CONSORTIUM FOR BATTERY INNOVATION

Lead and the Transition to Green Energy

ILZSG
19 October 2022

Presented by:
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INCREASE SPEED OF RESEARCH

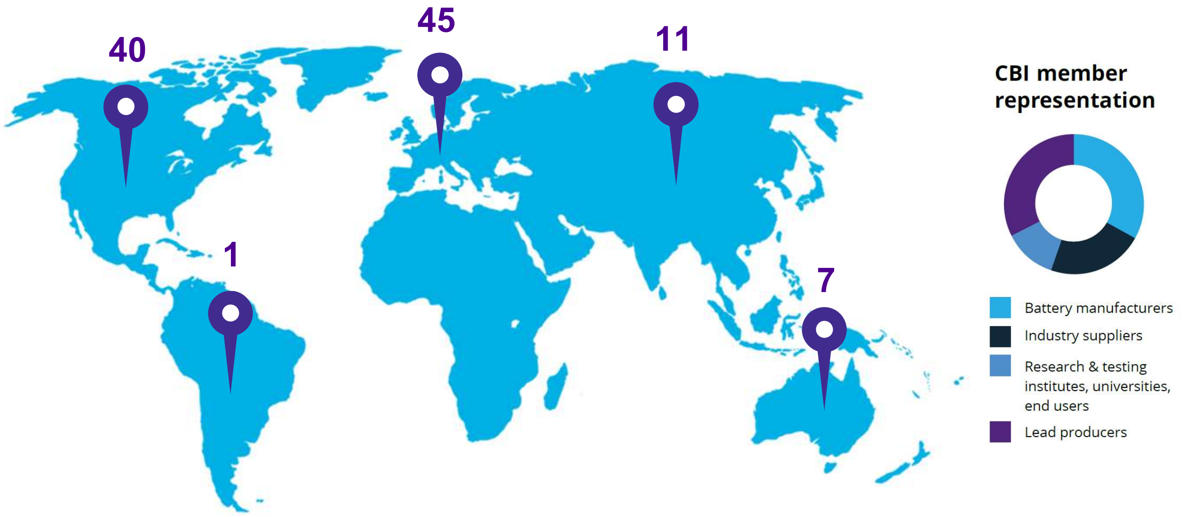
INCREASE GOVERNMENT FUNDING

CHANGE LEAD BATTERY PERCEPTION

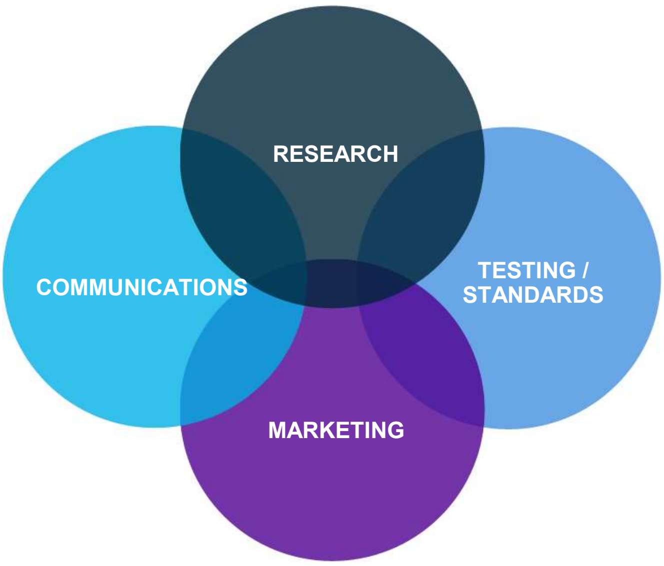
CBI Members

CBI Partners

Map of Members and Partners



CBI areas of work




01.
Technical Program


LEAD BATTERIES
CONSTANTLY INNOVATING

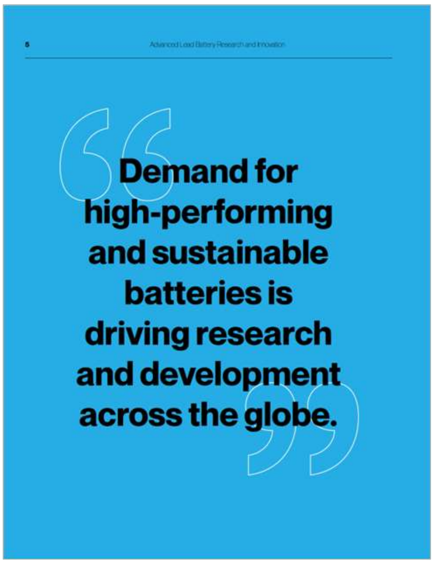
CBI’s 2021 Technical Roadmap

CONSORTIUM FOR BATTERY INNOVATION

Technical Roadmap

Research and innovation pathways for next-generation advanced lead batteries

September 2021



“Demand for high-performing and sustainable batteries is driving research and development across the globe.”

