CONSORTIUM FOR
BATTERY
INNOVATION

A Golden Age for Advanced Lead Battery Innovation

FENIBAT
22-24 May 2022

Presented by:
Dr Alistair Davidson, Director, Consortium for Battery Innovation

Map of Members and Partners

CBI member representation

- Battery manufacturers
- Industry suppliers
- Research & testing institutes, universities, end users
- Lead producers

CBI Members


ABERTAX® TECHNOLOGIES
Addenda Corporation
ADITYA BIRLA GROUP
Advanced Battery Concepts
Better Batteries, Better World®
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AMER-SIL
ArcActive
apg
ATOMIZED PRODUCTS GROUP, INC.
Aurubis
Metals for Progress
Banner Batterien
THE POWER COMPANY
battery energy
power solutions for tomorrow's world
BLACK DIAMOND STRUCTURES™
BOAB
METALS LIMITED
BOLIDEN
Metals for modern life
Borregaard LignoTech
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CABOT
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Ceylon Graphene Technologies
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Digatron
power electronics
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Electric Applications Incorporated
EASTPENN
EBL
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RAISING EXPECTATIONS. KEEPING THEM THERE.
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GRIDTENTIAL
Hakunas Lead Works Ltd.
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STRYTEN
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BATTERY COMPANY
VILLANOVA
UNIVERSITY
WAVETECH
WIRTZ
GORE
Creative Technologies Worldwide

CBI Partners

CBI Overview

RESEARCH

Better batteries

Facilitate improvements in battery and systems performance

- Market analysis
- Technical roadmap
- Core research program
- Government & other funded research
- Technical exchange

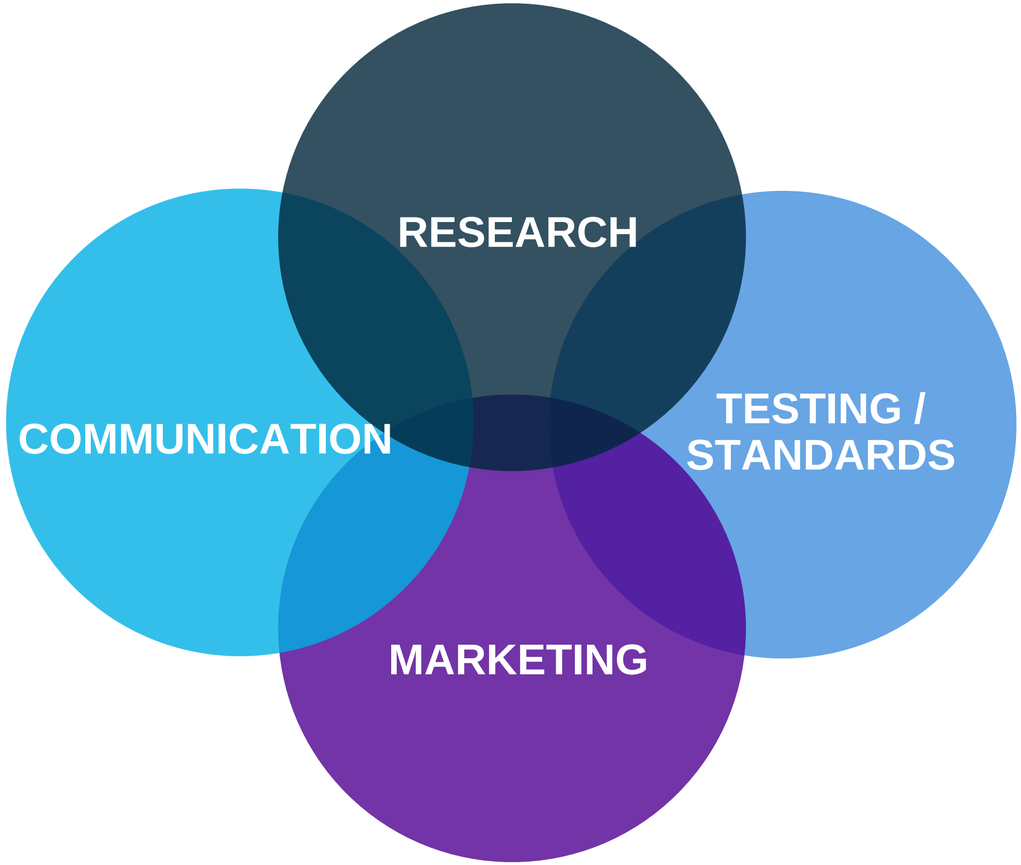
COMMUNICATION

Better recognition

(non-user stakeholders)

Communicating innovation in lead battery performance and applications

- Demonstrate lead batteries technology of future-change perception
- Direct stakeholder engagement (MEPs, Commission, DOE, Governments)
- Media Narrative (Social Media, articles, videos, PRs, blogs etc.)
- Lead battery information hub (website-technical data, market information etc.)



TESTING / STANDARDS

Better recognition

(industry/legislative standards)

Tests and standards that recognize lead battery benefits

- Test method development
- Technical exchange on testing
- Linking research to standards
- Coordination of industry input into standards committees

MARKETING

Better recognition

(end users)

Improve end user recognition of lead battery benefits

- Workshops
- Interactive Map
- Case studies and videos
- Battery Match
- Target industry media
- Demo projects
- Conferences and exhibitions
- Technical papers and publications
- Lead battery resource hub (website)

01.

