ALABC

The Advanced Lead-Acid Battery Consortium

PROSPECTUS

2013-2015

ALABC Prospectus 2013 -2015

ALABC

Executive Summary

The automotive sector remains by far the largest of the markets for lead–acid batteries and thus the ALABC technical program has continued to focus primarily on the necessary research and development to allow the lead–acid community to anticipate and to satisfy the changes in demands on the battery that will be made by future automobile systems. Sound technical progress has been made allowing the successful demonstration of lead–acid systems in medium HEVs and in a micro-hybrid that is capable of providing the emissions reduction of a more complex vehicle. Both of these approaches offer routes to the achievement of the fuel economies offered by medium or full hybrids but without the cost of expensive battery systems. The ALABC Public Affairs and Marketing team is building on these technical advances by undertaking a vigorous program of publicity to make sure that auto companies are fully appraised of the opportunities that they present.

A secondary but nonetheless important opportunity involves the growth of interest in stationary energy storage applications including the timely accommodation of energy from renewable sources and the covering of power supply interruptions in parts of the world that lack total stability of supply. There are some parallels between the duty cycles for batteries in HEVs (i.e. high-rate partial-state-of-charge operation) and those in some of the stationary operations which offer the possibility of spin-off benefits from the technical program that has so far been focused primarily on vehicles.

This prospectus outlines the state of the art as the ALABC program for 2010 – 2012 approaches completion, and outlines a program for 2013 – 2015. Continued work on HRPSoC duty will also show benefits in the optimization of batteries that can be rapidly recharged for a variety of applications and in batteries that can be used to store renewable energy.

ALABC membership application forms and an outline of ALABC general operating procedures are included within the prospectus.

Contents

Introduction

The share of world lead production that is absorbed in the production of secondary batteries continues to grow and now stands at over 80%. At the same time the demand for energy storage, in both vehicular and stationary applications, is burgeoning as never before. The pressure on resources of hydrocarbon fuels, combined with insistent concerns to limit the emissions of carbon dioxide to the earth's atmosphere, serve to drive automotive design towards increased fuel economy through expanded electrical functionality and to promote an increase in the fraction of primary energy supply that is garnered from renewable sources. The commercial opportunity that is presented by these trends quite naturally attracts strong competition for the lead–acid battery industry from the purveyors of batteries based on alternative chemistries. The mission of the Advanced Lead–Acid Battery Consortium (ALABC) is to take lead–acid battery technology forward to levels of performance in appropriate duty cycles that will ensure that the lead–acid battery, with its substantial cost and recycling advantages, will remain the battery of choice in most future electrical energy storage markets.

Principal Applications of Secondary Batteries 2013 – 2015

Continuing changes in automotive design

The largest market for rechargeable (secondary) batteries, by a large margin, is for the storage of energy on board road vehicles, primarily automobiles, and here major changes are taking place in the demands that are placed on the battery in service. The introduction of 'stop–start' technology (the major component of micro-hybrid vehicles) to automobiles in many parts of the world is proceeding at a great pace. As in the earlier medium and full versions of hybrid electric vehicles (HEVs), the battery in a stop–start vehicle must perform a duty that is far more demanding than the 'traditional' provision of energy for starting, lighting and ignition (SLI) operations. Within a few years, new automobiles with only SLI battery functions will be in the minority. The shift in technology towards hybrid, and perhaps all-electric, vehicles poses major challenges for the battery. But predictions of the shape of future automotive markets in terms of the types of vehicle that will dominate are continually shifting.

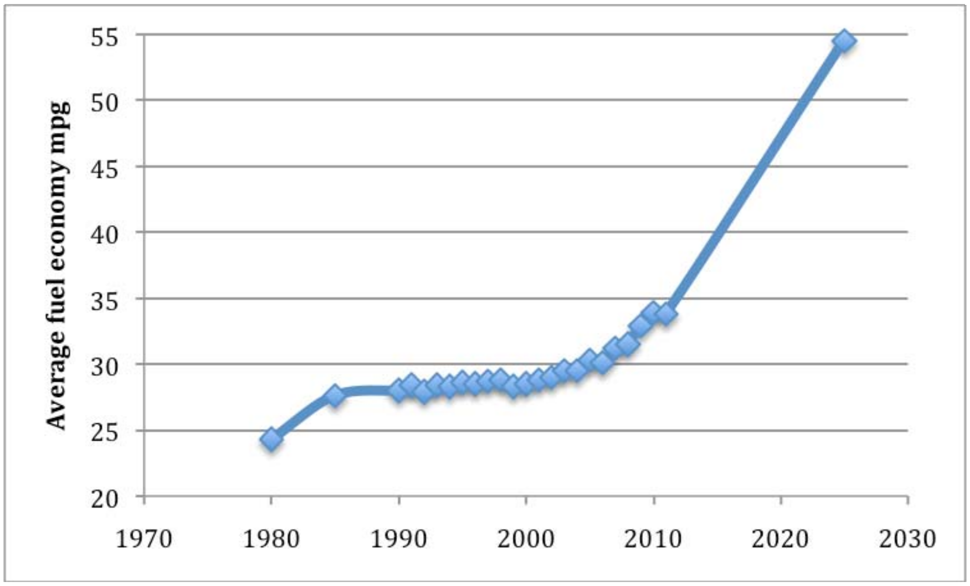
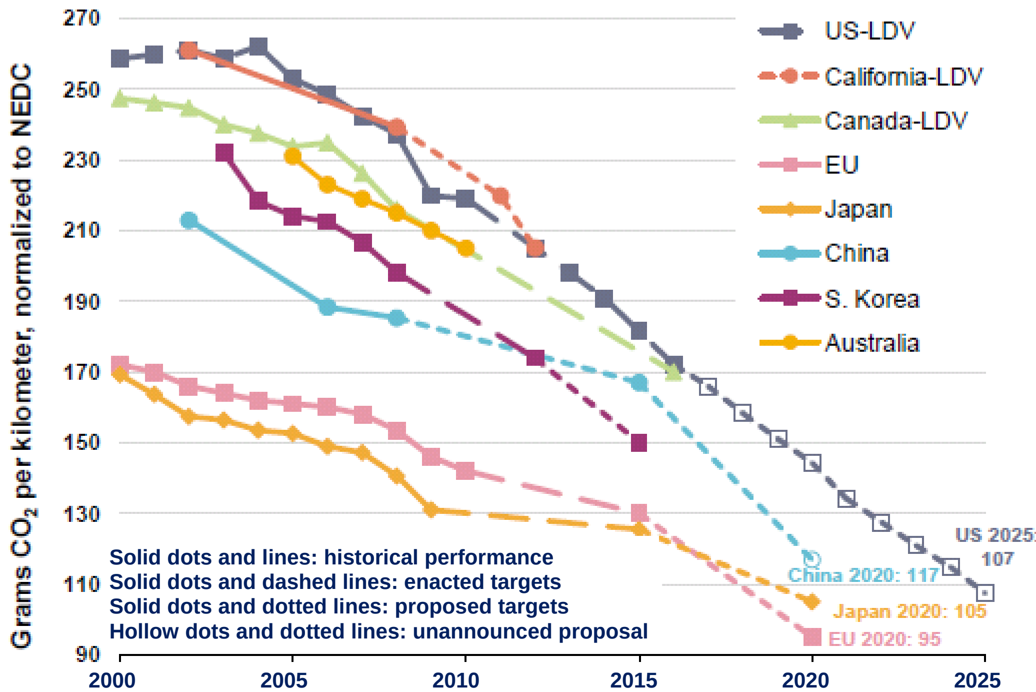


Figure 1 Average fuel economy of small cars in the USA and target for 2025 (Figures from the Research and Innovative Technology Administration, Bureau of Transportation Statistics).