Foreword

A Golden Age for Battery Research

As global warming continues to have a dramatic impact on the world’s climate, the imperative for decarbonization is greater than ever.

Battery energy storage is a key pillar in the move to electrification and supporting innovation and performance improvements is the highest priority. Soaring demand for battery technologies across all applications has ushered in something of a golden age for batteries. From clean energy storage to hybrid and electric vehicles, demand for high-performing and sustainable batteries is driving research and development across the globe.

Analysts predict a spike in demand for a range of battery technologies, each of which display different strengths and are designed to support a range of applications. Combining pioneering research with the latest market insights, the Consortium for Battery Innovation is leading the way by ensuring advanced lead batteries continue on their innovation journey supporting ambitious climate goals set out by policy makers.

Building on the Technical Roadmap launched in 2019, the new and updated roadmap reflects the performance improvements achieved to date and sets out new goals designed to tap the unlimited potential of advanced lead battery technology. With continued performance improvement and technological advances, the opportunities for the global lead battery industry to provide cost-effective and reliable energy storage solutions remain very positive.

Economies need batteries and lots of them. It is clear through intensive market-driven analysis that end-users across the automotive, energy storage, industrial and motive power sectors want greater performance from all battery technologies.

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

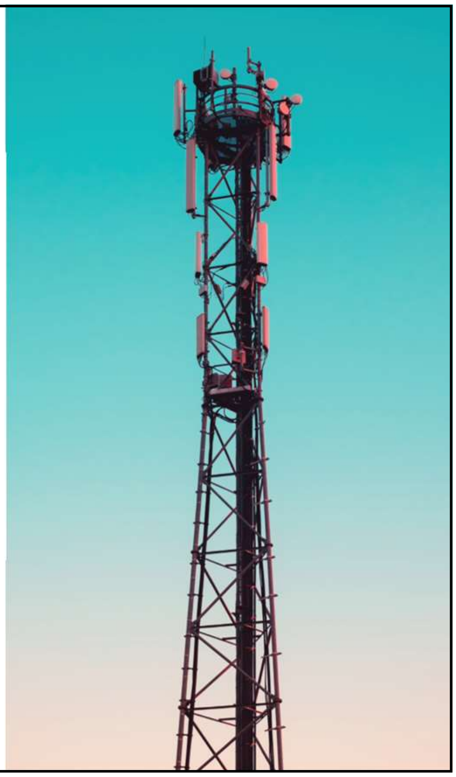
Improving cycle and calendar life, whilst reducing battery costs.

Motive Power

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

Other applications
(including e-bikes)

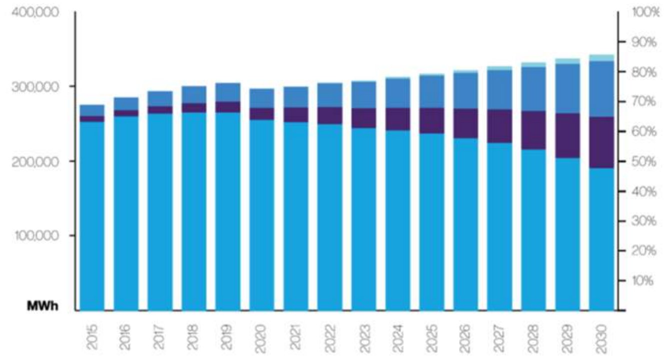
Improving gravimetric energy density, recharge capability and service life.



12 V Automotive Battery Market

CBI market report 2021, Avicenne

Battery Market for SLI



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%.