Technical Program


LEAD BATTERIES
CONSTANTLY INNOVATING

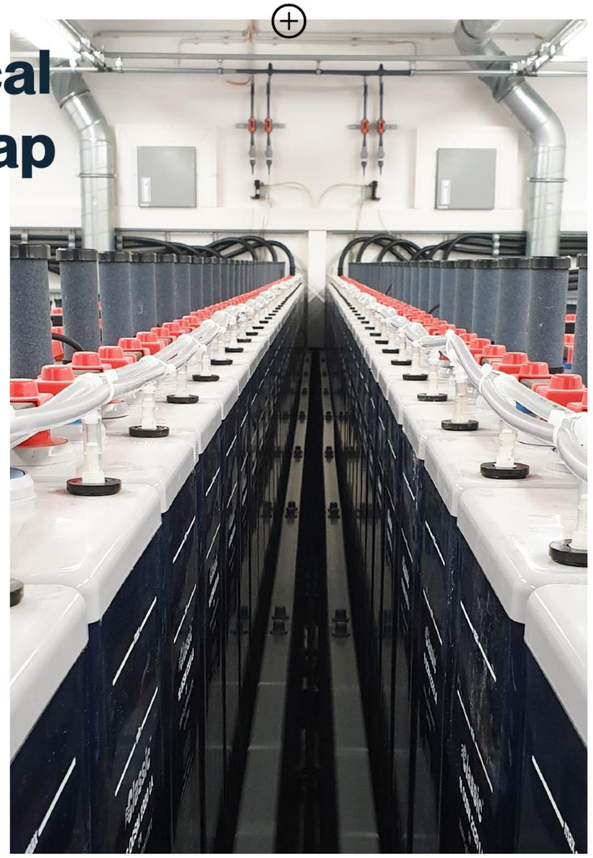
CBI’s 2021 Technical Roadmap

CONSORTIUM FOR
BATTERY
INNOVATION

Technical Roadmap

Research and innovation pathways for next-generation advanced lead batteries

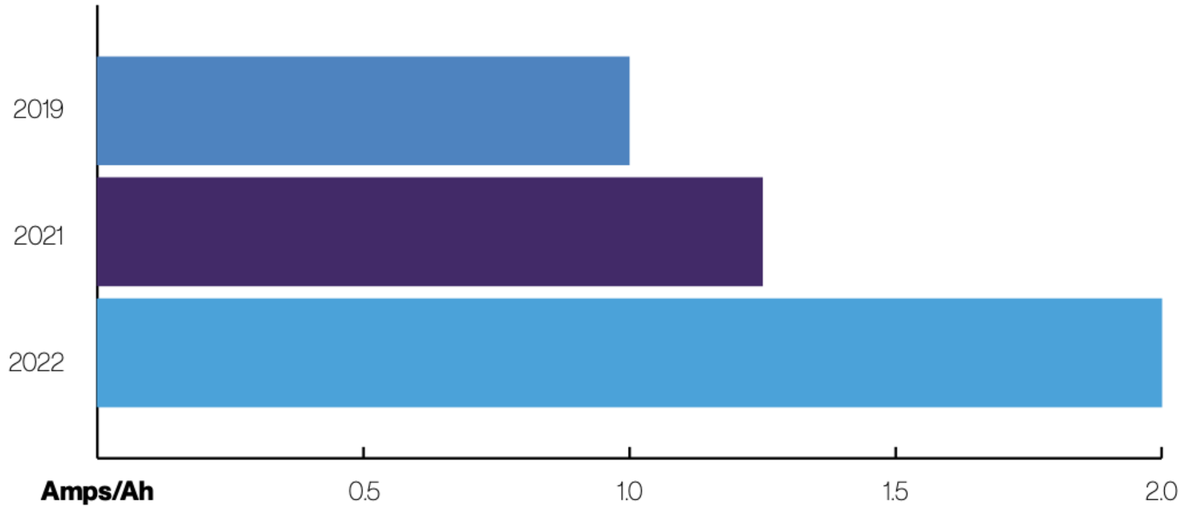
September 2021



Progress since last CBI’s 2019 Technical Roadmap

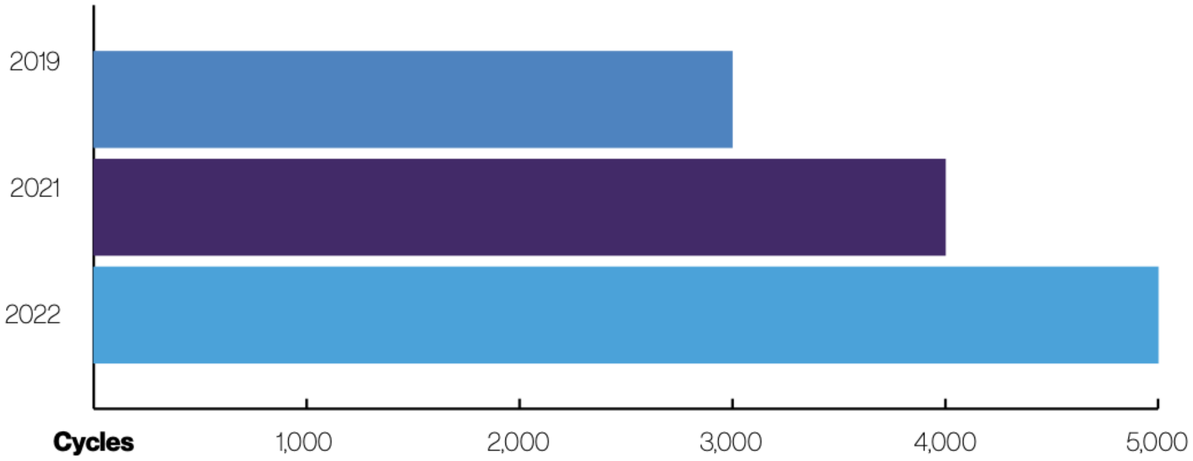
Auto

Dynamic Charge Acceptance



80% DOD

Cycle life



CBI 2021 Technical Roadmap

Automotive
(start-stop/micro-hybrid)

Ensure that recent improvements in Dynamic Charge Acceptance (DCA) are maintained, whilst improving high-temperature performance and ensuring no trade-offs in key parameters such as Cold Crank Amps (CCA) and water loss.

Automotive
(low-voltage EV)

Improve DCA and charge acceptance, whilst increasing charging efficiency and lifetime.

Energy Storage Systems

Improving cycle life, calendar life and round-trip efficiency whilst reducing acquisition and operating costs.

Industrial applications

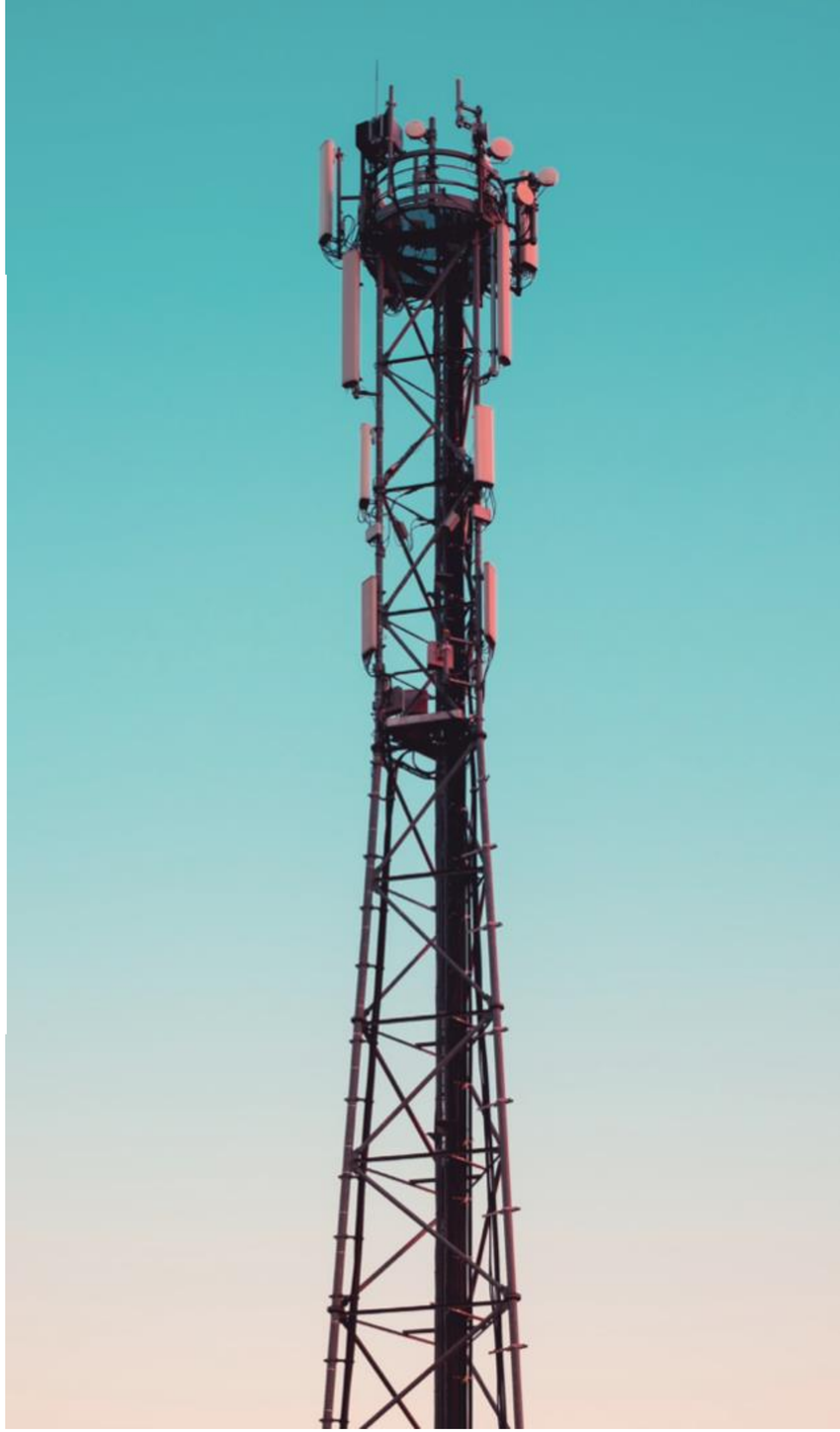
Improving cycle and calendar life, whilst reducing battery costs.