A major incentive for the automobile manufacturers to change their designs is the legislation that is emerging in many parts of the world to limit allowable fleet-wide emissions of carbon dioxide, CO_2, under pain of serious financial penalties for non-compliance. The targets to be met are often presented in terms of the quantity (grams) of CO_2 that may be emitted per kilometre driven. In Europe that targets are 130 g per km by 2015 and 95 g per km by 2020. In the U.S.A. the aims are also sometimes quoted in terms of the CAFE (Corporate Average Fuel Economy) objectives. Since the turn of the century the average fuel economy for small cars in the U.S.A. has been rising but in 2011 the Obama administration proposed a dramatic increase to 54.5 miles per gallon (U.S.) by 2025 (see Figure 1).

In general the legislation governing allowable emissions requires the progressive tightening of targets with time in all regions of the world, as shown in Figure 2. It is anticipated that the first rank of targets can be met by introducing 'stop/start' technology and, following the lead of BMW in 2007, all major car companies have plans in place or have already launched stop/start vehicles. In this way around 6 % of reduction in emissions can be saved and this could be extended to about 8 % if regenerative braking were to be included.



[1] China's target reflects gasoline fleet scenario. If including other fuel types, the target will be lower.
[2] US and Canada light-duty vehicles include light-commercial vehicles.

Figure 2. The progressive reduction in allowable emissions of carbon dioxide in various parts of the world. Source: N. Jackson, The Cars of Tomorrow, Ricardo

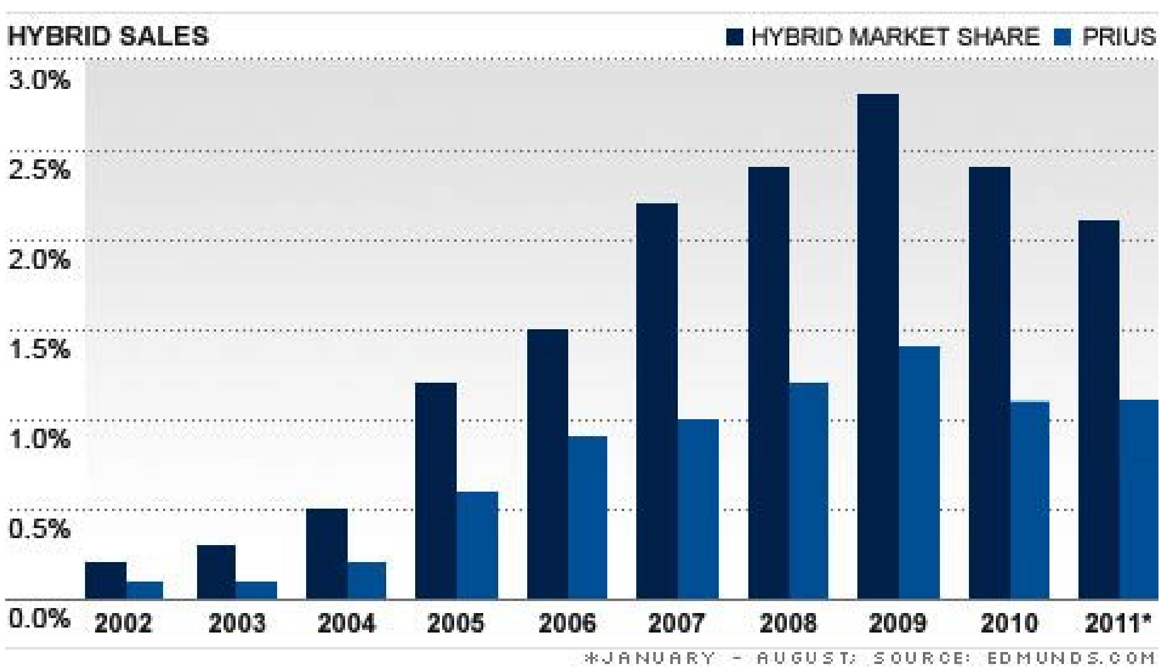


Figure 3. Sales of hybrids as a fraction of total automobile sales in the U.S.A.

A report by Lux Research in January 2012 predicted that world sales of ‘Micro-hybrids’ (stop/start technology) would grow to 39 million in 2017 with Europe contributing 12.6 million, China 8.9 million and the U.S. 8 million.

It could have been anticipated that when the stages of tighter emissions regulation were reached car companies could move on to the widespread adoption of diesel-engined vehicles or hybrids which offer higher fuel economy than does the bare stop/start vehicle. However the hybrid vehicles on the road today make use of batteries that have high voltages (150 V and more) and, as a result, attract a considerable cost premium in comparison with the equivalent non-hybrid models. Also hybrids only provide significant improvement in fuel economy and emissions during urban driving where the vehicle stops frequently. They offer little advantage during highway driving. Thus, after considerable early success in the marketplace, the most recent sales figures (Figure 3) appear to show the uptake of hybrids stalling in the U.S.A. Vehicles with diesel engines improve fuel economy for all types of journey but, as yet, have not been welcomed in the U.S. A. and Japan.

Figure 4. The Honda Civic in which the original nickel - metal hydride battery has been replaced with an ‘UltraBattery’.

If the sales of hybrids are held back by the extra cost of their batteries then it can be anticipated that the market might be freed-up by the use of a lead–acid variant. It is in order to explore such a possibility that the ALABC program has included demonstration projects in which the nickel metal hydride batteries in, first, a Honda Insight and, second, a Honda Civic were replaced by the lead–acid 'UltraBattery'. The success of the Insight project in driving over 100,000 miles with no significant battery degradation is well documented. The project that has involved the Civic, which is a larger car (Figure 4), has been proceeding more recently and so far has proved equally successful.

Drive Cycle	***UltraBattery Civic (mpg)***	***Unconverted Civic (mpg)***
UDDS	**61.7**	53.1
Highway	59.8	61.0
US06	35.6	37.0
UDDS with A/C on	**49.8**	36.0
Highway with A/C on	45.9	47.7

Table 1. Drive cycle performance comparison of the UltraBattery Civic with that of the unconverted model.