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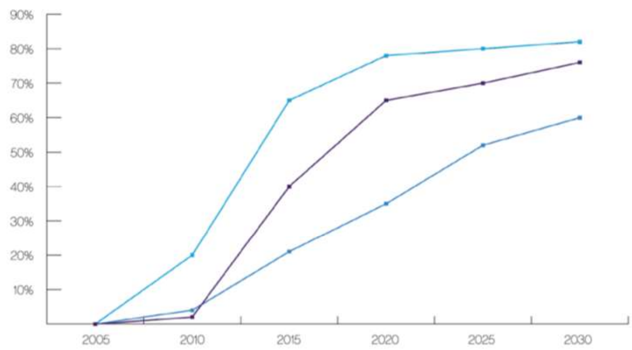
Micro-hybrid Car Sales



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

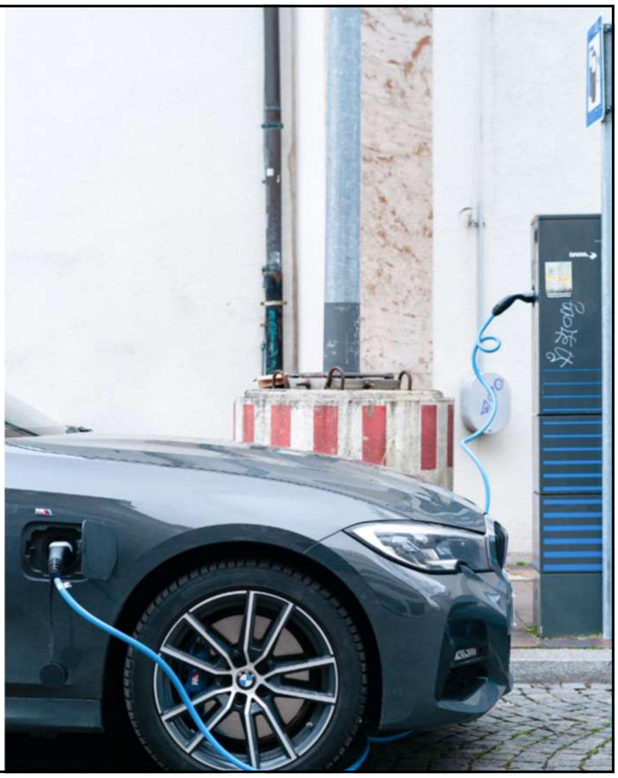
EN 50342-6:2015 (M1, M2, M3 classification) should be used for cycle life requirements
Maintain 15 weeks of SAE J2801

[a] DCA testing from EN 50342 – 6 : 2015 theoretically only allows a DCA value up to 1.67 A/Ah (33*120). DCRss discharge rate may be too low. An adjustment of the EN DCA protocol would be necessary.

Automotive KPIs – Low Voltage EV (Auxiliary)

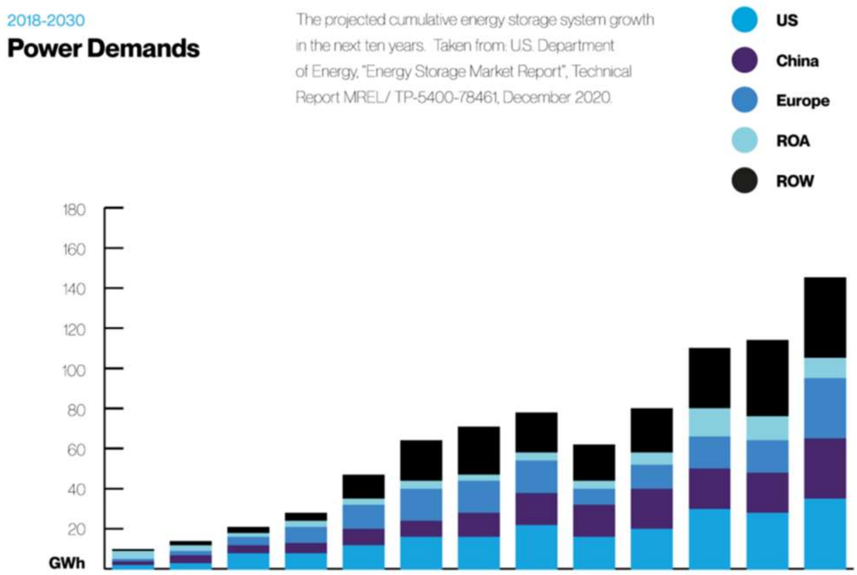
- **DCA and CA are important metrics to consider in auxiliary batteries.**
- **The actual use of auxiliary by OEs and the consumer alike is unpredictable, and further test development is likely needed.**
- **Float charging may be a concern – accurate testing of this use case is underway within IEC.**

> ⊕ **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).