Motive Power

Lowering TCO by increasing cycle life, recharge time, and producing maintenance-free batteries.

Other applications
(including e-bikes)

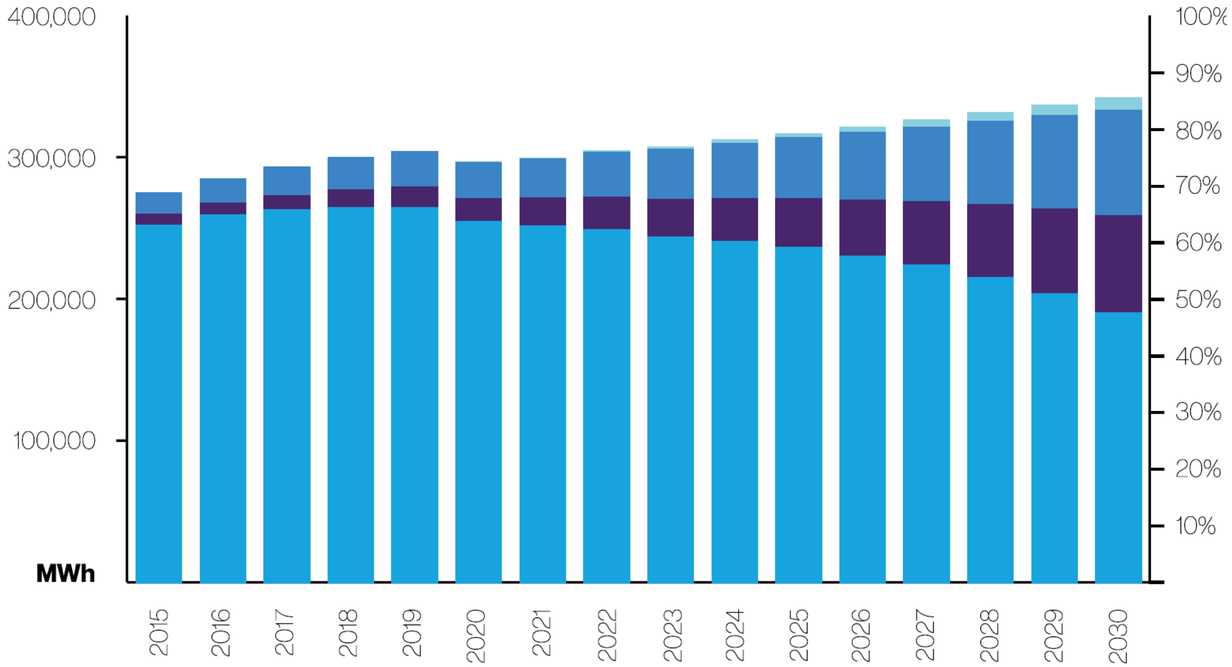
Improving gravimetric energy density, recharge capability and service life.



12 V Automotive Battery Market

CBI market report 2021, Avicenne

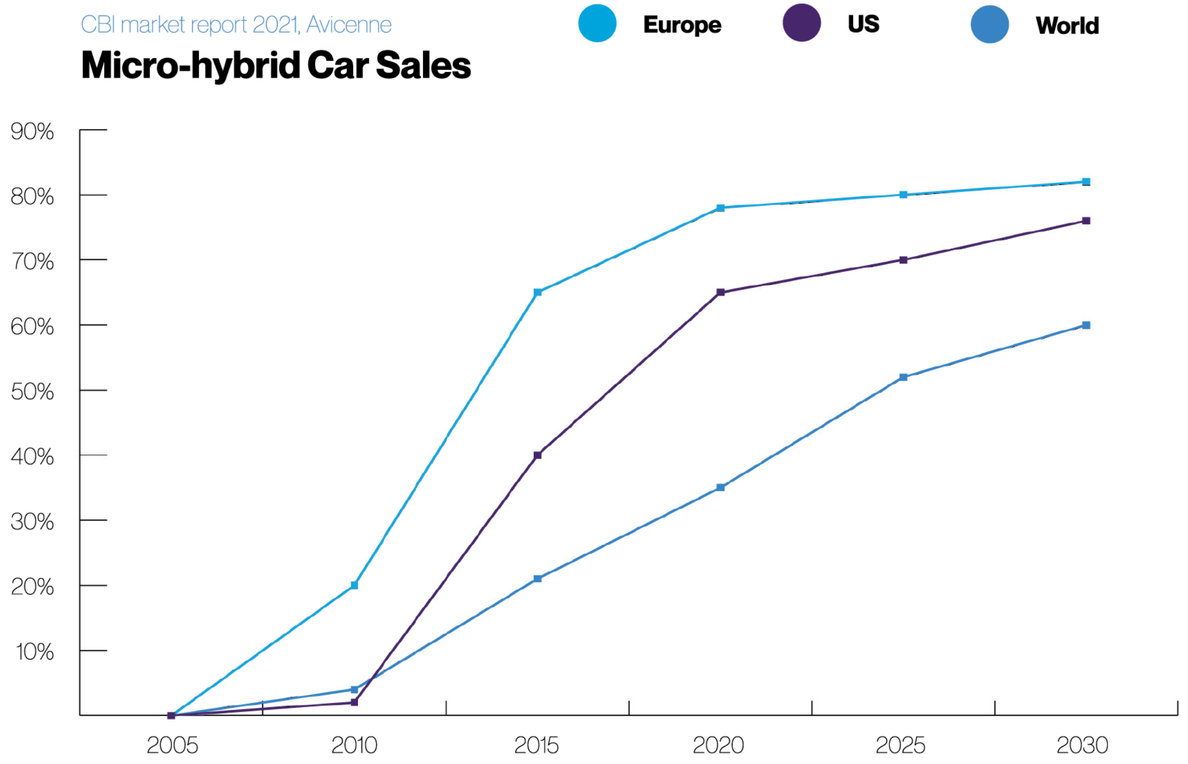
Battery Market for SLI



Flooded
EFB
AGM
LIB

CBI market report 2021, Avicenne

Micro-hybrid Car Sales



Micro-hybrid vehicles continue to grow as a significant market for the global automotive battery sector. By 2030, 60% of global sales will be micro-hybrids, with Europe leading the way with an expected 82% of sales by 2030, and the US close behind with 75%.

Automotive KPIs – ISS/Micro-hybrid

Automotive
(start-stop/micro-hybrid)

Ensure that recent improvements in Dynamic Charge Acceptance (DCA) are maintained, whilst improving high-temperature performance and ensuring no trade-offs in key parameters such as Cold Crank Amps (CCA) and water loss.

Indicator (start-stop, micro/hybrid)	**2021/2022**	**2025**	**2030**
DCA (EN 50342-6, A/Ah)[a]	1.25	2.0	2.0
Ford Run-In Test B (A/Ah)	1.0	1.5	2.0
Durability: HTE (IEC/CENELEC draft)	16	20	20
Water Loss – EN/HTE (g/Ah)	<3	<3	<3
CCA, RC (comment)	Must not be compromised	Must not be compromised	Must not be compromised

EN 50342-6:2015 (M1, M2, M3 classification) should be used for cycle life requirements
Maintain 15 weeks of SAE J2801

[a] DCA testing from EN 50342 – 6 : 2015 theoretically only allows a DCA value up to 1.67 A/Ah (33*I20). DCRss discharge rate may be too low. An adjustment of the EN DCA protocol would be necessary.