Table 1 shows that the fuel economy of the UltraBattery Civic has actually been superior to that of the unconverted Civic during some of the standard drive cycles and little different in others. The vehicle is currently in every-day use on the streets of Phoenix and performing well after having completed 35,000 miles without failure.

Metric	**Micro-Hybrid**	**12 V 'Micro/Mild'**	**48 V 'Micro/Mild'**	**Mild Hybrid**	**Full Hybrid**
Battery Voltage (V)	12	12	48	~150	>200
Regen. Power (kW)	0.5 - 3	3	8	10	20
OEM On-cost ($)	200 - 900	1000	2000	4000	6000
CO_2 Emission Reduction (%)	6 – 8	15	25	12	20
Cost / Benefit (US $ per % CO_2 reduction)	50 - 130	66	80	300	300

Table 2. Comparison of estimated costs and benefits for different categories of hybrid electric automobile.

An alternative approach to achieving significant reductions in CO_2 emissions is based on upgrading the performance of the base micro-hybrid. Such a vehicle, offering only stop/start functionality, represents the least expensive modification of a standard car design in pursuit of fuel economy but provides only a modest benefit. As shown in Table 2 mild and full hybrids yield greater reductions in carbon dioxide emissions but at a much greater cost supplement – much of which is due to the use of costly high voltage NiMH or Li-Ion batteries.

The two 'Micro/Mild' categories offer emissions that are reduced as a result of down-sizing the engine but with no overall reduction in power thanks to the incorporation of an electric super-charger that draws on regenerative braking energy.

Vehicle ► Feature ▼	**Unit**	**Unconverted TSI engine VW Passat**	**LC Super Hybrid VW Passat**	**Unconverted TSI engine VW Passat**	**Atmospheric 2.0L engine Volvo S40**
Engine volume	liters	1.4	**1.4**	1.8	2.0
Power	hp	122*	**142****	160*	145*
Torque	Nm	200*	**275****	250*	185 *
Acceleration	(0-62 mph)	11.1 s**	**8.7 s****	8.5 s*	9.5 s*
Mileage (combined)	mpg	47.9**	**50.5****	40.9*	37.2*
Fuel consumption (combined)	liter/100 km	5.9**	**5.6****	6.9*	7.5*
CO_2 Emissions	g/km	140**	130**	160*	176*
Weight	kg	1451*	~1480	1505*	1370*
		** - measured by AVL			
		* - producer's data			

Table 3. Comparison of the performance of the 'LC Super Hybrid' VW Passat (a 'Micro/Mild' type) with those of an unconverted VW Passat and a Volvo that offers similar power.

Similar strong reductions in emissions to those achieved in mild and full hybrids can be achieved with low-voltage vehicles, however, as exemplified in the two columns marked 'Micro/Mild'. In these vehicles an efficient integrated starter/generator (ISG) is used to collect regenerative energy and this is used to power an electric super-charger. These vehicles are equipped with smaller engines than those in the normal, non-hybrid, versions and this change results in the substantial reductions in CO_2 that are shown in the Table. Normally the use of smaller engines would lead to some degradation in vehicle performance but the presence of the electric super charger – coupled with a conventional turbocharger - makes good the power of the vehicle. The result is a vehicle that provides the higher levels of fuel economy that will be required in the second round of vehicle emissions legislation, at a cost that is much lower than those of the medium and full hybrids.

This ‘down-size and boost’ strategy has the merit of providing improved fuel economy and emissions reduction for all types of driving (urban and highway).

An ALABC project was devoted to the first exploration of this concept, using the 12 V variant, with the results that are shown in Table 3. The next step is a project that will aim to access the additional benefits that appear to be available when the system is implemented at 48 V – still with a lead–acid battery.

Stationary Energy Storage

Concerns about global warming and possible climatic effects are also driving major changes in the generation of electricity in many parts of the world. Major programs to install wind generating systems and photovoltaic arrays are underway, often with heavy subsidy from governments or the utility companies.

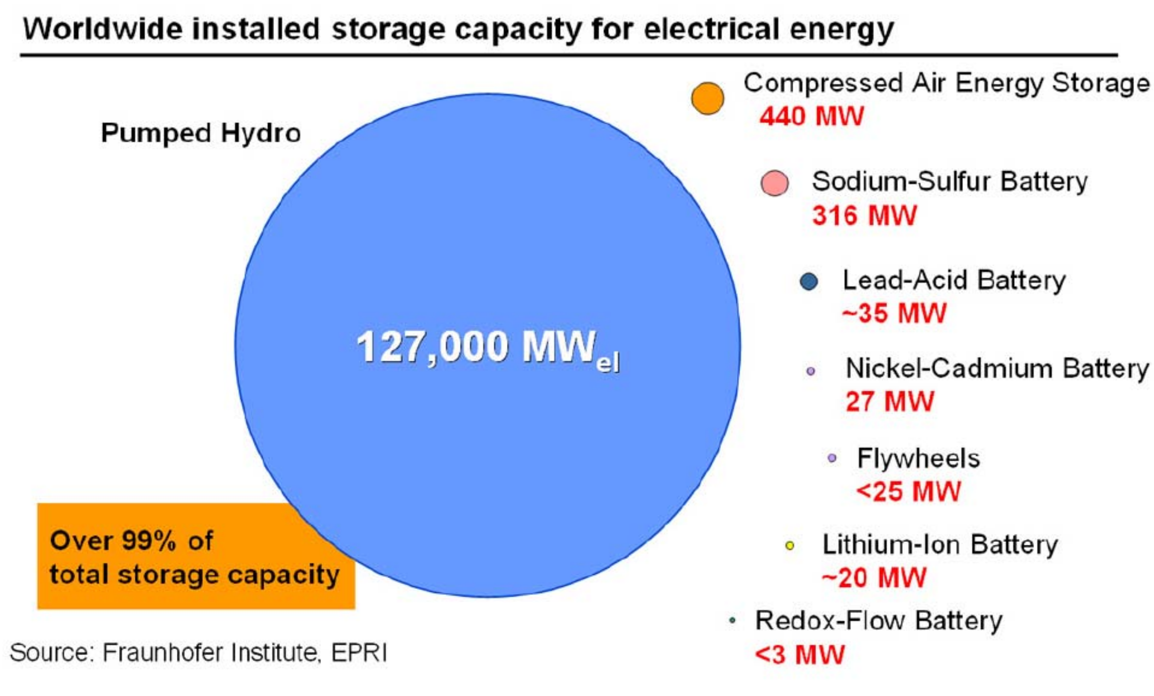


Figure 5. Worldwide Installed Storage Capacity for Electrical Energy (Source EPRI primer -Electric Energy Storage Technology Options, December 2010)

