CONSORTIUM FOR BATTERY INNOVATION

CBI Innovation Roadmap

Presented by:

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CBI four pillars of work

Pillars	RESEARCH	TESTING / STANDARDS	MARKETING	COMMUNICATION
Programs	BETTER BATTERIES	BETTER FRAMEWORK	BETTER RECOGNITION	BETTER RECOGNITION
	Improve battery and systems performance	Tests and standards that recognise lead battery merits	Improve end user recognition of lead battery benefits	Communicating innovation in lead battery performance and applications

CONSORTIUM FOR BATTERY INNOVATION

An innovation roadmap for advanced lead batteries

Technical specifications and performance improvements

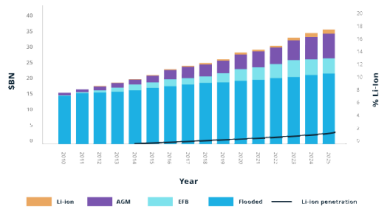


Figure 1

Actual and projected sales of automotive batteries by type from 2010 to 2025 in $BN and percentage of Li-ion batteries.

The projections by market analysts Avicenne indicate there will be growth for lead batteries particularly for automotive applications. Figure 1 shows the forecast sales for lead batteries in automotive service by type. A penetration of 5% for new cars by Li-ion 12 V batteries is forecast by 2025 but since 70-80% of the automotive market is for replacement, less than 2% of the market will move to Li-ion batteries. The original equipment market (OEM) will continue to use EFB and absorptive glass mat (AGM) batteries in increasing numbers and there will be a growing market for these types in the replacement market. However, a substantial part of the market will continue to use conventional flooded SLI batteries. In Europe, 80% of OEM sales will be micro-hybrid by 2025 with the USA and other regions following more slowly. The overall market will grow by ~5% annually in MWh and ~6% annually in $BN driven by continued growth in vehicle production and the car parc. Electric vehicles of all types will also use lead 12 V auxiliary (AUX) batteries, and as more functions are electrified on internal combustion engine vehicles, AUX batteries will also be used as secondary batteries for safety and security. This provides a significant future opportunity for lead batteries if they are able to adapt, improve and meet current and future OEM technical requirements.

For industrial batteries, the competitive position of Li-ion is different. Overall sales of batteries for telecommunications are forecast to grow by 2% annually from $3.2 to $3.8BN with Li-ion batteries potentially taking around15% market share which would mean a small

Overall, OEM battery requirements are moving rapidly, especially in Europe, to meet ever increasing emission standards. Lead batteries still retain most of the market both now and in the medium-term, but Li-ion are getting better and cheaper. Improving DCA and resolving the associated water loss issues needs to be addressed urgently. The requirements are high and stable DCA, PSoC durability with fast SoC recovery to provide stable SS/micro-hybrid capability over life and lower failure rates in hot climates. More realistic high temperature tests are a key to improved DCA. More precise SoC and SoH measurements are needed for batteries supporting safety and vehicle functions whether they are SLI, EFB, AGM or AUX batteries. Li-ion batteries are always fitted with a BMS and lead batteries need to have a similar capability if they are safety critical.

1.8. Key Performance Indicators for automotive batteries

Indicator	2018	2022	2025
DCA. A/Ah	0.4	2.0	2.0
PSoC, 17.5% DoD	1500 EFB	2000 EFB	3000 EFB
Water loss, g/Ah	< 3	< 3	< 3
Corrosion, J2801, Units	12	18	22

Table 4

DCA does not need to exceed 2.0-2.5 A/Ah for small cars (L3 battery) as this matches the alternator output; PSoC continuous test; water loss and corrosion targets are not important if new life tests are specified. Priority areas in red

Note DCA does not need to exceed 2.0-2.5 A/Ah for small cars (L3 battery) as this matches the alternator output; PSoC continuous test; water loss and corrosion targets are not important if new life tests are specified

The analysis of battery performance requirements has resulted in the definition of a small number of key performance indicators (KPIs), shown above as the main objectives defined

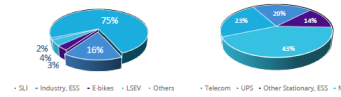
1.2. Marking more than 25 years of successful innovation

The Consortium was originally formed in 1992 with the aim of improving performance of VRLA batteries especially where better cycle life was required. This was achieved and the success of VRLA batteries in automotive and industrial service is, in no small measure, the result of much of this work. More recently, research work has been directed towards the development of batteries with enhanced shallow cycle life in high-rate partial state-of-charge (HRPSoC) service with carbon-enhanced designs for automotive start-stop or micro-hybrid duty cycles and for energy storage. Recently this has focused on improving the understanding of the function and behavior of different forms of carbon in the negative plate, and whilst battery performance is meeting current technical requirements, increasing demands for energy recovery in automotive service and for partial state-of-charge in energy storage are providing a strong impetus for further work.