Automotive KPIs – Low Voltage EV (Auxiliary)

- **DCA and CA are important metrics to consider in auxiliary batteries.**
- **The actual use of auxiliary by OEs and the consumer alike is unpredictable, and further test development is likely needed.**
- **Float charging may be a concern – accurate testing of this use case is underway within IEC.**

Automotive
(low-voltage EV)

Improve DCA and charge acceptance, whilst increasing charging efficiency and lifetime.

ESS Growth

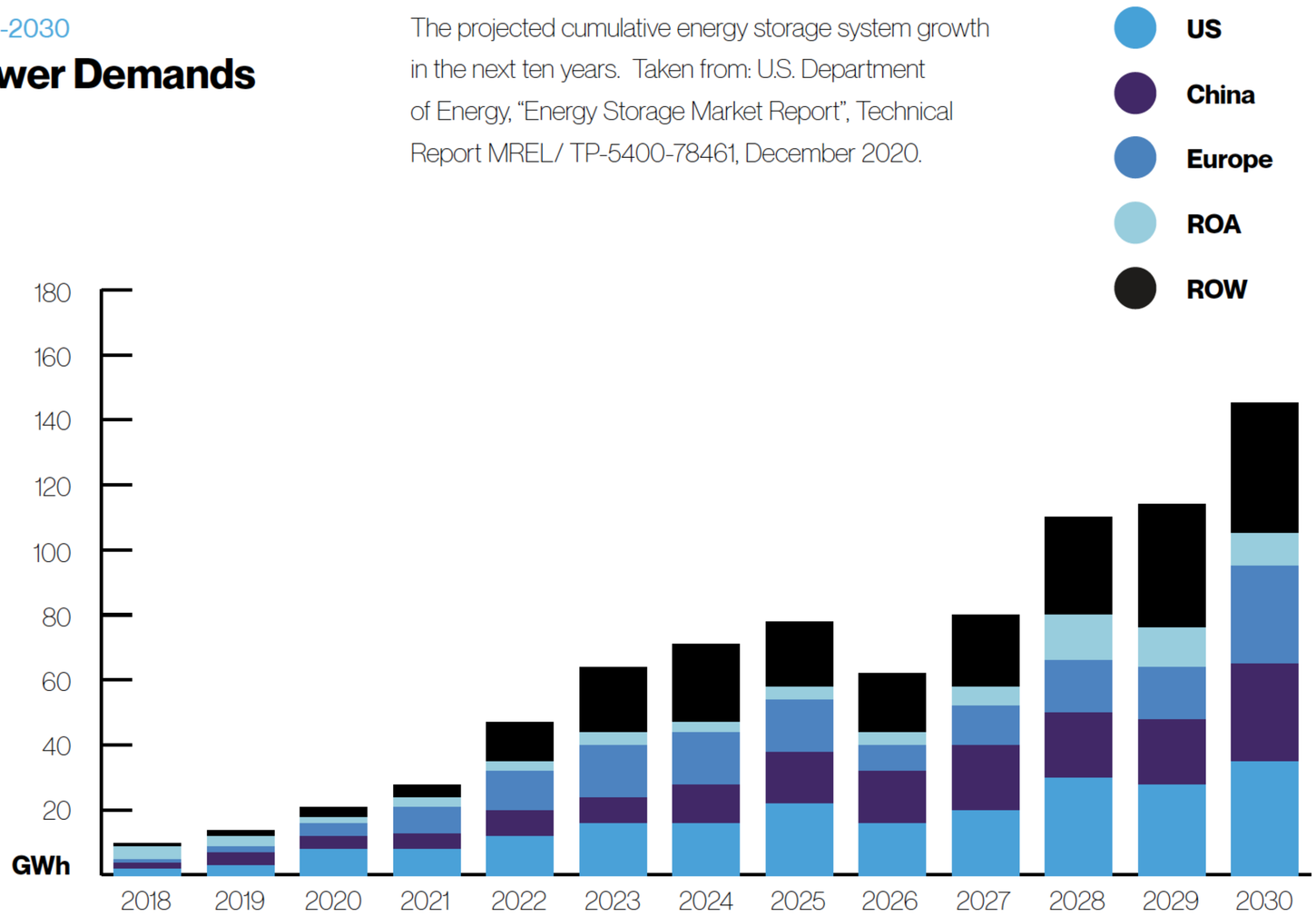
- **Conservative reporting predicts massive growth**
  - Strong growth in all areas.
  - 100’s of billions of dollars of government moneys directed toward this sector.

- **Key growth area for lead battery industry.**
  - Productization is vital.
  - Residential (Safe, advanced batteries)
  - 1-10 MW industrial (Multiple technology approach
  - Long duration, shallow cycling (Lead battery chemistry excels in this duty cycle).

2018-2030

Power Demands

The projected cumulative energy storage system growth in the next ten years. Taken from: U.S. Department of Energy, “Energy Storage Market Report”, Technical Report MREL/ TP-5400-78461, December 2020.



ESS Battery KPIs

Energy Storage Systems

Improving cycle life, calendar life and round-trip efficiency whilst reducing acquisition and operating costs.

Indicator	2021/2022	2025	2028	Stretch Target 2030
Service life (years)	12-15	15-20	15-20	15-20
Cycle life (80% DOD) as an estimate for C10 or higher rates	4000	4500	5000	6000
Operational cost for low charge rate applications (above C10) – Grid scale, long duration	0.12 $/kWh/energy throughput	0.09 $/kWh/energy throughput	0.06 $/kWh/energy throughput	0.04 $/kWh/energy throughput
Operational cost for high charge rate applications (C10 or faster) - BTMS	0.25 $/kWh/energy throughput	0.20 $/kWh/energy throughput	0.15 $/kWh/energy throughput	0.10 $/kWh/energy throughput
Energy Storage efficiency (Wh in vs Wh out)(%)	75-90	80-90	85-90	88-92

ESS Battery KPIs

Energy Storage Systems

Improving cycle life, calendar life and round-trip efficiency whilst reducing acquisition and operating costs.

Indicator	2021/2022	2025	2028	Stretch Target 2030
Round Trip Efficiency (%)	85	88	90	92
Acquisition Cost (cell level) ($/kWh – 10 MW assumption)	175	140	100	75
Energy Density (Wh/l)	80-100	110	120	140
Acquisition cost, ESS level ($/kWh)	350	325	300	275
Safety	Maintain safety – deploy charging algorithms to control gassing			