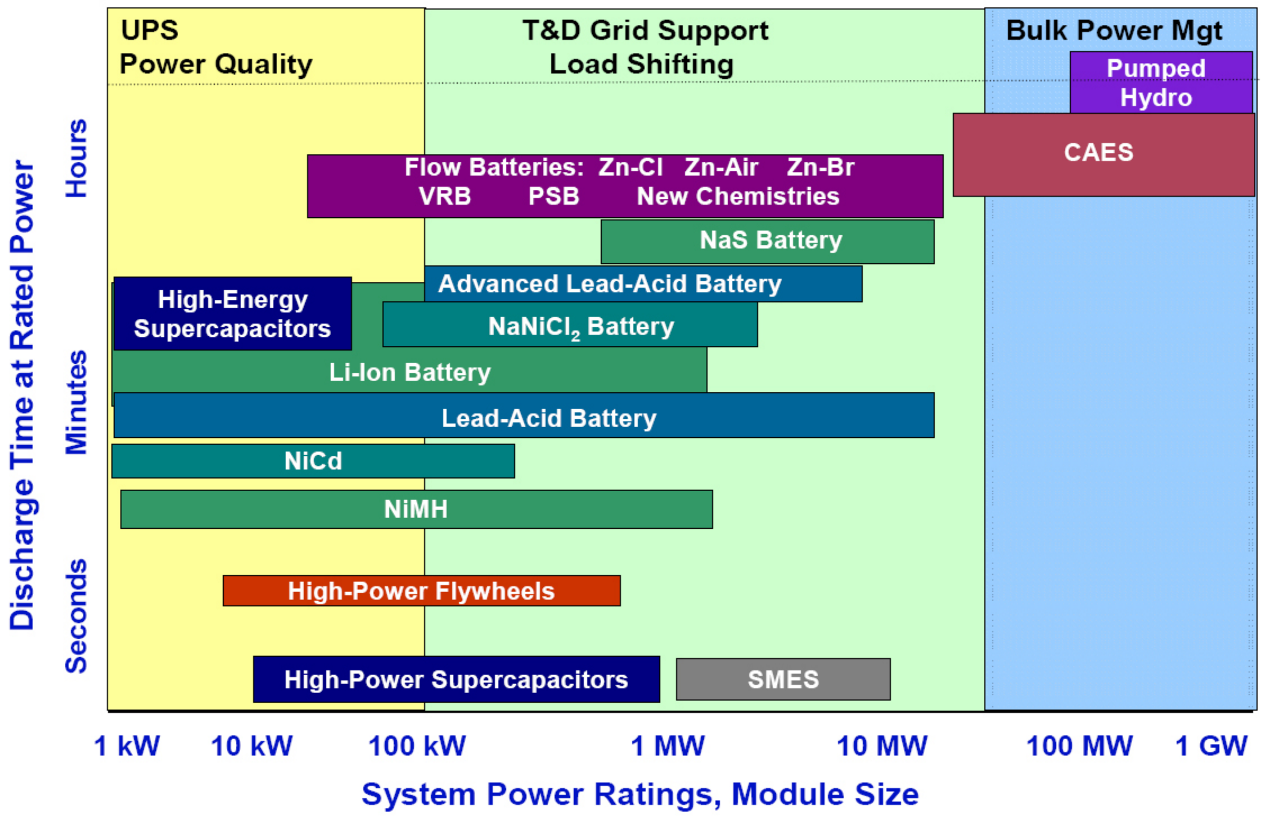


Figure 6. Positioning of Energy Storage Technologies (Source EPRI primer - Electric Energy Storage Technology Options, December 2010)

While such endeavors are undoubtedly laudable they are likely to pose major problems for the transmission and distribution operations in the electricity supply industry. Electricity from renewable sources can be absorbed into supply grids as long as it does not constitute more than a small fraction of the power in the system.

If renewable energies become called upon to contribute a majority of the electric power then provision will have to be made for the storage of energy. On the Supply side the amounts of energy are likely to be so large that conventional batteries will not be considered but, on the Demand side, there are likely to be opportunities for battery energy storage and the least expensive system will continue to be of interest (see Figures 5 and 6).

One of the key factors governing acceptability will be operating life in the necessary duty cycle and, since high charge acceptance will be a characteristic of such duty, there will be some focus on the same life-limiting processes as are experienced in hybrid electric vehicles, namely high-rate partial-state-of-charge (HRPSoC) operation.

Another area where HRPSoC operation is required is in the provision of uninterruptible power supplies for electrical equipment in countries where power cuts are rife. Evidently it would be of value to explore in these stationary applications the effectiveness of the measures that have been developed to allow lead–acid to operate in hybrid electric vehicles.

Status of the ALABC Program during the second half of 2012

During the latter part of 2012, the ALABC still has program areas active, and results in prospect, in the following general areas:

Demonstration projects

1. A unique combination of advanced engine control devices and lead-carbon batteries has been used to create the LC Super Hybrid – a further development of the micro hybrid concept which combines the fuel and CO_2 efficiency of a full hybrid at a price of a non-hybrid vehicle. The vehicle was built with CPT, Valeo, and Provector in England, and with AVL Schrick and Mubea in Germany. The interest of journalists and car /battery manufacturers in this new concept and in the demonstrator vehicle (a VW Passat with downsized to 1.4L turbocharged engine) increases steadily. The 12V LC Super Hybrid is and will continue to be displayed at various car and battery shows in Europe and in the USA. In addition, real road test data will be acquired by the battery monitoring system (BMS) installed in the vehicle. Based on the LC Super Hybrid concept, a simulation study with AVL Schrick GmbH has shown that it is possible to modify a small three-cylinder, four seat vehicle into a 88.5 mpg (US) (or 106 mpg imperial) vehicle. This result has already attracted car manufacturer's attention in Asia.

2. A computer simulation of a 48V LC SH vehicle with a 25 Ah battery and a 4.5 kW electric machine took into account the superposition of cranking and some E-assist power, the amount of brake energy which can be delivered back to the battery by the ISG and the charge and discharge power of the battery in the 36% to 40% SOC range in the NEDC profile (Fig. 7). The study showed that the 48V LC SH vehicle will be able to provide 5%- 7% more fuel and CO_2 economy.