1.3. The battery industry in 2019

The battery industry has seen unprecedented growth over the last 25 years. Lead batteries have continued to be more widely used in automotive and industrial applications and still provide 75 per cent of global rechargeable energy storage. New technologies have entered the market and lithium-ion (Li-ion) batteries in particular are set to grow substantially in electric vehicles of all types and in energy storage. However, significant growth in demand for energy storage is predicted over the next 5-10 years and this will require battery technologies that can demonstrate continuous improvement and scale-up quickly to meet new requirements.

In 1990 the rechargeable battery market was ~$15BN worldwide for lead batteries and ~$3BN for nickel-cadmium batteries. By 2017, the lead battery market had grown to $37BN and Li-ion battery sales were $36BN with ~$3BN for other rechargeable batteries including nickel-metal hydride which has overtaken nickel-cadmium. Lead batteries, however, represent 75% of the market in MWh because of the large price difference in $/MWh. For the future, Li-ion battery sales will continue to grow, and the total battery market is expected to double in value to ~$150BN by 2025.



contraction of the market of 1% for lead batteries. Li-ion batteries can offer a lower lifetime cost for certain applications. For UPS the overall market will grow at 3% annually from $2.8 to $3.5BN and although lead batteries retain the cost advantage, Li-ion batteries will take an overall share of 14%, with a small growth (1%) for lead batteries.

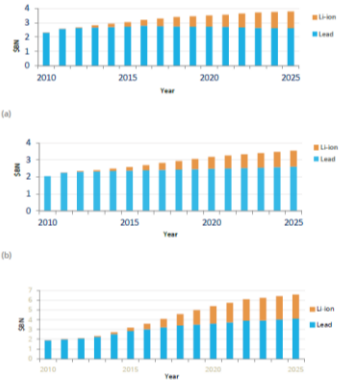
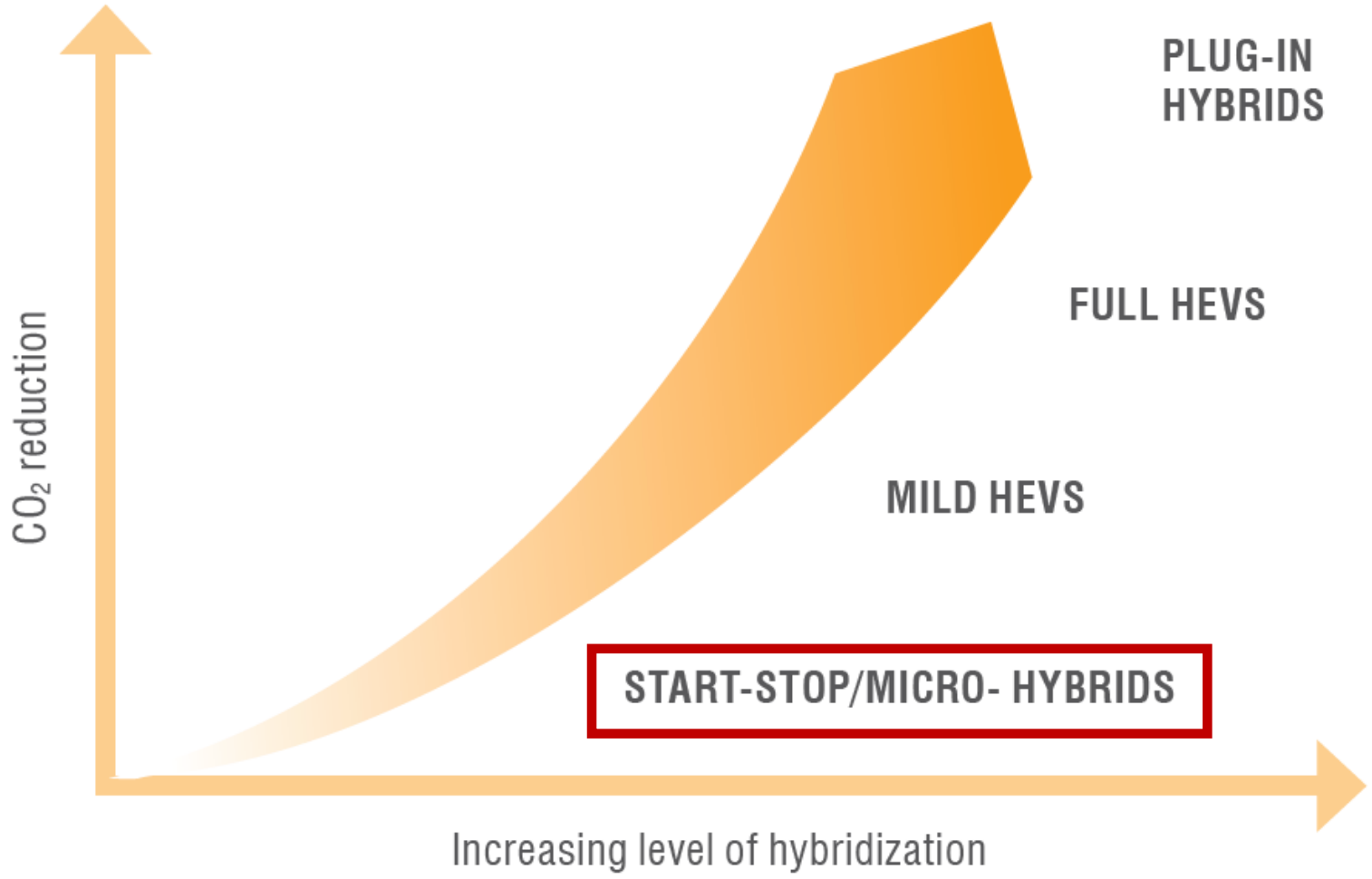