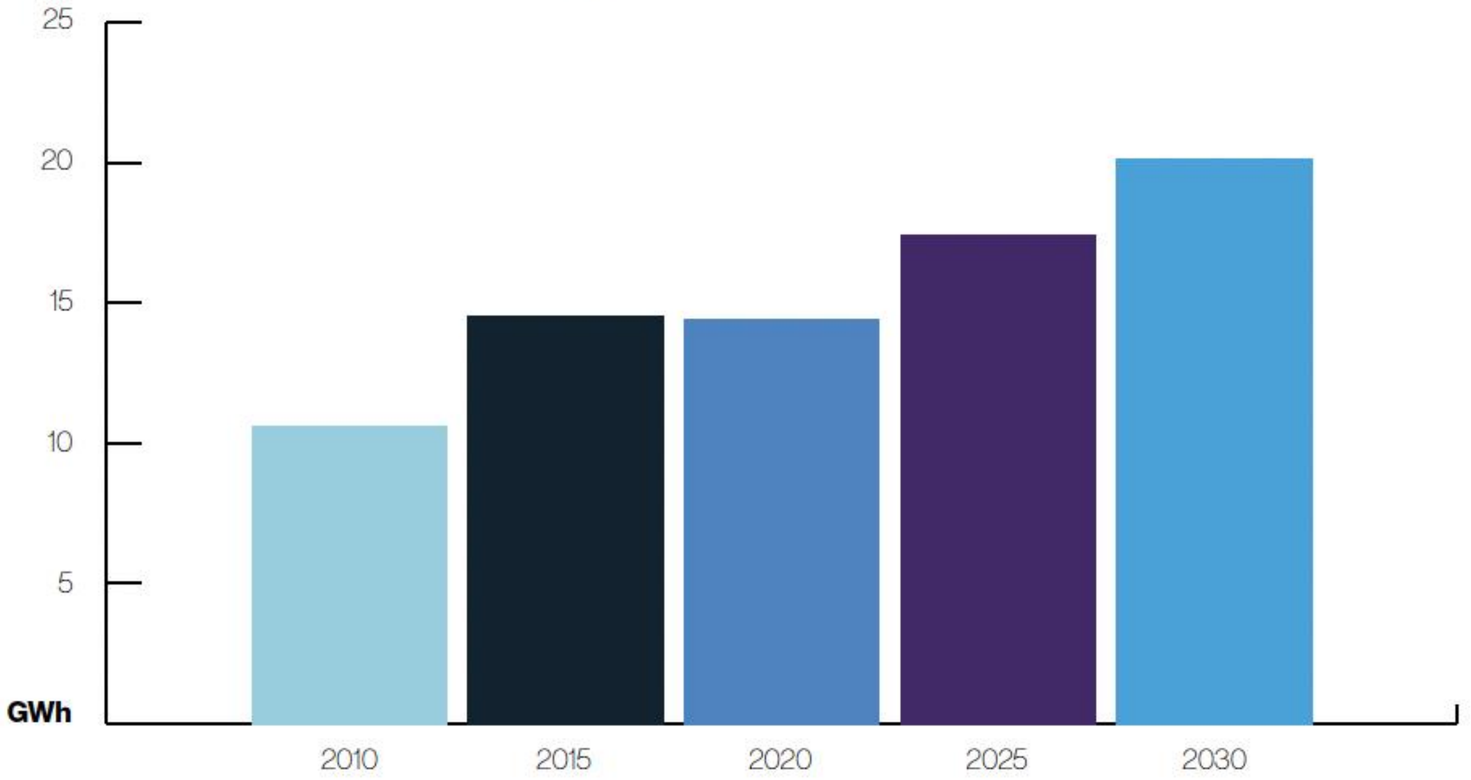
Telecom Market and Drivers

- **Strong market growth beyond current reports.**
  - H&V market information gathering has indicated ~23% growth in market to April 2021.
  - 5G deployments combined with deferred orders during 2020 (due to COVID).
  - Demand is very strong.
- **Healthy CAGR ~4-6% over next decade.**
- **5.6 GWh predicted.**

CBI market report 2021, Avicenne

Telecom Market

Lead batteries remain the dominant technology for telecom, back-up and UPS applications. For telecoms and back-up they provide an invaluable resource in keeping the power on in blackout events, with a growth of 5.6 GWh predicted between 2015 and 2030.



Lead Battery KPIs for Telecom Applications

Industrial applications

Improving cycle and calendar life, whilst reducing battery costs.

Research targets

KPIs for lead batteries in telecom applications

Indicator	2021/2022	2028
Calendar Life on float	15 y at 20°C	7-10 y at 40°C 20 y at 20°C
Cycle life (Testing should follow IEC 60896-21/22)	300 at 80% DoD	500 at 80% DoD
Cost	$175/kWh	$150/kWh

Maintain Safety and Recyclability, Maintain Shelf life

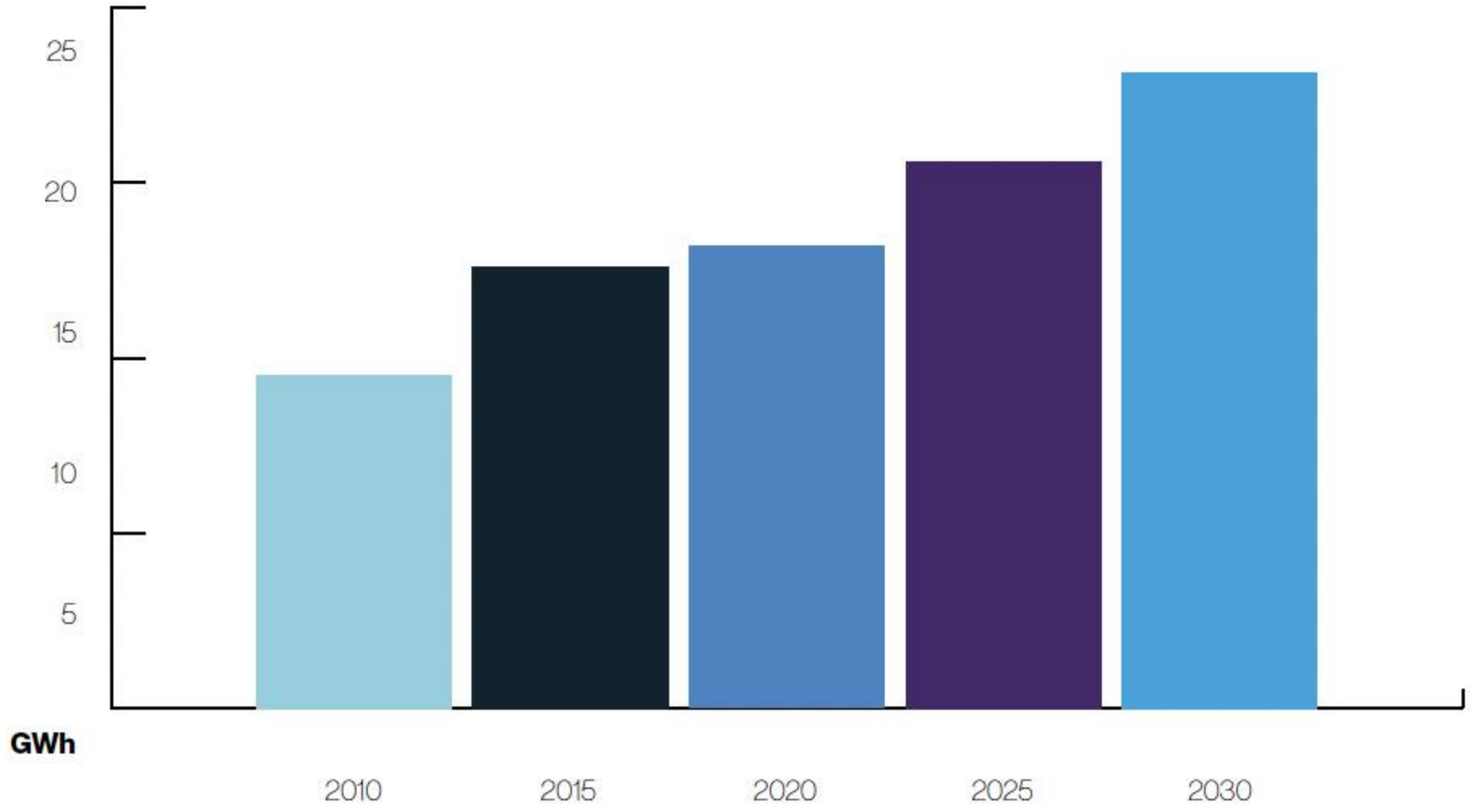
UPS Market and Drivers

- **Data center growth has pushed this market to new plateaus.**
  - Lead batteries enjoy a small footprint due to current IFC/NFPA standards.
- **Similar to Telecom market, approximately 5.5 GWh growth from 2020.**
- **Also similar to telecom, unprecedented market growth (~17%) due to back orders and investment in data center growth.**

CBI market report 2021, Avicenne

UPS Battery Demand

By enhancing the cycle life and charging efficiency of lead batteries, whilst lowering total cost of ownership (TCO) future opportunities for lead battery technology in this market are substantial.