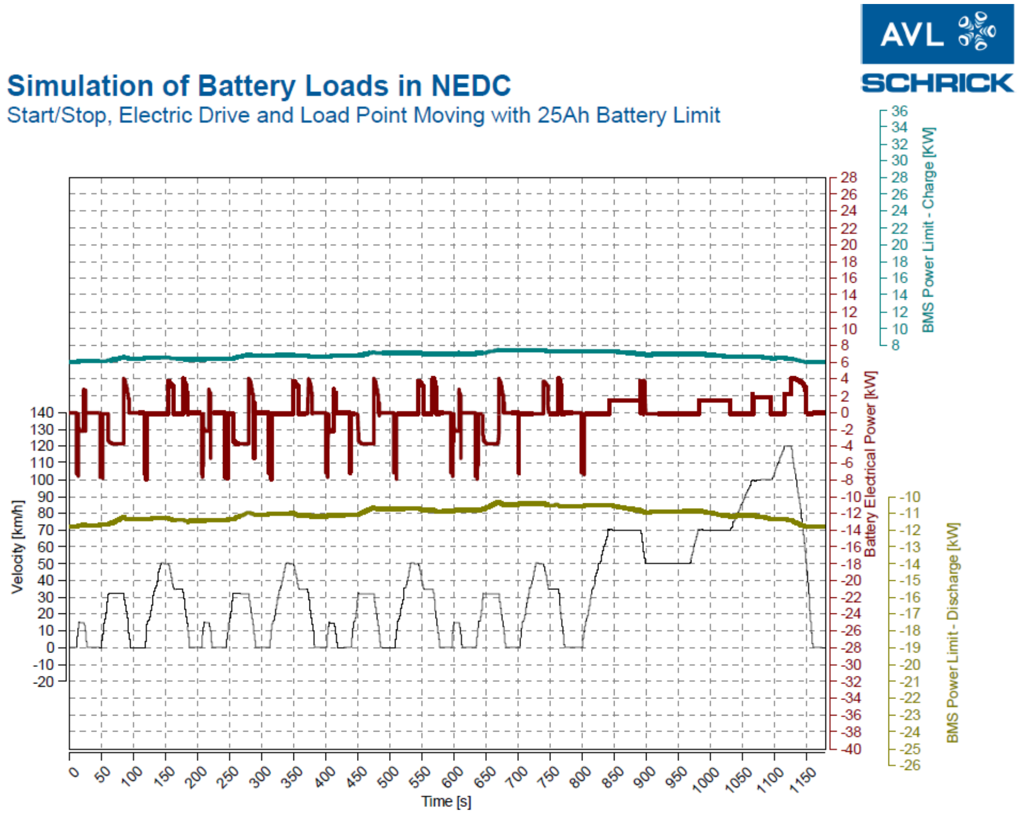


Figure 7. Battery power, BMS charge and discharge limits and velocity profile with a 25 Ah battery, ALABC project 1012N with AVL Schrick GmbH, 2012.

3. Further development and production of 2V/6Ah cells with advanced current collector design, positive and negative terminals located at opposite walls of the cell, and carbon added to the negative active material. The cells will be assembled in a battery to replace the original NiMH battery in a 2011 Honda Insight mild hybrid vehicle which will be tested on the road in the UK.

4. The potential of using lead-carbon batteries in vehicles with down-sized engines reinforced by boosting techniques and advanced brake energy recovery hardware integrated to a stop-start system was proven by the HYBOOST project. Significant savings in emissions – 41% - were achieved along with excellent driving dynamics and without significant additional powertrain expenditure unlike the medium hybrid approach. The vehicle used a combination of a lead–acid battery and an ultra-capacitor. The prohibitive price of the latter promoted the huge potential of lead–carbon batteries for similar applications.

5. Development of a spiral wound 6V/10Ah module for hybrid electric vehicles. This work is a further development of the projects with Exide, with the addition of advanced carbon black

additives to the negative active material. The modules will be used in a battery replacing the original NiMH battery in a 2010 Honda Civic Hybrid after passing lab tests according to the profile developed with Ecotality (Arizona) especially for this vehicle.

6. Testing of automotive and photovoltaic lead–carbon batteries with new types of advanced organic expanders developed by Borregaard - Lignotech for HRPSoC applications. The results of the model cell tests were statistically analyzed. Batteries with the best expanders were produced by Acumuladores Moura and are currently under test in Brazil.

7. Further road testing of the Honda Civic with NiMH batteries replaced by UltraBatteries in Arizona. The vehicle has already completed 35,000 miles and continues to perform as well as or better than the original version.

Research projects

1. Studies on model cells confirmed that, as in all absorptive glass mat (AGM) valve-regulated lead-acid (VRLA) cells, mechanical compression has a beneficial effect on cycle life in lead–carbon cells also. The optimal compression value to be considered for battery design is about 4 $N.cm^{-2}$.

2. Fundamental studies on the thermodynamics of the carbon electrode in sulfuric acid solution pointed to the possibility of carbon oxidation to CO_2 and, consequently, its loss due to the oxidative action of oxygen at the negative plate in VRLA cells.

3. Fundamental electrochemical studies performed to explain the specific interaction between carbon additives and lead, lead sulphate, barium sulphate and lignosulphonates on high rate partial state-of-charge (HRPSoC) cycling showed that this interaction is rather complex. Outstanding NAM performance was observed with carbon only and no expander, or with carbon and barium sulphate only and no lignosulphonates, or with new organic expanders and no carbon, no lignosulphonates. The latest results have shown that carbon particles will be incorporated in various ways into the microstructure of the negative active mass (NAM) and change dramatically its porosity and the rate of the electrochemical processes in the pores. Lead sulfate crystals growing and re-crystallizing in parallel to the charge-discharge reaction, and formation of lead

monoxide as a result of the membrane properties of the lead sulphate crystals are critical for the performance of the negative plate and are strongly influenced by carbon additives.

4. Another factor was identified which influences strongly the cycle life of the negative plate along with state-of-charge and amount/type of carbon additives: the duration of the rest period between the charge and discharge pulses (Fig. 8). Finding ways to optimize the combination of these factors can provide the battery industry with methods to decrease cycle life shortening of advanced lead-acid batteries at HRPSoC.