Figure 2

Forecast sales for lead and Li-ion batteries for (a) telecommunications, (b) UPS and (c) traction applications in $M from 2010 to 2025.

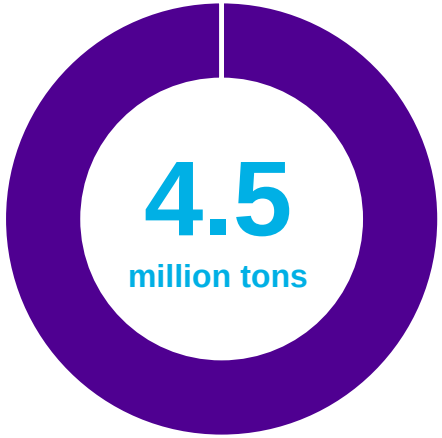
Automotive opportunities



Start-Stop Batteries

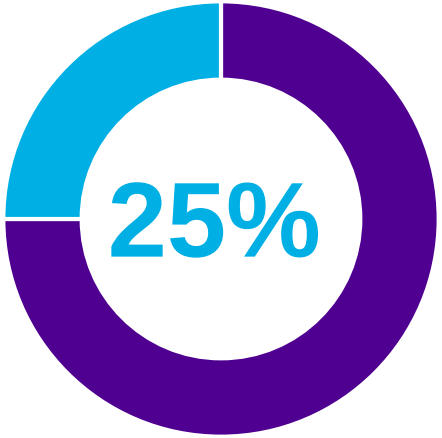
Big Impact at Low Cost

CO_2 Savings



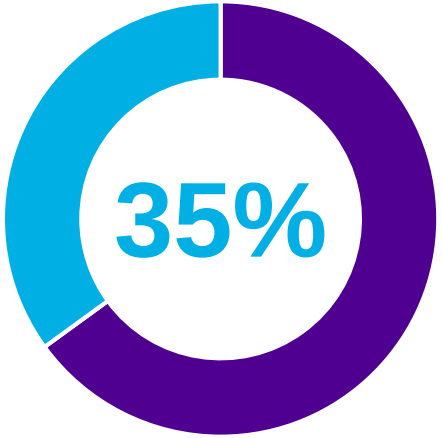
Lead batteries help start the engine, supply power to lighting and ignition systems, provide safety functions, power infotainment, **and improve gas mileage**. The improvements in fuel efficiency lower CO_2 emissions and this number is growing annually.

Percentage of New ICE Cars



New cars are showing a drastic increase in the use of start-stop technology, which has served as a valuable home-grown tool to increase fuel efficiency and lower CO_2 emissions

Percentage of Light Trucks/SUVs



The fastest growing segment in America has utilized start-stop technology to meet performance and decarbonization goals across not only the United States, but the world as well.

