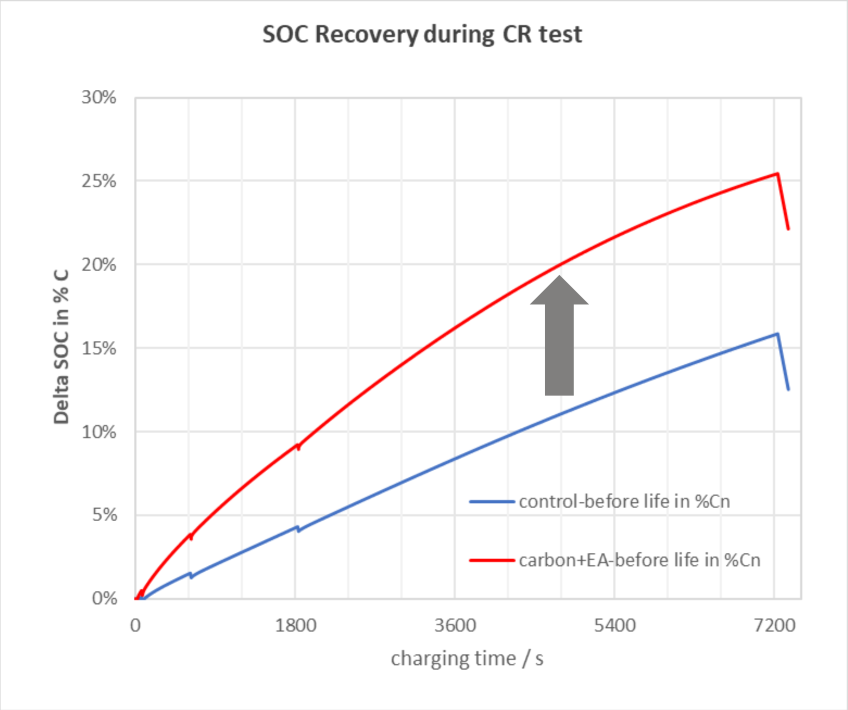
Pulse power characterization (PPC)

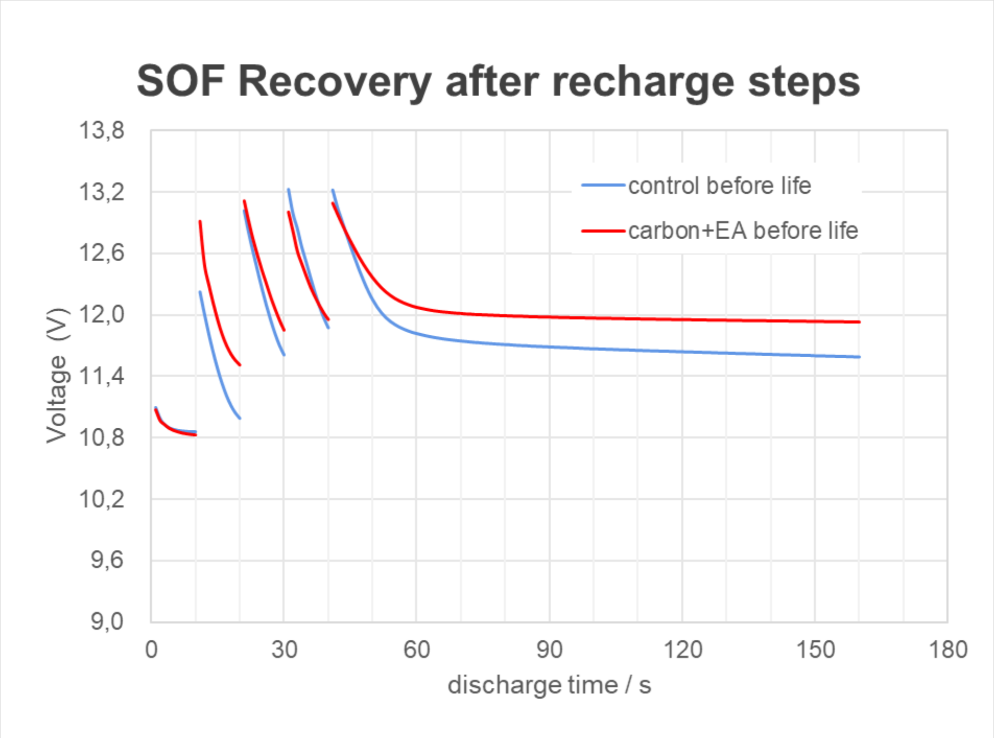
- Engine cranking is not a requested function for auxiliary and back-up batteries
- PPC test is used as an indicator of general power performance
- PPC test includes a sequence of progressively increasing short pulses at constant current at full and PSoC and low temperature