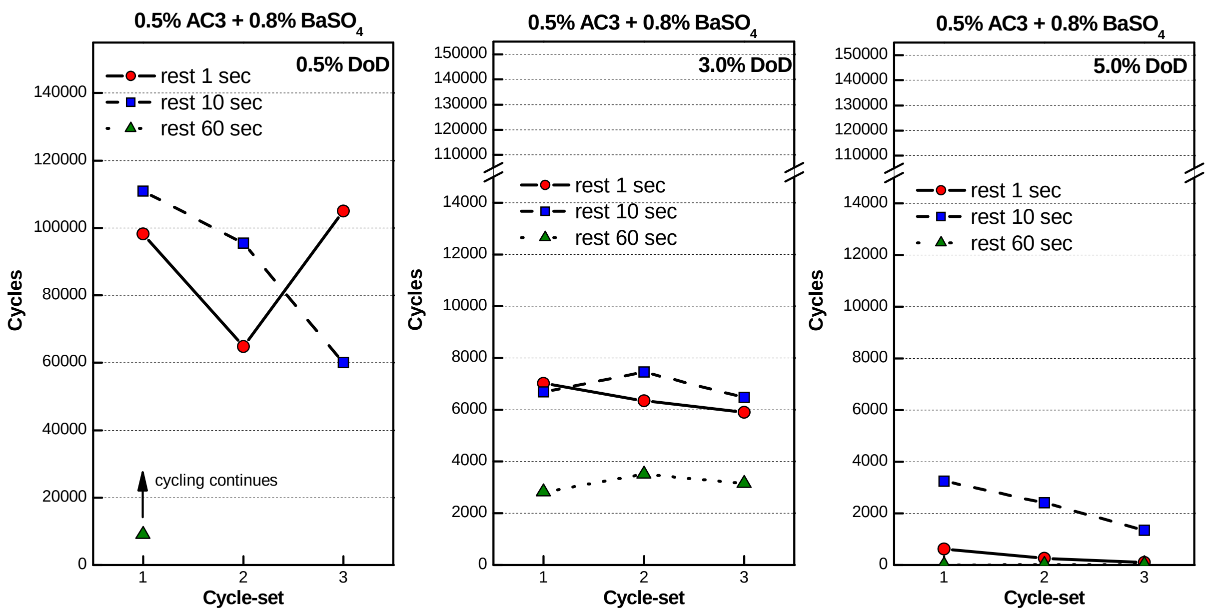


Figure 8. Cycling plots of cells with same additives at three DOD levels and three rest times , ALABC project 1012G with the Bulgarian Academy of Sciences.

5. On HRPSoC operation processes of double layer rearrangement (capacitance) and Faradaic electrochemical reactions (capacity) take place. They proceed at different rates, the slow Faradaic processes are considered to be the reason for the capacity loss. Up to now it was possible to reduce the limitations caused by the slow-rate Faradaic processes by separating both processes by space – achieved in the UltraBattery. Recent ALABC studies have shown that the duration and sequence of the high rate charge-discharge pulses in the range between 0.1 and 100 seconds is what determines which process will control the charge/discharge reaction. During the short pulses mainly capacitive processes take place, and the capacity doesn’t decline. Selecting the right pulse duration allows separating both processes by time. Until now, the control of the duration and sequence of charge/discharge pulses has been left to the battery charger and to the

load. As Dynamic Charge Acceptance (DCA) has become an important factor for batteries in hybrid electric vehicles, the time structure of the battery charge/discharge profile becomes a priority for battery life optimization in the future.

6. The rate of hydrogen evolution on pure carbon electrodes was measured using various carbon powders provided by most of the ALABC carbon producing members. The results of the study showed that on all carbon electrodes, hydrogen evolved much more slowly than on pure lead. The reaction rate and the onset potential depend strongly on the type of carbon (graphite, carbon black, activated carbon). Activated carbons have the smallest hydrogen evolution rate. These observations appear to be in conflict with accelerated water loss in batteries with carbon-added NAM observed by some battery makers. The higher surface area of the carbon phase could be an explanation of accelerated gassing, and further studies are necessary to assess how to keep water losses as low as possible in the presence of carbon additives.

Public Affairs and Marketing

Over the 2010-2012 period, the ALABC has taken steps to increase the awareness of advancements in lead–acid battery technology among key policymakers throughout the world. The ALABC Public Affairs and Marketing (PAM) Committee, under the leadership of its new Chairman, John Likarish of the Doe Run Company, has expanded awareness the ALABC program and developments in the lead battery market to three key international audiences: 1) automakers and other end-users, 2) government officials and policymakers, and 3) program members (both current and prospective). These steps included:

- Addition of a part-time professional to manage ALABC marketing and communications efforts
- Expansion and update of current media vehicles (Keeping Pace newsletter, website, informational collaterals and information sheets)
- Development of new media vehicles and branding initiatives
- Enhanced publicity efforts toward international media around program news (project updates, membership expansion, and general ALABC news)
- Expansion of PAM resources in formerly underserved areas.

In late 2010, the welcome addition of Chip Bremer in the marketing and communications position previously held for several years by Rob Putnam, who had taken a similar position with the International Zinc Association (IZA), initiated the process of upgrading the overall efforts of the ALABC PAM Committee to achieve its objectives. The ALABC not only continued to promote its activities through the Keeping Pace newsletter, but did so at a more consistent rate (every 2-3 weeks). The PAM Committee also made updates to the members' website and initiated designs of a new public site at www.alabc.org, which was launched in mid-August 2012.

Along with the website redesign, the PAM Committee developed an 'LC' logo to help brand the burgeoning lead–carbon technology, as well as the Super Hybrid developed by the European ALABC in partnership with Controlled Power Technologies, AVL Schrick and others. This LC logo was designed with the intent to associate the technology with several descriptors, such as "Low Cost," "Life Changing," and of course, "Lead–Carbon." The logo will continue to be used in the branding of the LC Super Hybrid demonstrators, and may become part of a larger branding initiative to promote lead carbon offerings of other battery manufacturing members.

Other branding initiatives executed over the past three years include: enhanced event displays showcasing significant program milestones and demonstration vehicle projects, informational print collaterals and information sheets, a new tri-fold brochure for ALABC member recruitment at various events (2012 BCI Convention, 13ELBC, The Battery Show 2012), an updated list of upcoming events and opportunities for publicity, and a social media presence for enhanced publicity. In the next few years, the PAM Committee is looking to expand its branding initiatives, and use the new public site and associated logos collectively as an identity for the ALABC moving forward.

The Committee's public relations activities were centered around three major themes:

1. The debut and promotion of the LC Super Hybrid, as well as promotion of the Honda Civic hybrid demonstration vehicle in Arizona, and the resulting positive test data
2. The 20th Anniversary of the ALABC (celebrated at 13ELBC in Paris)
3. The continued expansion of ALABC membership

The promotion of the LC Super Hybrid is significant because not only does it represent the fruits of ALABC research and development over the past several years – offering yet another opportunity to promote the practicality of state-of-the-art lead–acid battery technology - but it also represents the first time a demonstrator HEV using lead–acid or lead–carbon batteries has been developed with the direct assistance of Tier 1 suppliers to the automotive industry. With this in mind, ALABC contracted with industry writer Rob Palmer of Palmer PR (www.palmerpr.com) to spearhead public relations efforts in Europe as the vehicle was test-driven by auto industry trade writers and made its international debut at the 82nd International Geneva Motor Show (http://www.alabc.org/press-releases/LC_Super_Hybrid_PR_29_Feb_2012.pdf). The PAM Committee followed with extensive marketing materials and promotional pieces to further the visibility of the demonstration vehicle.

PAM efforts around the ALABC's 20th Anniversary include a new 20th Anniversary logo, a 20th Anniversary section on the website, press releases and spotlight articles, and promotion of the 20th Anniversary event in Paris at 13ELBC (http://www.ldaint.org/conferences) in September 2012. The Committee also took the opportunity to highlight new members and report on the increasing numbers of companies in ALABC membership, as the tally has grown from 55 to over 70 members – the Consortium's highest total ever. In addition, the ALABC invested in a new PR/news clipping service through Meltwater to enhance media profile and expand news reach.