2019 Program Overview

Companies and Institutions Involved

Advanced Battery Concepts
Better Batteries, Better World©

EAI
Advancing Energy Solutions

Wrocław University of Science and Technology

Fraunhofer ISC

CABOT

HAMMOND
THE CHANGE CATALYST®

Technische Universität Berlin

MOLL BATTERIEN

EASTPENN
East Penn Manufacturing Co.

Borregaard LignoTech

EXIDE TECHNOLOGIES

icma
Instituto de Ciencia de Materiales de Aragón

THE UNIVERSITY OF CALIFORNIA
LET THERE BE LIGHT
UCLA

Ford

2019 RFP – Focus Areas and KPIs

Application specific fundamental research

KPIs automotive: targets

Indicator	2018	2022	2025
DCA. A/Ah	**0.4**	**2.0**	**2.0**
PSoC, 17.5% DoD	1500 EFB	2000 EFB	3000 EFB
Water loss, g/Ah	<3	<3	<3
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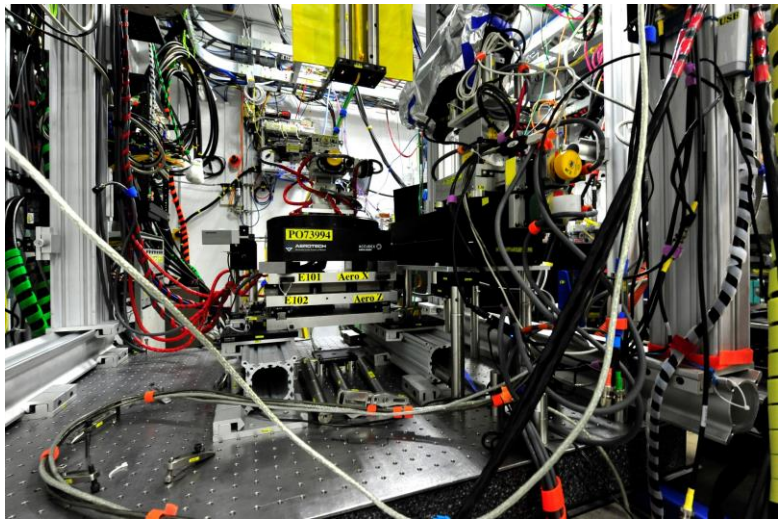
2019 RFP – Focus Areas and KPIs

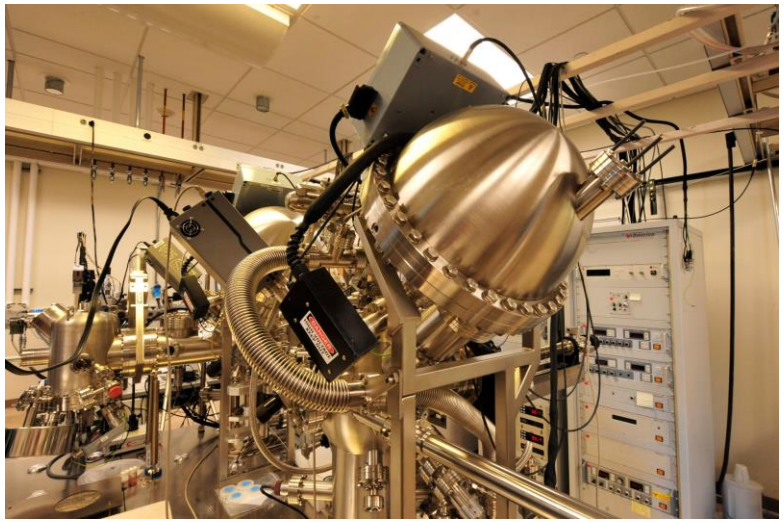
Application specific fundamental research

KPIs energy storage systems: targets

Indicator	2018	2022	2025
Service life, y	12+	12-15	15-20
PSoC, PV	1500	2000	2500
Cycle life	**1000-3000**	**5000**	**6000**
Charge efficiency	85-90%	90-95%	>95%

Project with ANL and US Department of Energy





EAI
Advancing Energy Solutions

Advanced Battery Concepts
Better Batteries, Better World®

Borregaard LignoTech

CABOT

Argonne NATIONAL LABORATORY

CROWN BATTERY

THE DOE RUN COMPANY

EASTPENN

Trojan BATTERY COMPANY

EnerSys
Power/Full Solutions

EXIDE TECHNOLOGIES

Johnson Controls

MICROPOROUS
Proven. Partner. Focus.