Lead Battery KPIs for UPS Market

Industrial applications

Improving cycle and calendar life, whilst reducing battery costs.

Research targets

KPIs for lead batteries in UPS applications

Indicator	2021/2022	2028
Calendar Life on float	10 y at 20°C	15 y at 20°C
Peukert Capacity (15-minute vs. 10-hour capacity)	65-80%	85-90%
Cycle life Testing should follow IEC 60896-21/22	1000 at 50% DoD 6000 at 10% DoD	5000 at 50% DoD 12000 at 10% DoD
Cost	$175/kWh	$150/kWh

Maintain Safety and Recyclability, Maintain Shelf life

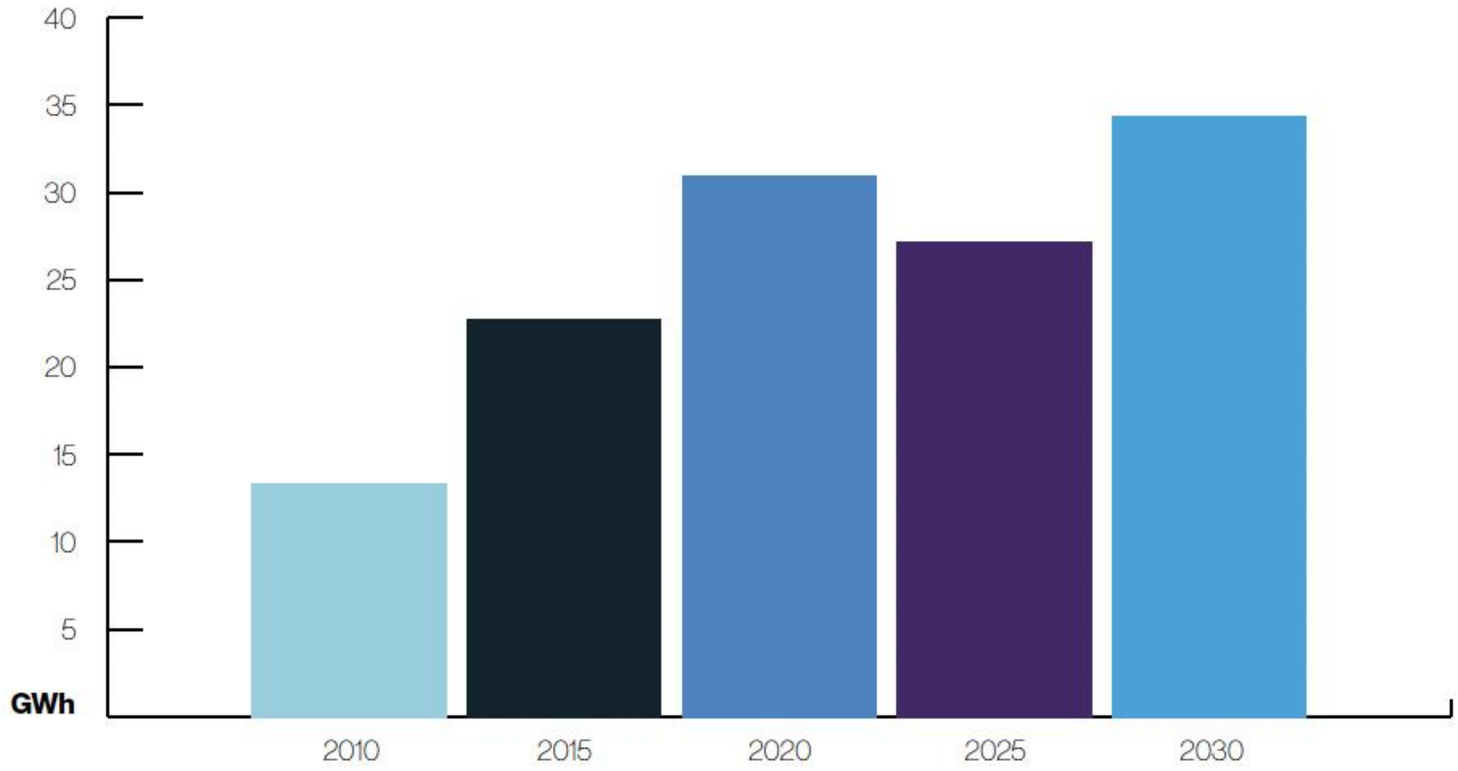
Motive Power Market (Forklift/Lift Trucks)

- **Significant penetration from Li-ion**
- **“Lift all ships” currently happening in market.**
  - Heavy demand for trucks and replacement batteries.
  - Lead battery demand is up 6% relative to 2019.
- **High volatility in market predictions.**
- **CARB initiative in California is an example of electrification efforts posing a great opportunity.**
  - Similar initiatives are possible NY and parts of EU.

CBI market report 2021, Avicenne

Motive Battery Demand

With the market predicted to grow to 34.3 GWh by 2030, this is a significant sector for lead batteries.



Motive Power Battery KPIs

Motive Power

Lowering TCO by increasing cycle life, recharge time, and producing maintenance-free batteries.

Research targets

KPIs for lead batteries in motive power applications

Indicator	2021/2022	2025	2028
Service life	5	5-6	6-7
Energy throughput	1200 equivalent cycles	1400 equivalent cycles	1600 equivalent cycles
Cycle life IEC 60254	2400 (50% DOD)	2800 (50% DOD) 1750 (80% DOD)	3000 (50% DOD) 2000 (80% DOD)
Energy density (specific to charge efficiency)	35 Wh/kg	40 Wh/ kg [c]	42-45 Wh/kg [c]
Charge time to 30 – 80% Opportunity Charging (Highly dependent on charger/charge current)	Less than 2 hrs	1 – 1.5 hrs	1 hr or less
Technology requirements	- Maintenance free present - Management of the battery [a] - Harmonization with Chargers [b] - Few products capable of opportunity charging	- Maintenance free more common - Management and monitoring of the battery [a] - Harmonization with Chargers - Capable of opportunity charging	- Maintenance free typical. - Management and monitoring of the battery [a] - Harmonization with Chargers - Capable of opportunity charging

2019-2020 Technical Program

Project ongoings…

Exide/ICMA –In-operando” Neutron Diffraction analysis of the Charge/Discharge Processes inside the Positive Active Mass

Fraunhofer ISC/WUST – “Investigations on the Effect of Carbon Surface Functional Groups on Electrochemical Behavior of Lead Carbon Electrodes

UCLA - “Visualizing the Dynamics of Carbon – Enhanced Negative Electrodes in Lead Batteries”

EAI – “Grid Energy Storage Performance Improvement Using Controlled Overcharge”

Borregard Lignotech, East Penn, Cabot, Hammond – “Investigation into the Combined Influence of Carbon Black and Organic Expander to Improve Micro-Hybrid Service of Enhanced Flooded Batteries”

Fraunhofer ISC/TUB/Ford/Moll – “Improving Dynamic Charge Acceptance and High-Temperature Durability in Automotive Lead Batteries”

New additions

…

Exide/ICMA – “In-operando Neutron Scattering Analysis of the Charge/Discharge Processes inside the Battery Electrodes – ESS focus” – 24 month project

Hammond Group, Inc./East Penn – “Examination of the Effects of Surfactant Coatings & Particle Size of Barium Sulfate on the Structure Changes and Overall Performance of NAM in Energy Storage Systems (ESS) Application” – 27 month project

University of Warwick/Loughborough University - “HALO-SMART-ESS-LAB: Health And Lifespan Optimization with Smart Management Algorithms & Recuperative Testing of ESS of Lead Acid Batteries”

Gridtential/EAI – “Bipolar Lead Batteries for Energy Storage Systems Applications”

Key Results from Technical Program

DCA - 40% improvement

- **Optimization of additives**
- **Bipolar designs**
- **Novel techniques for understanding battery fundamentals**