Future publicity efforts are expected to include: continued coverage of the LC Super Hybrid and other demonstration vehicles, further ALABC updates (new members, new projects, new website), and promotion of ALABC achievements (micro-hybrid technology, energy storage technology, renewable systems, etc.).

The ALABC also made a significant effort in 2012 to initiate a PAM Committee for the Asian sector of its membership. Organized by Nyrstar on behalf of ALABC management, the Asian PAM Committee is intended to achieve a public affairs and marketing presence for the ALABC program in China, Japan, Korea and India. Its work will focus on specific applications that are key to these Asian markets, including E-bikes, automotive, and stationary (UPS, renewable storage).

The first meeting of the Asian PAM Committee is expected to coincide with the upcoming Sino Lead–Acid Battery Summit, Oct. 16-18, 2012, in Beijing, which the ALABC has partnered with Battery Energy Storage Technology (BEST) Magazine to promote and implement. The first day of the event will be an ALABC meeting with Chinese members to discuss with Consortium management the latest achievements of the Consortium in developing and demonstrating advanced lead–acid batteries, as well as the new 2013-15 ALABC program and possible research proposals from the Chinese members. For the second day, the ALABC and BEST Magazine are inviting

Chinese lead–acid battery producers and suppliers (over 70 companies) to an open meeting, free-of-charge, to discuss current battery market trends. ALABC representatives will be on hand during this portion to discuss its latest achievements and generate interest in new membership.

The ALABC has also entered into cross-promotional partnerships with Smarter Shows (U.K.), organizers of The Battery Show (www.thebatteryshow.com), and EUROSOLAR (Germany), organizers of the IRES conferences (www.eurosolar.org). For The Battery Show 2012, which will be held in Detroit, MI, USA, Nov. 13-15. The ALABC will have its own booth and is working with member battery companies to display the Consortium's latest demonstration vehicles, the LC Super Hybrid and the retrofitted Honda Civic HEV. Exide Technologies has agreed to display the LC Super Hybrid at its booth, and East Penn Manufacturing will display the Civic from Arizona. The ALABC PAM Committee is looking to attract significant media attention, as this will be the first event in which two ALABC demonstration vehicles will be on display for the general public.

Links to government initiatives

Governments throughout the world, particularly in the USA, remain committed to reducing pollution, but are increasingly turning to energy solutions that will be more readily accepted by cost-conscious consumers. Making the economic advantages of advanced lead–carbon technologies more attractive to government research programs is a primary objective of the ALABC.

The ALABC continues efforts to position the lead–acid industry as an influential presence in key industries and government entities in the USA. Government briefings entities are taking place with committees of the Congress, the Department of Energy and the Office of Management and Budget. Other contact points are industry organizations such as the Electric Power Research Institute, the Alliance of Automobile Manufacturers, the Society of Automotive Engineers and the Progressive Policy Institute. Another key contact is the American Gas Association, which is active in the natural gas vehicle (NGV) industry and with which the ALABC is consulting in the development of NGH hybrid vehicles.

Within recent years, the ALABC was invited by the USA Science Committee and the USA Senate Energy Committee to consult on the drafting of legislation to reauthorize and restructure the vehicle technologies research programs within DOE. The legislation, S. 734, the "Advanced Vehicle Technology Act," has passed the Senate Energy Committee. DOE staff have invited the ALABC to contribute white papers in the development of research initiatives. These initiatives will result in new funding opportunities for which the ALABC can organize teams to compete for research and development funding.

In the last year special emphasis has been put on merging two low cost CO_2 reduction concepts: the conversion of gasoline engines to natural gas, and downsizing combined with electro boosting of turbo charged engines. The combination can result in the development of affordable, relatively large vehicles, with the fuel efficiency improvements of pricy full hybrids.

Long term cycling studies from Sandia and Idaho national laboratories have shown recently that the entirely new ALABC-sponsored lead–carbon batteries are the best performing and most price efficient technology for utility and renewable energy storage. These batteries and the game changing role they will play in future energy storage, however, are still largely unknown to consumers. The policy of the Consortium continues to be focused on promulgating these innovations and looking for partnerships in the government research programs. The US DOE is consulting with ALABC on the development of additional programs to advance the use of batteries and other energy storage technologies to bring about greater efficiencies in the management of the electric power grids. For example, the ALABC is participating in a US DOE program to develop protocols to measure the operational and economic efficiency of energy storage products. The ALABC also is being consulted as US DOE prepares a new solicitation for innovative technologies in grid storage. New tools are being implemented, such as the USA federal policy blog in the ALABC website to inform ALABC members of issues affecting the lead–acid battery industry. Recent topics in the blog have included grid storage, energy taxes, federal R&D budgets, etc. Articles for non-technical readers (for example, "Has the obvious been overlooked") have been and will continue to be produced.

Essential Development Areas

The ALABC program has recently been driven by the major changes that are taking place in the electrical components of automobile design. The technical program aims to understand the life-limiting processes for batteries exposed to HRPSoC operation, and to overcome them by suitable grid design and by the appropriate use of carbon on the negative plate. This approach has been very successful and the resultant potential of lead–acid-based batteries to meet the new environment-related performance targets at minimal cost has been demonstrated in on-the-road vehicle projects. If the 48V LC Super Hybrid vehicle is added to the group of demonstration vehicles, all of the immediate technical targets in the automotive sphere will have been met. However, there is a need to show and publicize the performance of these vehicles to car companies, to the technical press, and to governments. This publicity campaign will be a very high priority of the ALABC and should be pursued vigorously.

The ALABC will also coordinate its research goals with other industries active in transportation and energy storage such as electricity producers, grid/transmission utilities, and the natural gas industry, who are interested in advanced batteries for their programs. In this effort, the Consortium will aspire to get involved in their larger research and development projects.

To support these technical advances, there is a need for continued up-stream (pre-competitive) work going forward including:

1. Developing and demonstrating a 48V LC SH vehicle with CO_2 emissions reduced by one third - a figure hardly achieved by even the best hybrids – will offer to the lead-acid community a great chance to meet the legislative CO_2 emission limits with regular size, affordable vehicles in an economical manner.

2. Development of a full mechanistic model of the function of the battery under HRPSoC operation with a view to highlighting the limitations imposed by grid design and the potential role(s) that can be played by different forms of carbon.

3. Exploration of the facility of high-carbon batteries to handle some deeper cycling as in EVs and PHEVs. In this circumstance, earlier ALABC work showed that fast charging can be beneficial to VRLA batteries in cycling duties. Indeed, in Project A 1.1, not only was benefit seen from fast charging, but also the ultimate failure mode seemed to be shifting from the positive plate to the negative. Thus, it is possible that additional carbon may assist the performance of VRLA batteries in a PHEV duty also. Further, it has been noted that the individual modules in high voltage strings of some types of high-carbon batteries remain closely matched without any periodic equalization. This finding could make these batteries very attractive candidates for some EV applications. Test batteries would need to be exposed to a duty cycle that combines HRPSoC operation with some significant depth-of-discharge cycling.