Charge Recovery Test for Auxiliary Batteries

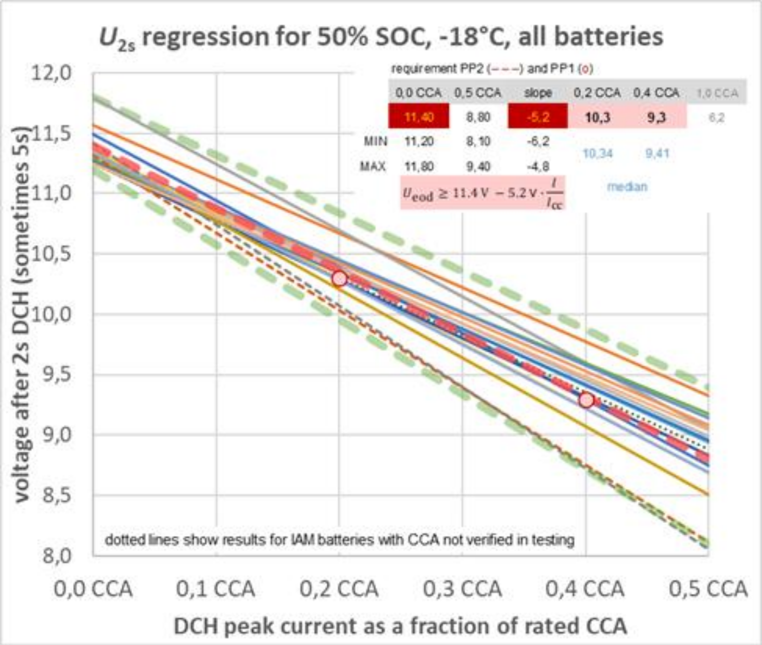


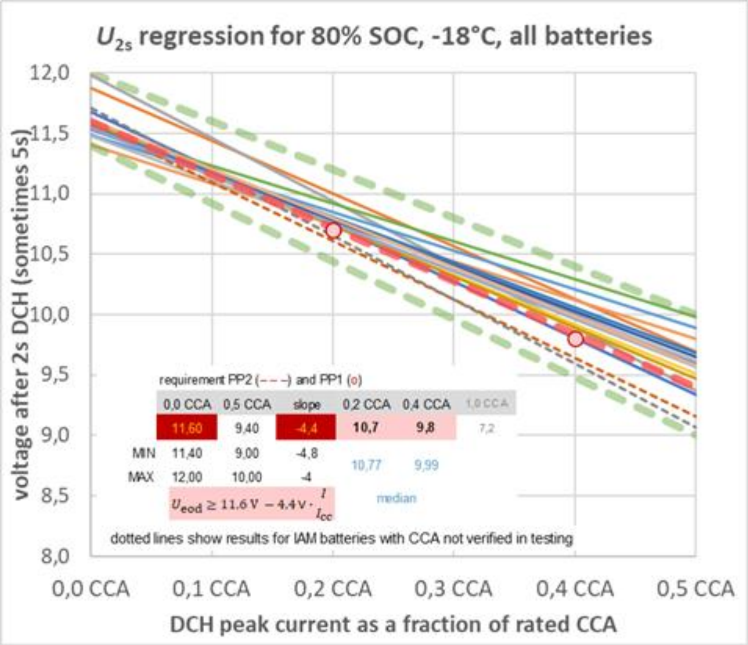


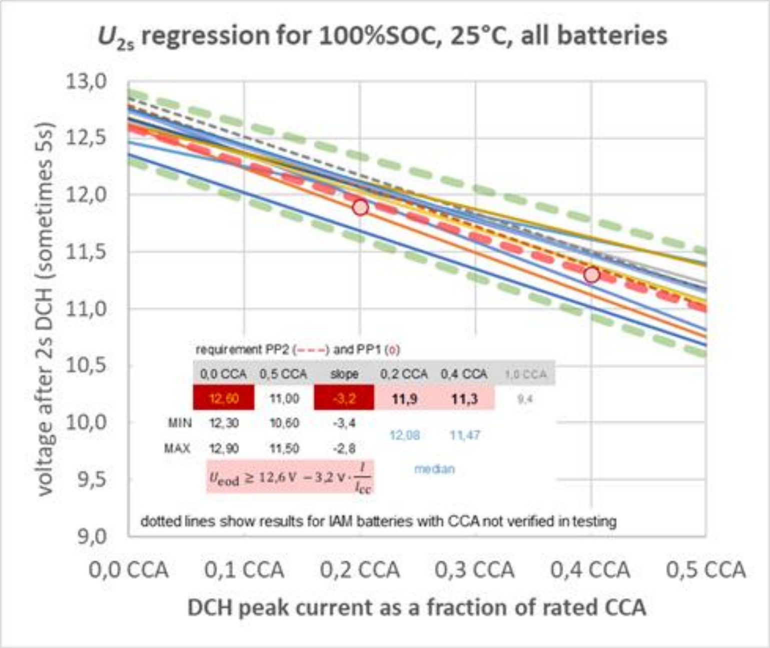
- CR test determines the state-of-charge (SoC) recovery and state-of-function (SoF) recovery -18°C (draft IEC 60095-8)
- SOC recovery is measured after total of 1, 10, 30 and 120 min charge → charge balance is recorded
- SOF recovery measurement involves 10 s discharge pulses after defined charge time → relative voltage uplift is recorded

Graphs: Yu Ping, ALBA Asia 2025, Kota Kinabalu.

Pulse Power Characterization Test for Auxiliary Batteries







- PPC test is the optimized power performance test, as CCA may not be sufficient for auxiliary & back-up batteries
- Test involves two different pulse profiles (PP1 and PP2) and is performed at beginning of life (BOL) and end of life (EOL)
    - Different temperatures & SoC levels w.r.t. battery categories (1,2 & 3) and BOL & EOL
- Requirements should be met according to IEC 60095-8

Graphs: L. Brisotto, ALBA 2025, Turin.

Draft version

Performance Indicators for Auxiliary Batteries

	Performance Indicator		Current (2025)	2027	2030