Teck

NorthStar

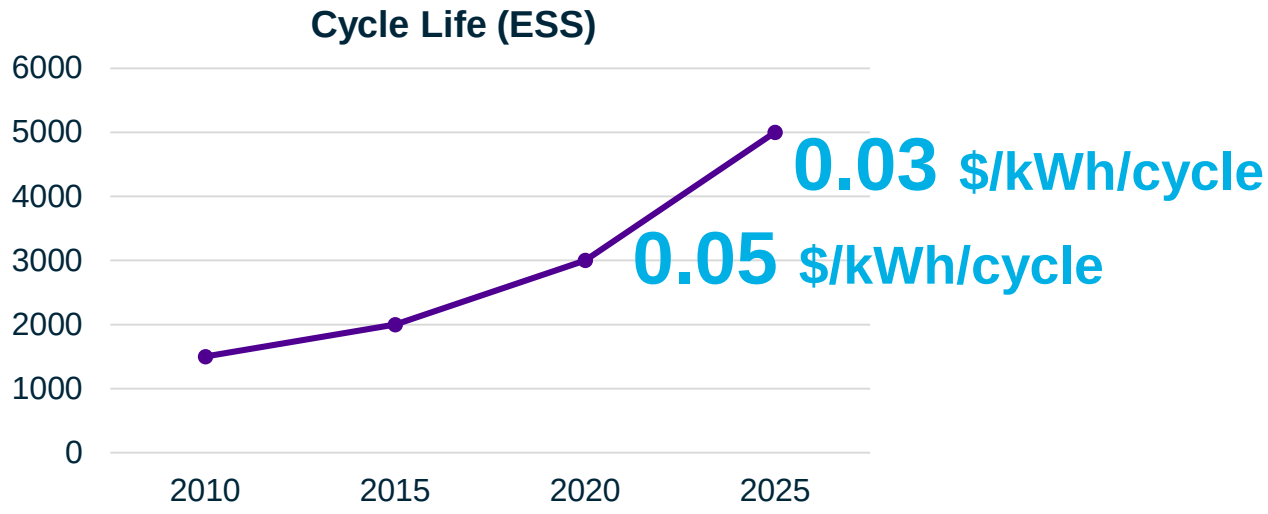
RSR CORPORATION

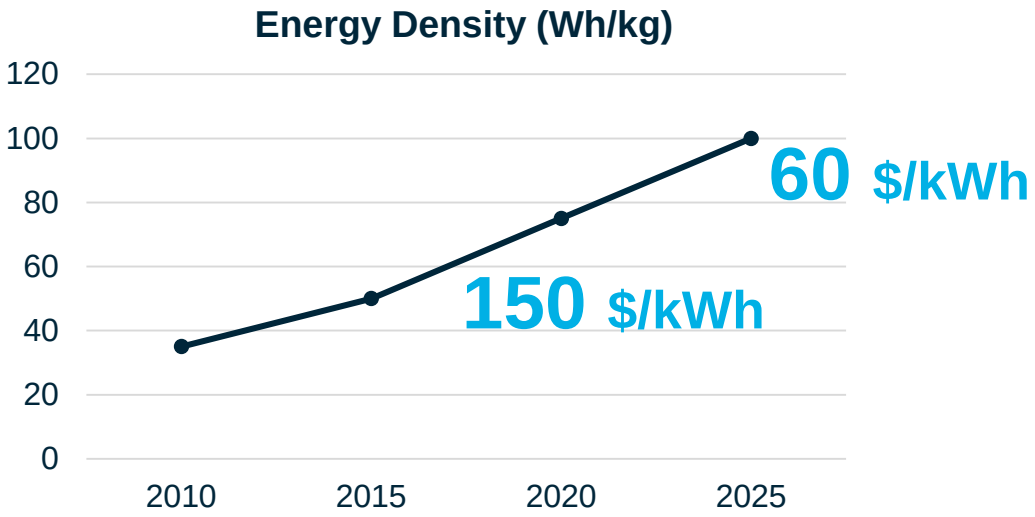
SUPERIOR GRAPHITE

HAMMOND
THE CHANGE CATALYST®

Lead Batteries Role in ESS

Steady Progression over the last ten years





US DOE Goals

US Department of Energy goals for ESS are techno-economic:

Less than 0.05 $/kWh/cycle

Less than 50 $/kWh

Thank you!

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