ESS Battery KPIs

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

⊕ Energy Storage Systems

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

ESS Battery KPIs

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			

⊕ Energy Storage Systems

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

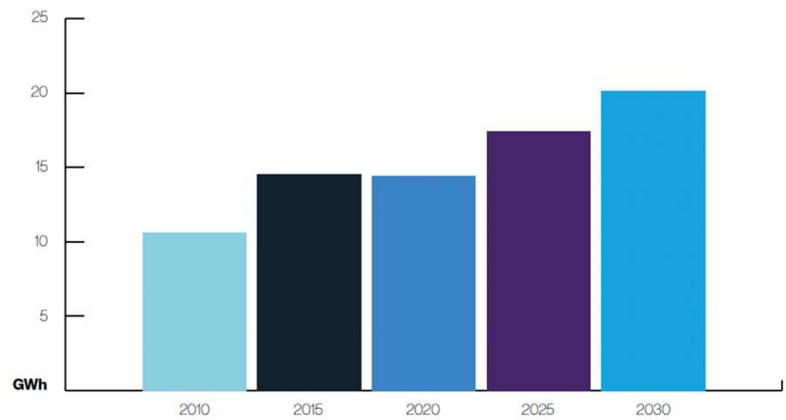
Telecom Market and Drivers

- **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

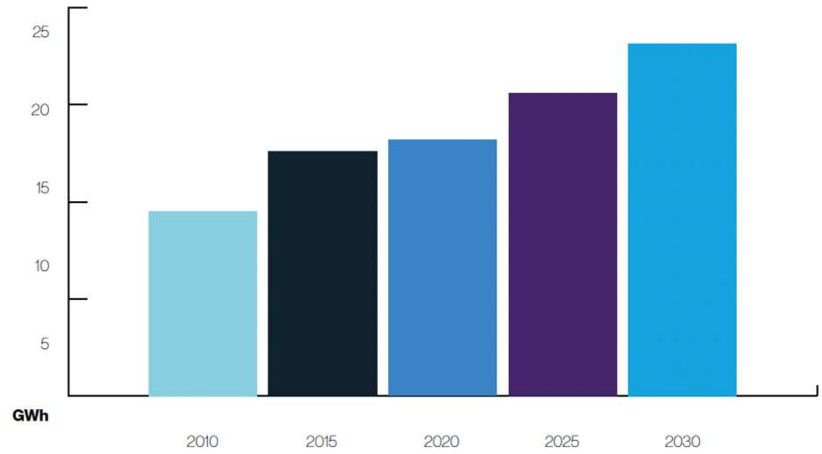
UPS Market and Drivers

- **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

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

Industrial applications

Improving cycle and calendar life, whilst reducing battery costs.

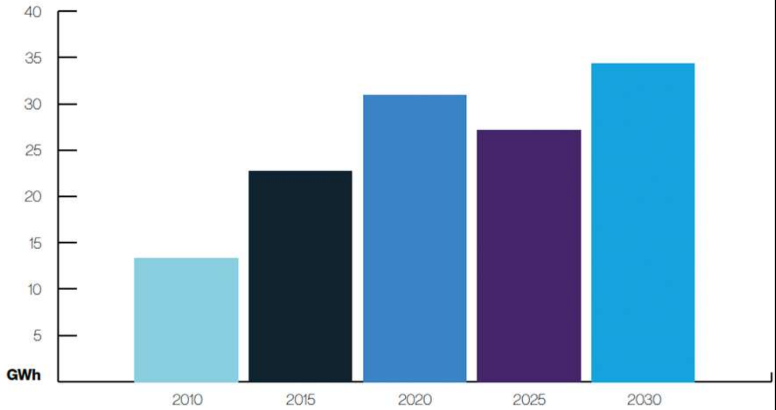
Motive Power Market (Forklift/Lift Trucks)

- **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

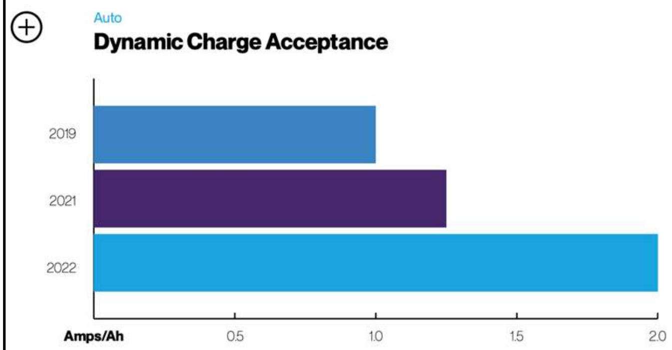
Lowering TCO by increasing cycle life, recharge time, and producing maintenance-free batteries.