Research Goals	PPC	Category 1	Within IEC 60095-8 (Tables 18-21) are suggested voltage requirements for PP1 and PP2 pulse profiles conducted at BOL and EOL and at 25°C (BOL) and -18°C (BOL,EOL).		
		Category 2 & 3			
	Charge Recovery	SOC Recovery (30’)	Q(30’) ≥ 4 %C_n	Q(30’) ≥ 12 %C_n	Q(30’) ≥ 15 %C_n
		SOC Recovery (120’)	Q(120’) ≥ 15 %C_n	Q(120’) ≥ 35 %C_n	Q(120’) ≥ 50 %C_n
		SOF Recovery (1’)	$\Delta U_{10s} \geq 0.2$ V	$\Delta U_{10s} \geq 0.5$ V	$\Delta U_{10s} \geq 0.8$ V
		SOF Recovery (10’)	$\Delta U_{10s} \geq 0.5$ V	$\Delta U_{10s} \geq 0.8$ V	$\Delta U_{10s} \geq 1.1$ V
		SOF Recovery (30’)	$\Delta U_{10s} \geq 0.7$ V	$\Delta U_{10s} \geq 1.0$ V	$\Delta U_{10s} \geq 1.3$ V
		SOF Recovery (120’)	$\Delta U_{10s} \geq 0.9$ V	$\Delta U_{10s} \geq 1.5$ V	$\Delta U_{10s} \geq 1.6$ V
Requirements, no longer need development	Static Charge Acceptance at 0°C		Used as a comparison for charge recovery at 0°C.		
	All charge retention, CCA, endurance cycling, vibration resistance, corrosion, water loss		Conform to requirements in IEC60095-8		
	CCA		$U_{10s} \geq 7.5$V; must be on label		
	Service life		5 years	7 years	7 years

Effects of Novel Metal Silicates on Improved Pulse Power and Charge Acceptance Capabilities of Lead Acid Batteries for BEV