Cycle life - on target to deliver 5,000 cycles

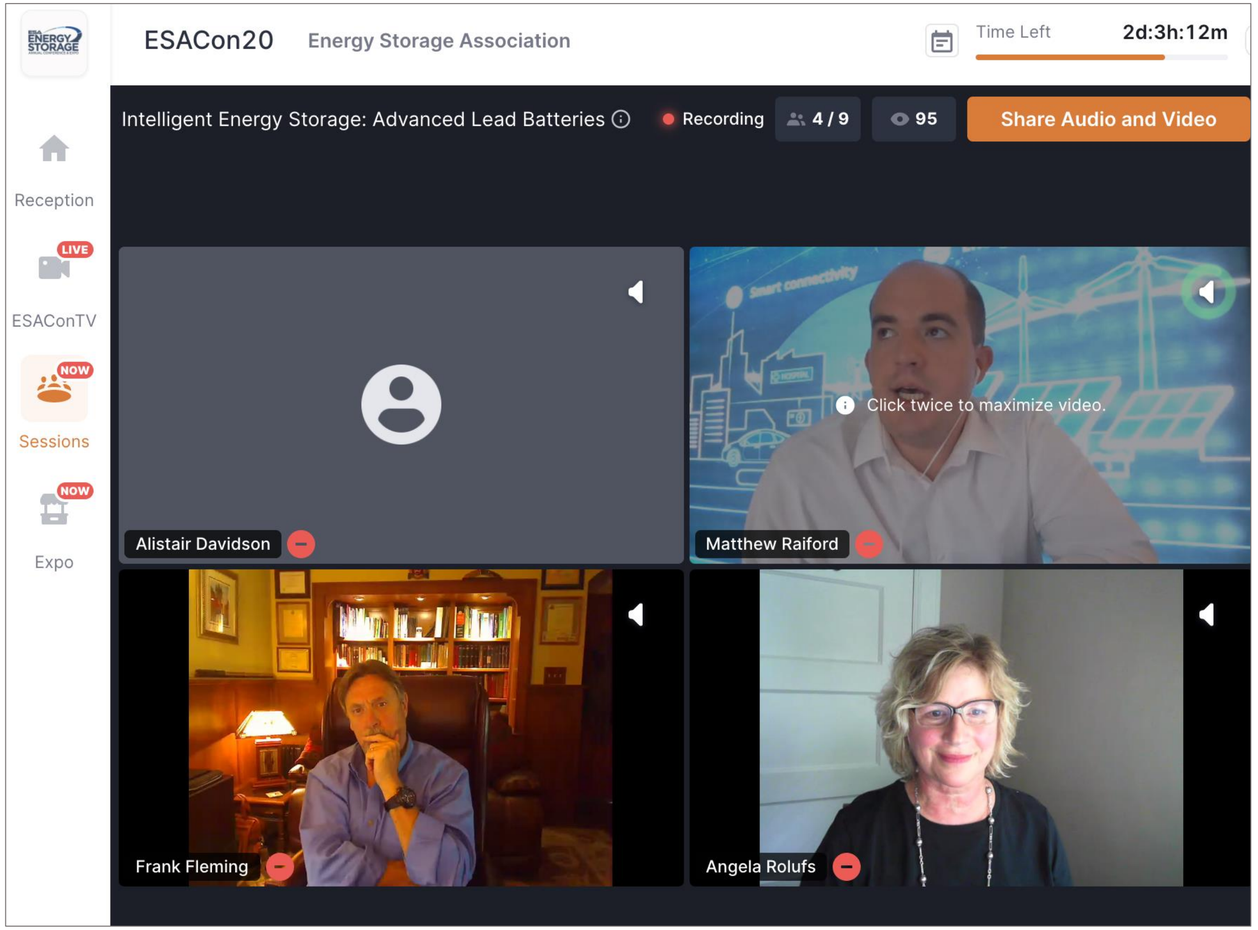
- **New understanding on failure modes**
- **Controlled overcharging**
- **Novel techniques for understanding battery fundamentals**

02.

Marketing Program

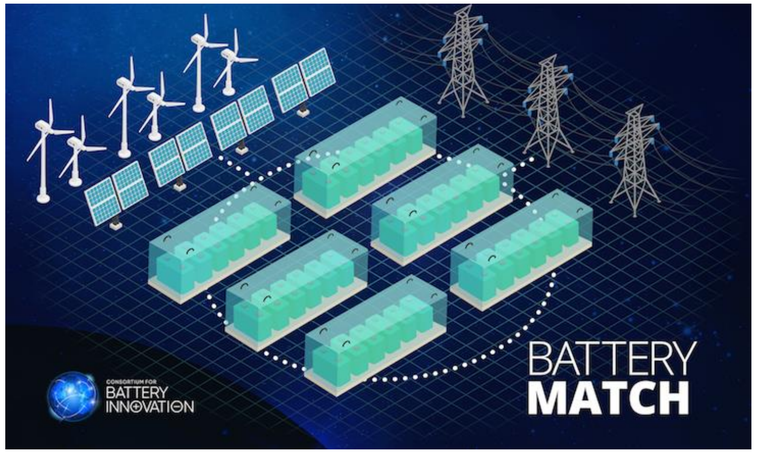
ESS Workshops

- Virtual meetings held in 2020/2021
- Objective to provide information about lead battery benefits in ESS system to end users.
- Well attended, but clear end users only currently consider lithium batteries when choosing batteries for these systems.
- Clear that examples of projects (case studies) currently underway using lead batteries is the best way for communicating our messages.
- **Last years workshop was held in conjunction with the US Energy Storage Association's Conference in August (ESACon20)**
  - **View the event blog here: https://batteryinnovation.org/energy-storage-will-fundamentally-change-the-energy-landscape/**



Marketing

Interactive map, energy storage case studies, resources hub and CBI Battery Match



Consortium for Battery Innovation @CBIbatteries · Apr 6

Join CBI at #ESACon21, the top US #EnergyStorage industry event. Held on April 21-22, Virtual ESACon21 will feature keynote discussion, education panels & networking. Registration is free, plus save the date for the in-person December event in Phoenix: bit.ly/3qiwsOg

2

CONSORTIUM FOR BATTERY INNOVATION

EASTPENN

LEAD BATTERIES: ENERGY STORAGE CASE STUDY

East Penn Manufacturing

Restoring Power Using Lead Batteries

Ciales, Puerto Rico

As part of disaster relief efforts following 2017's Hurricane Maria, residents from the Toro Negro Community in Puerto Rico partnered with local businesses and NGOs to restore power and ensure future resiliency.

Pairing a solar microgrid system with lead batteries in the remote, mountainous region of Ciales, provided 26 families with clean and reliable energy.

"East Penn Manufacturing and its wholly owned subsidiary, MK Battery, are proud to have been a part of such a project to help the wonderful people of Toro Negro get back on their feet after a natural disaster of monumental proportions."

Mark Wels, Vice-President & General Manager, Sales – Reserve Power, East Penn Manufacturing

Technical Specification

Collaboration between the Puerto Rico Community Foundation (FCPR), non-profit SOMOS Solar and a key Deka customer Maximo Solar Industries, resulted in an efficient and sustainable energy system for the Toro Negro Community.

By reducing dependency on the electrical grid, the solar microgrid + lead battery storage system ensures future resiliency in the face of extreme weather events.

The system features:

- 312 Deka Solar 8L16 batteries
- 598 solar panels
- 5.54 MWh of stored energy

The system is managed by the community-based organization in the area, with training and maintenance services provided by Maximo Solar Industries.

Consortium for Battery Innovation @CBIbatteries · Jan 11

Analyst Christophe Pillot from Avicenne predicts strong market growth for lead #batteries, underpinning the global shift to a low-carbon future. Click here for insights into future predictions for lead #battery #energystorage and #automotive markets: batteryinnovation.org/analysts-predi...