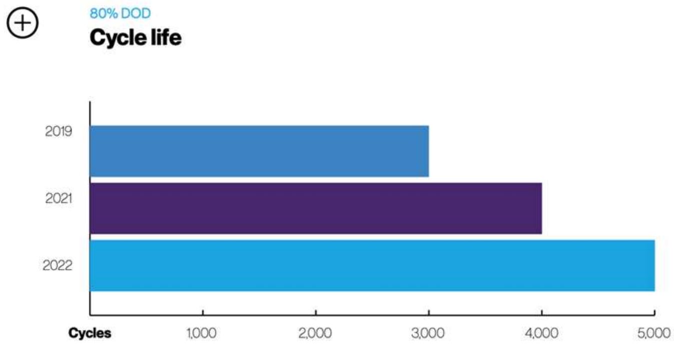
Research targets

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

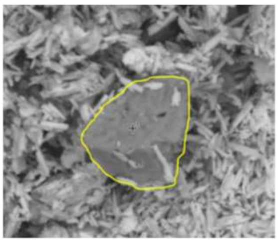
Progress since last CBI's 2019 Technical Roadmap

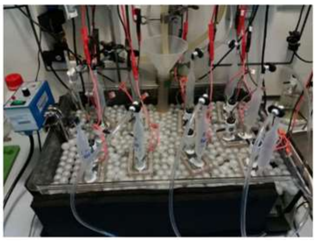


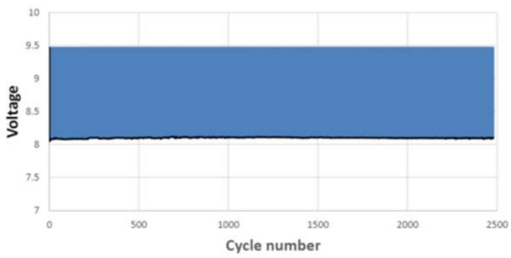


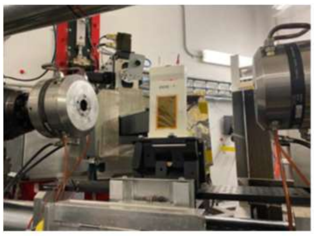
CBI Technical Program Key Results

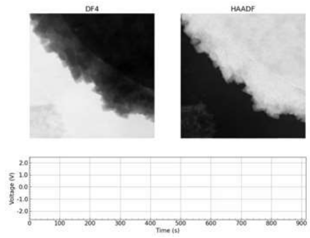
- **DCA – up to 100% improvement**
  - By optimization of additives (carbon/lignin)
  - Using carbons with functionalization that balances water loss and DCA
- Supporting research in member laboratories by defining and solving issues in testing and cell manufacturing
- Novel techniques for understanding battery fundamentals – Neutron Diffraction and EIS
- **Cycle life - on target to deliver 5,000 cycles**
  - New understanding on failure modes
  - Controlled overcharging – reaching **100% increases in energy throughput** in current commercially available products
  - Dynamic BMS methods governed by machine learning











02.

Government funding work

Worldwide funding for batteries

U.S. Government Pledges $45 Million to Develop Better EV Batteries

The Department of Energy has set up a new program that will fund the domestic development of batteries for electric vehicles that can charge faster and last longer.