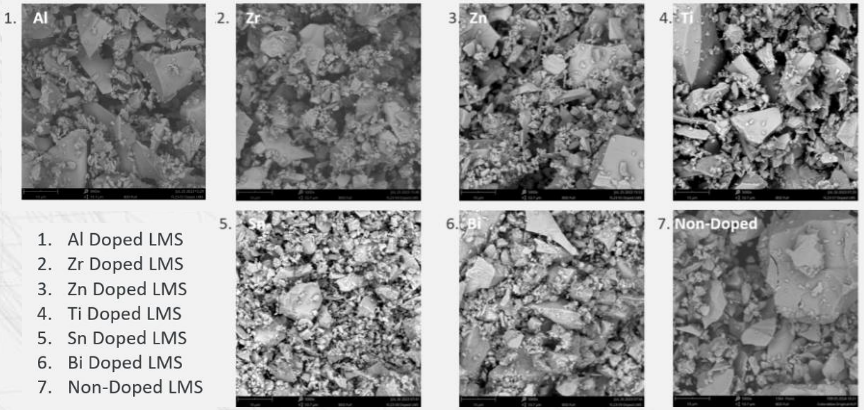
Partner: Hammond Group, East Penn, Bulgarian Academy of Sciences

Duration: 2 years

Objective:

- Enhance PPC and charge recovery performance by incorporating silicate and metal oxide additives in the positive electrode
- Assess if CCA improvements by using silicate additives can be transferred to charge acceptance

2V, 4.5 Ah lab cell (2P/3N)



1. Al Doped LMS
2. Zr Doped LMS
3. Zn Doped LMS
4. Ti Doped LMS
5. Sn Doped LMS
6. Bi Doped LMS
7. Non-Doped LMS

Initial results:

- Preparation and characterization of control LMS and 6 doped LMS variables
  - BET-SA, ICP-OES, SEM, pH and XRD
- Paste preparation (2% loading) and characterization of cured and formed electrodes
  - XRD, BET, SEM, Hg porosimetry
- Electrical testing of 2V cells
  - C20 capacity and CCA at -18°C
  - Charge recovery at 80% SoC at 0°C and -18°C
  - PPC at 80%, 50% SoC at -18°C (IEC 60095-8 draft)

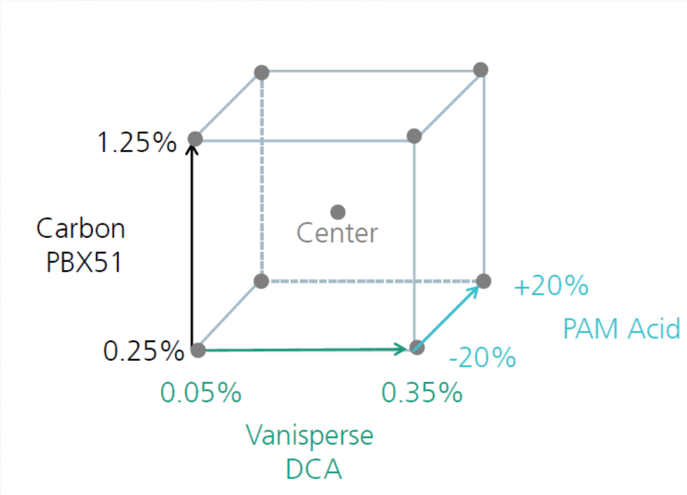
Testing Charge Recovery for Auxiliary Lead Batteries on Laboratory Scale

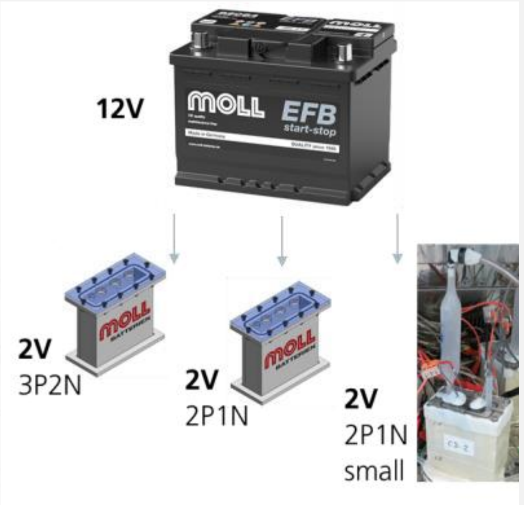
Partner: Fraunhofer ISC, Moll Batterien, Dr. Karden