03.

Tests and Standards Program

2019-2022 Standards Work

CBI has been working closely with Automotive OEM in Europe to develop new test methods and investigate gassing and water loss

- Supporting European OEMs to address concerns with high temperature durability of automotive lead batteries
- Develop test methods to show improved performance
- Yearly meeting attended by over 100 individuals, including experts from automotive companies and experts from within battery industry
- Demonstrates commitment of European OEMs to continue using lead batteries in future vehicles
- Including looking at auxiliary lead batteries
- Workshops have been held in Germany, Spain and Belgium
  - Successful virtual meetings last week-over 170 attendees over three days
  - Face to face meeting expected later this year

Topic	Plenary and Breakout topics
1. New Key Life Test (nKLT) for battery durability in hot climate	• Can nKLT predict water consumption in the field? • Can nKLT predict corrosion-limited high-temperature battery life? • Charge balance – weight loss – gas emissions: Quantifying EFB side reactions • Taxi fleet evaluation of EFB with high DCA • Introduction scenario for a new standard test?
2. Dynamic Charge Acceptance (DCA): Definitions and test methods	• OEM perspective: DCA motivation and observations • Comparing battery bench simulations of vehicle CO_2 homologation (WLTP) • Run-in vs. fresh battery: Which test predicts which use case? • Elements and sequences for a new global DCA test
3. Sharing insights for high-temperature durability cell testing	• nKLT results for test cells in comparison to 12V batteries • Discussing a 5Ah test-cell construction for NAM evaluation in nKLT • Reality check of CBI proposed best practices – invitation for a compact round-robin test • Exchange about common lab implementation topics
4. Positive electrodes under high-temperature microcycling duty	• Compare morphology & material parameters of positive vs. negative active mass • Can PAM additives reduce water consumption? • Analytical Techniques for PAM and positive grid • Corrosion under microcycling conditions: Do we need new evaluation methods? • Can impedance spectra (EIS) track corrosion layer growth in-situ? • In-situ information about grid corrosion from gassing and half-cell measurements
5. Structure – function relationship behind the DCA Memory Effect	• The physical attributes of the DCA "memory effect": A rapid shared experiment • Voltage effect on DCA: new experimental data for 12 battery types • A simple impedance spectroscopy experiment: in-situ DCA tracking? • Origin of the DCA Memory Effect: The Pb^{2+}/organic buffering theory • Origin of the DCA Memory Effect: Role of Ostwald ripening & recrystallization • Alternative hypotheses and experimental ideas to verify or falsify thm
6. New requirements and standards: Auxiliary batteries and functional safety	• Market trends for "auxiliary" 12V batteries • DKE/IEC draft for standardizing new small AUX battery sizes • Do we need a norm for "FIT batteries" assuring ASIL compliance? • Power tests for 12V batteries beyond CCA • Example of a tier-1 solution: Breakdown of Functional Safety requirements to battery, pole-niche sensor and other power supply system components • A generic approach to state-of-function (SoF) verification
In additional plenary talks, representatives of OEMs and battery suppliers will report • new battery requirements and ongoing standardization activities, • validation results of the new Micro-Hybrid Test (MHT) at 40 °C – is it mature to be published in EN 50342-6 ?	

Further Standards work

- *Auxiliary lead battery standard development with EU OEMs* – CBI is organising with European OEMs a new working group to develop standards for auxiliary batteries, a key future market for lead batteries.

- *Functional safety standards development with OEMs* - Further working groups developing functional safety standards for lead batteries - a key attribute for lead batteries and vital to further market assess

- *Fire prevention standards* (NFPA) - Coordination of lead battery industry input showing safety benefits of lead batteries

- *UL standards for energy storage applications* - Coordination of lead battery industry input in UL standards which are key to lead batteries being used in energy storage applications

- *IFC standard for energy storage applications* - Coordination of lead battery industry input into building standards which are key for energy storage applications

- *IEC standards for auto applications* - Coordination of lead battery industry input to key IEC automotive standards

04.

Communications Program

Media coverage

Highlights from across the globe

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Innovations in energy storage will reduce carbon emissions

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News

Gridtential Energy and EAI to further develop solar powered energy storage systems

Battery Industry

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Home › Home batteries › Hi-tech batteries support boost in demand for household solar energy

Hi-tech batteries support boost in demand for household solar energy

26 February 2021

CONSORTIUM FOR BATTERY INNOVATION

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Consortium for Battery Inn… climate-friendly technologi…

MINING.COM Staff Writer | January 21, 2021 | 6:10 am | Battery Metals | Europe | USA | Lead | Lith…

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Blogs

electric/hybrid

Battery research critical in battle to reverse climate change, says new consortium chairman

Tuesday, 19 January 2021

Robin Whitlock

Investment in battery research is key to reducing carbon emissions and boosting electrification, according to the newly appointed chairman of global battery research hub the Consortium for Battery Innovation (CBI).

Dr Christian Rosenkranz is calling on governments and industry to work more closely to help accelerate the development of advanced battery technologies.

"We need to see a huge uplift in rechargeable battery energy storage if countries are to get anywhere near the global targets for reducing carbon emissions" said Dr Rosenkranz, who is Vice President Industry and Governmental Relations EMEA of CBI

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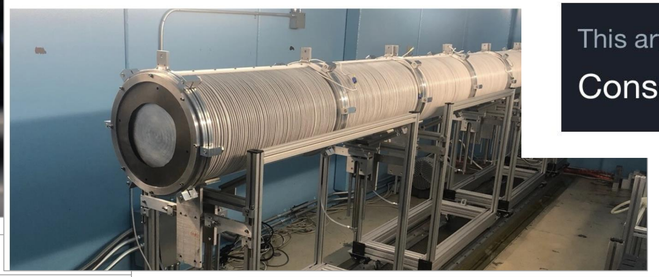
Almacenamiento

Los científicos del CBI colaboran en un pro para mejorar la vida útil de las baterías de almacenamiento de energía

9 marzo, 2021



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Innovación para mejorar la vida útil de las baterías

WORLD ECONOMIC FORUM

How lead batteries could make EVs safer

Lead batteries are highly safe and reliable.

Image: Unsplash/ Andrew Roberts

This article was originally published by the Consortium for Battery Innovation

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by Baset Asaba

Mar 25, 2021

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Growing Demand For Energy Storage Drives Research In Advanced Battery

Increased demand for energy storage in the utility sector has resulted in a broad spectrum of application developments for advanced batteries, with the global grid-scale stationary battery market predicted to exceed $40bn by 2030

How are we promoting new research?

Social

Consortium for Battery Innovation @CBIbatteries · Mar 4

Using @Gridtential's advanced lead #batteries & the expertise of EAI, CBI's #research project is driving #energystorage #innovation. Quick and safe 'plug & play' #solarenergy storage systems are being developed to meet booming demand for #renewableenergy: batteryinnovation.org/hi-tech-batter...

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The boom in demand for utility #energystorage is driving advanced #battery #research, and Hammond Group, Inc. and East Penn Manufacturing Co. have teamed up for a CBI project to meet the needs of this market. ...see more

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Expansion of Battery video series

All you need to know about lead batteries

- Ongoing project to cover all the key topics around lead batteries:
  - Definitions
  - Applications
  - Markets
- Seven videos currently live, with 10+ finalized for release over coming months
- Great engagement on social media:
  - 3000+ impressions on LinkedIn and 17 shares since launch
- Feedback from our audience to cover other topics such as traction batteries and the motive power markets
- Expanding to include versions in Chinese and other regions especially on important topics for the Asian market e.g. e-bikes

An event co-organised by

International Lead Association

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Thank you!

For information, please contact

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