US Department of Energy announces $45Mn in battery funding

State aid: Commission approves €3.2 billion public support by seven Member States for a pan-European research and innovation project in all segments of the battery value chain

ENERGY STORAGE

EU boosts battery R&D funding

US government announces $3.1 billion of funding for battery manufacturing, processing, recycling

Brussels approves €2.9 billion investment into battery innovation

LoCEL-H2 – European Funding Project

European Commission

LoCEL-H2
Sustainable Electricity and Hydrogen for Remote Communities

HOPPECKE POWER FROM INNOVATION

cea

Loughborough University

Université de Gabès

RHYDE RÉSEAUX HYDROGÈNE DÉCARBONÉ

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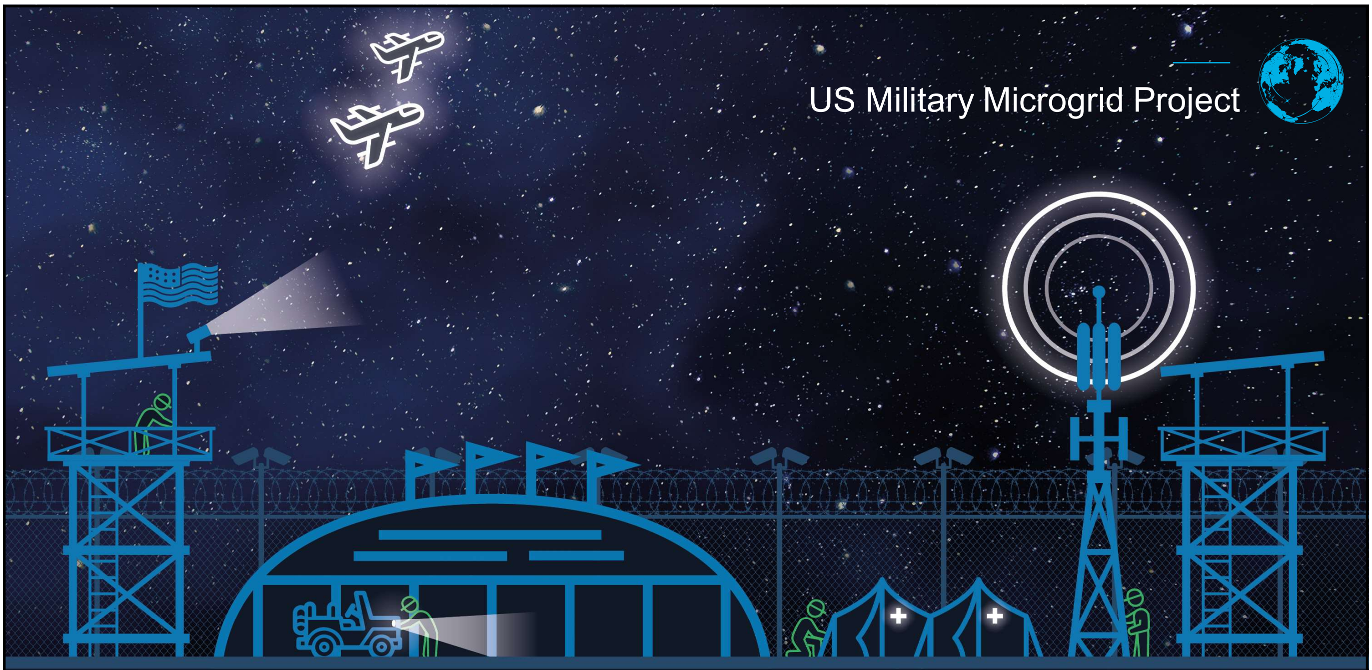
Hollingsworth & Vose® Creating a Cleaner World™

SUNKOFA ENERGY

US Military Microgrid Project



US Army Corps of Engineers®

Consortium for Battery Innovation

PARAGON SOLUTIONS, INC.

Advanced Battery Concepts Better Batteries, Better World®

EnerSys® Power/Full Solutions

EASTPENN

Electric Applications Incorporated

Advanced lead battery research

US Synchrotron at ANL
Argonne National Laboratory

Site of lead battery research

02.

Energy Storage Opportunities

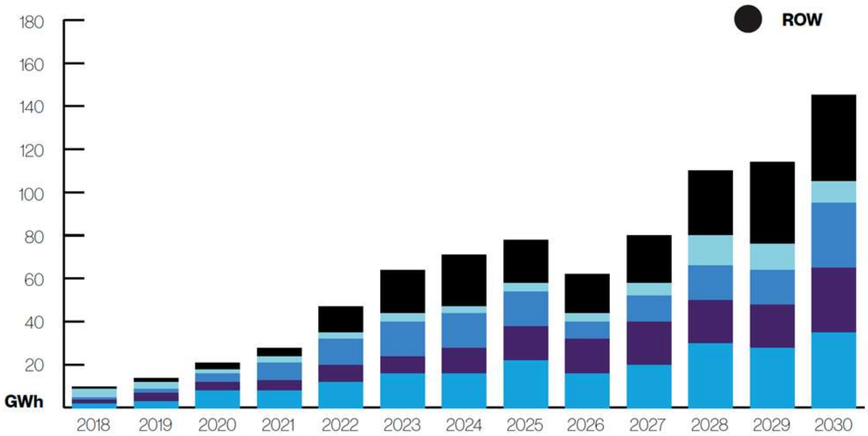
ESS Growth

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.