Duration: 1,5 years

Objective:

- Reveal the role of carbon additives in improving charge recovery and apply the DCA improvements to develop new formulations for auxiliary battery functions
- Assess how cell layout and different active material formulations affect charge recovery and pulse power performance, using both 2V and 12V platforms





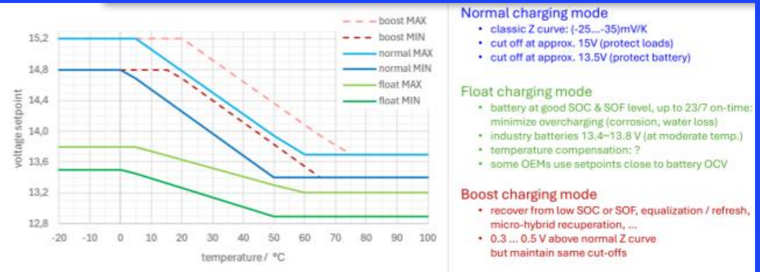
Initial results:

- Identification of the state-of-the-art additives and selection of carbon, lignin, and expander additives for further study
- Testing of PPC and various charge recovery test protocols according to IEC 60095-8 standard
- Preliminary electrical tests (EN DCA, PPC at –18°C, charge recovery variants) on 12 V SLI and EFB batteries

ALBA Plus: 3 New CBI Projects

1. Charge operations in BEVs

- **The project team** involves Combatec and Dr. Karden.
- **The aim** is to document and publish recommendations for 12V charging & operating strategy (such as informative annex of IEC 60095-8 or in a CBI document)



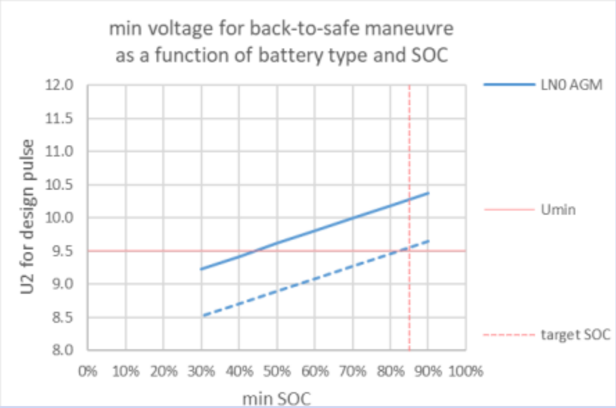
2. Charging strategies in BEVs

- The project team involves Röttger and Dr. Karden.
- The aim is to demonstrate effects of different charging strategies for 12V batteries in BEVs and establish test programs and evaluation methods

sample	1	2	3	4
initial performance testing	2 or 3 capacity tests (e.g., RC-RC-C20) with or without CCA tests as per lab / supplier preference			
early life overcharge run-in	60°C: 14.4 V, 7 days or 25°C EFB: 16 V, 7 days kindergarten: DCH by 20%			
checkup	weight, Hioki (U0, Ri), acid densities top & bottom			
weeks 1-2:				
application	Backup	Backup	Main12V	Main12V
strategy	Float	RAMP	Float	RAMP
voltage setpoint curves	MIN	as needed	MIN	-32mV/K
temperature (water bath)	60 °C	60 °C	25 °C	25 °C
checkup	weight, Hioki (U0, Ri), acid densities top & bottom kindergarten: IUIa charge, DCH by 20%			

3. Battery sizing tool (PPC-based)

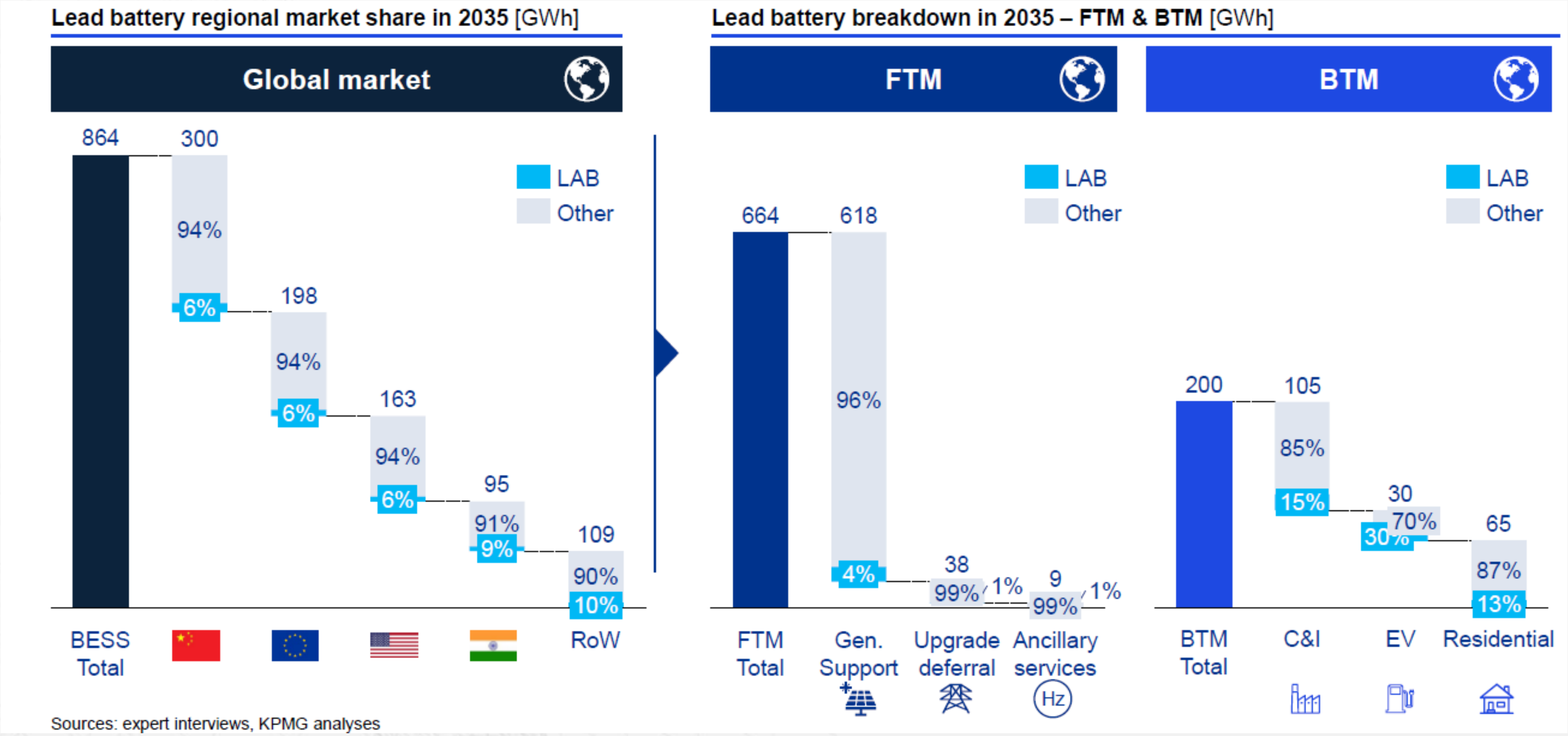
- The project team involves BattIng and Dr. Karden.
- The aim is to collect PPC data from several battery types to develop a model (e.g. SSOF as a function of SOC) and to develop a PPC sizing tool for non-starter 12V automotive batteries



ESS Applications

CBI Technical Roadmap (draft version) and Technical Program

Role of Lead Batteries: ESS Market



- KPMG market report highlights the lead battery regional market share and lead battery breakdown for FTM & BTM
- Lead batteries play a key role in
  - BTM, mainly EV fast charge backup
  - Residential and Commercial & Industrial
  - Long Duration Storage in FTM

Advancement in Lead Batteries for ESS

Cycle Life

- Battery management is key, and CBI has developed BMS with SEL.
- Bipolar and advanced AGM are showing incredible performance enhancement.
- Realistic Testing Regimes are being developed to understand performance

Energy Density

- Bipolar is dropping 40% of the weight out of lead batteries.
- Packing an ESS, the actual design for max density in an ESS, is being researched by CBI.
- Manufacturing (and Capex) improves with better energy density.