- US
- China
- Europe
- ROA
- ROW



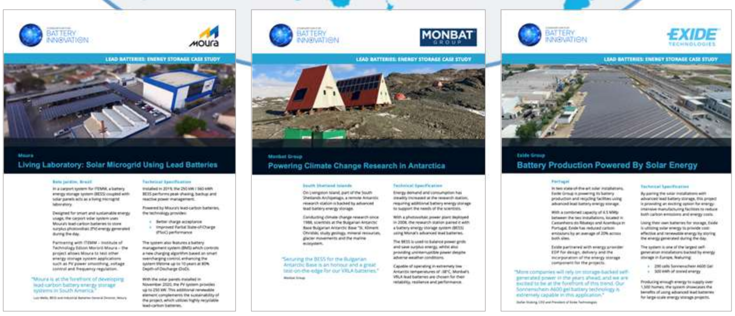
PERFORMANCE

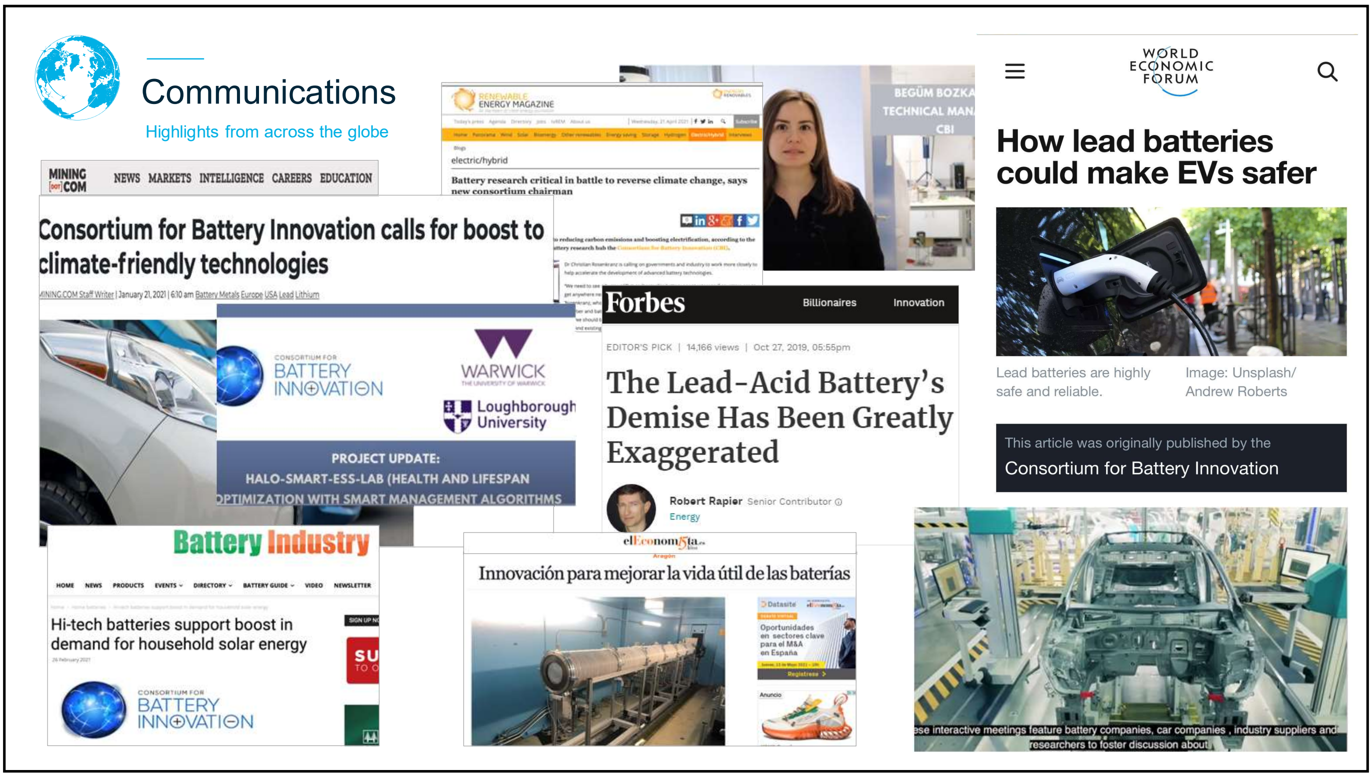
PRODUCTISATION

GOVERNMENT FUNDING

COMMUNICATIONS

Marketing Program

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How lead batteries could make EVs safer
Lead batteries are highly safe and reliable.
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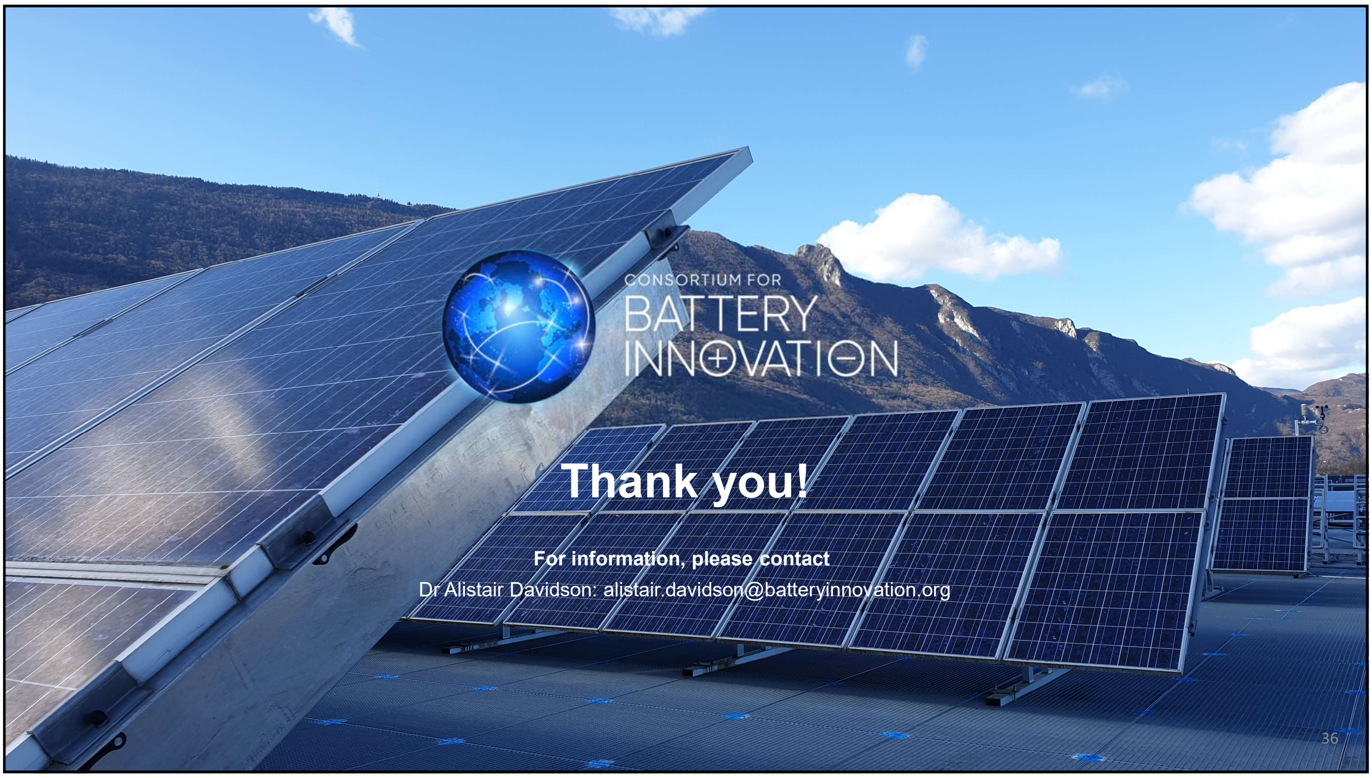
Innovación para mejorar la vida útil de las baterías
researchers to foster discussion about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Thank you!
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