Draft version

FTM/BTM – Longer Duration

Indicator	2025	2027	2030	Stretch Target 2035
Cycle life (60% DOD) as an estimate for C_{10} or higher rates	5000	6000	8000	10000
LCOS ($/kWh/energy throughput)	0.28	0.23	0.20	0.18
Round Trip Efficiency	75-78%	80%	82%	84%

Draft version

BTM – Modarate Duty – C&I and Microgrids

Indicator	State of the Art	2028	2030	Stretch Target 2035
Cycle life (50% DOD, PSOC) as an estimate for C_{10} or higher rates	5000	5500	6000	7500
Operational cost for high charge rate applications (C_{10} or faster) - BTMS	0.25 $/kWh/energy throughput	0.20 $/kWh/energy throughput	0.15 $/kWh/energy throughput	0.10 $/kWh/energy throughput
Acquisition Cost (cell level) ($/kWh – 10 MW assumption)	175	140	100	75
Energy Density (Wh/l)	80-100 Wh/l	110 Wh/l	120 Wh/l	140 Wh/l
Acquisition cost, ESS level ($/kWh)	350	325	300	275
Operational Life (1 cycle a day)	13	15	16.5	+20

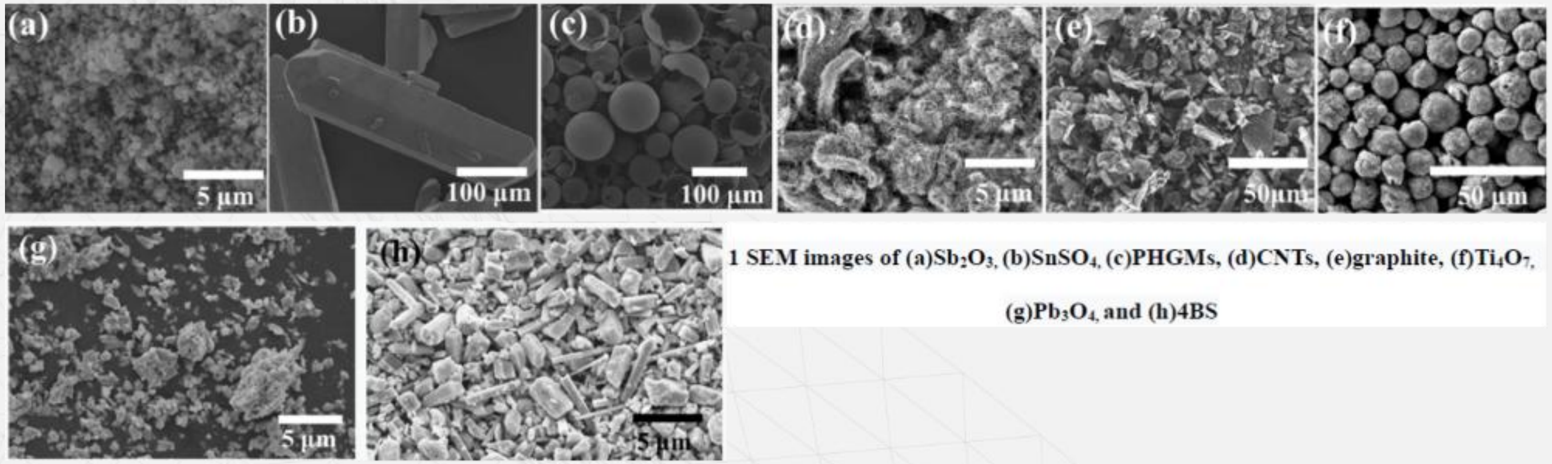
Positive Electrode Additives for Energy Storage Batteries

Partner: Jinkeli Power Technology

Duration: 3 years

Objective:

- Improving the performance of lead battery electrodes specifically in battery energy storage applications (ESS) like demand reduction or arbitrage
- Several additive salts (antimony trioxide, graphite and other carbons, stannous sulfate, tetrabasic lead sulfate, red lead, glass microspheres, and titanium oxides) in the positive electrode will be studied to maximize energy throughput



1 SEM images of (a)Sb_2O_3, (b)$SnSO_4$, (c)PHGMs, (d)CNTs, (e)graphite, (f)Ti_4O_7, (g)Pb_3O_4, and (h)4BS

Initial results:

- Analysis of additive materials and cured battery electrodes using various characterization techniques (XRD, SEM, N_2 sorption, dropping test)
- Preliminary tests to reveal the impact of $SnSO_4$ and Sb_2O_3 additives on paste properties and cured positive electrodes
- Establishment of the 2V cell testing (C/10 capacity test and cycle life test according to IEC 61427-1)

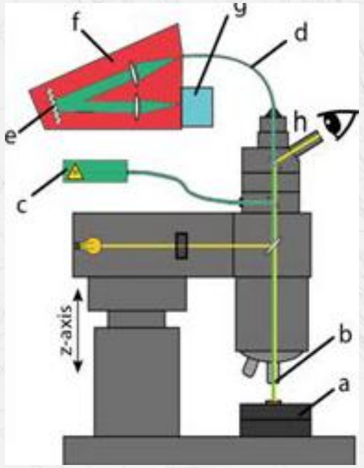
Characterization and Modelling of Mechanical Properties of Lead Batteries for Energy Storage Applications

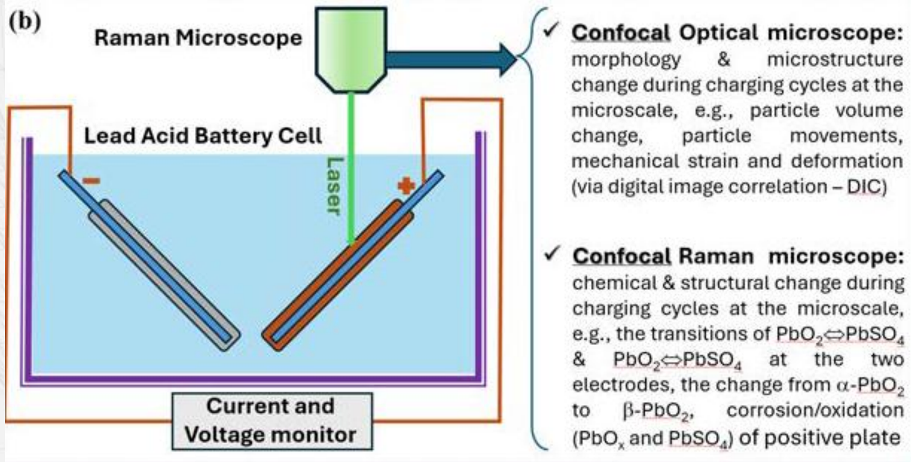
Partner: Villanova University, East Penn

Duration: 3 years

Objective:

- Model the observed behavior of the mechanical & electrochemical changes, and microstructure evolution in lead battery electrodes as a function of ESS cycle number, using AI methods to predict cell failure
- Provide recommendations on modifications to the lead battery electrodes to increase the battery's longevity in ESS applications





Initial results:

- Baseline information on the reference spectra for different lead species using Raman microscopy has been gathered.
- In situ Raman microscopy on preliminary battery electrodes has been conducted.
- Aged lead battery electrodes from prior use have been studied using a suite of analytical techniques
- The Raman microscopy technique is being developed to map the mechanisms of electrolyte and species changes under representative ESS testing

Integrating Cyclic Performance, Materials Science and In Situ Electrical Analysis to Elucidate Structure/Function Relationships

Partner: Black Diamond Structures, University of Texas at Austin

Duration: 2 years

Objective:

- Use comprehensive mechanical and physical testing to create a link to electrical performance (there is no mechanical testing standard for lead electrodes)
- Develop correlations between hardness and cohesion and their impact on battery cycle life in ESS applications

Mechanical testing of a lead battery using 3-point bend method.

Initial results:

- Screening various mechanical tests (e.g. Brinell hardness test) and selecting tests and instrumentation appropriate for lead battery electrodes
- Several characterization techniques (e.g. XRD, SEM, and Hg porosimetry) have been used to map microstructural and phase composition to mechanical characteristics
- Three commercially available lead batteries (5 of each) are under testing using IEC and PNNL standards
  - VRLA battery: 12 V, 100 Ah (C_{10})
  - TUB battery: 12 V, 103 Ah (C_{10})
  - Alternative VRLA battery: 12V, 119 Ah (C_{10})

Thank you!

21ABC, 5 September 2025, Kota Kinabalu, Malaysia

Dr. Begüm Bozkaya // Senior Technical Manager // Consortium for Battery Innovation

CONSORTIUM FOR BATTERY INNOVATION