4. The contact carbon-to-lead/lead sulphate and carbon-to-organic additives along with the role of sulphate growth rate redactors in the carbon-added negative active mass will be further studied in order to enhance cycle life of lead–carbon batteries for HRPSoC applications.

5. Evaluation of new lead–carbon battery designs with higher specific power and energy – bipolar, low profile or others - in the duty cycles required by the LC Super Hybrid.

7. Testing of high carbon batteries with various grid designs and positive plate designs for stationary applications, to UPS, grid quality, and renewable energy storage protocols.

8. Further improvement of the specific energy and power, dynamic charge acceptance at high SOC, impedance and cycle life of advanced lead–acid batteries to be used in hybrid electric vehicles.

6. Testing of advanced lead–carbon batteries at their operating temperature will help meeting battery life requirements in real vehicles. In Fig. 9 records of the battery temperature are shown for a five-year-old midsize vehicle in Texas. The average temperature at which the battery operates is about 45 degrees C, and often it rises up to 60 degrees.

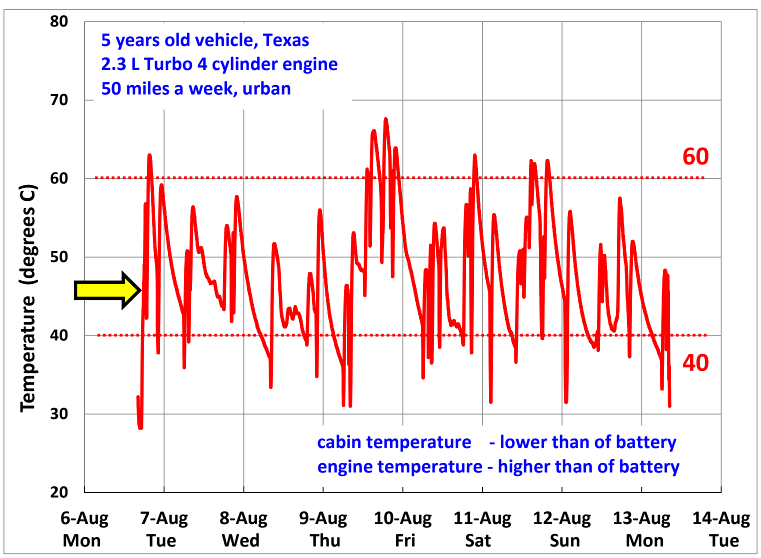


Figure 9. Battery temperatures in an 'average' vehicle used in city traffic in Texas (courtesy of Dr. J. Hohn, RSR).

7. Develop a standard test procedure to qualify advanced lead–carbon batteries for HEV applications and verify the test with some OEM producers and suppliers so that they can use the results to pre-screen lead–carbon modules for their own testing.

Consortium Research

The ALABC program to date has demonstrated the value of an industry-wide cooperative approach to pre-competitive research and development. Member organizations can have such a program carried out by a team comprising the pick of the world's expertise and all the necessary hardware without having to commit to taking on full-time specialist staff or investing in extra capital expenditure for analytical equipment.

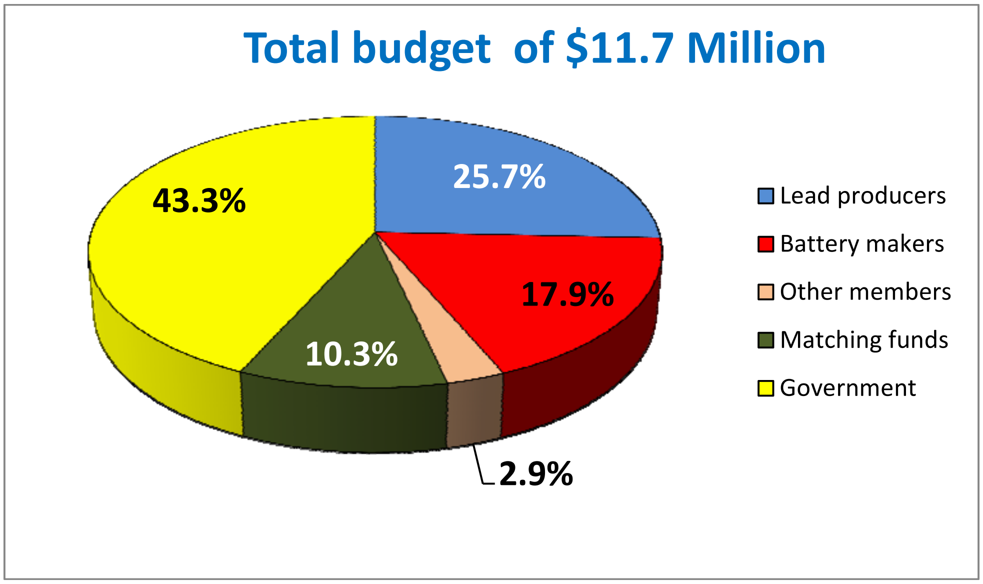


Figure 10. Composition of ALABC financial support in 2010 - 2012

The cost of this type of work is substantially leveraged, not only by cost sharing amongst the membership, but also by virtue of the contributions made by government and by contractor cost share, as shown in Figure 10. Finally it is becoming very clear that as many of the projects as possible should actually involve battery manufacturing companies. This will not only ensure the continued focus on relevance but also will be the best guarantee that successful R & D will be taken into product manufacture in the shortest possible time.

Summary

The looming pressures of a progressive tightening of the legislation on CO_2 emissions and the cost-at-the-pump of oil-based fuels are forcing world car manufacturers to produce ever more fuel-efficient vehicles. Initially the universal adoption of stop/start operation may be enough to enable manufacturers to meet their fuel economy targets but stop/start alone may not be sufficient as the targets are ramped up. A point will then be reached when much higher fuel economies will be needed and the work on ‘Micro/Mild’ hybrids offers the manufacturers a route to achieving the higher goals at an acceptable cost. Such a situation has been anticipated early enough for lead–acid to be developed and offered as the affordable battery to be designed into such vehicles. The ALABC program outlined in this prospectus constitutes an essential further step along the road to ensuring that this goal is achieved. If we fail to accept this opportunity to show the effectiveness of the lower cost advanced lead–carbon batteries in the 48V system, we will effectively be handing this promising market to the Li-Ion battery community. Simultaneously there are spin-off opportunities from the work that has enabled lead–acid batteries to operate in HEVs and this should give benefit as lead–acid batteries are produced specifically for storing energy from renewable sources and for satisfying the demands for truly uninterruptible power supplies.

Membership Forms

Membership Categories and Fees - ALABC Program 2013 - 2015

MEMBERSHIP CATEGORIES	MEMBERSHIP FEES (in US$ per annum)
Primary lead producers	0.50 per metric ton of production of lead
Secondary lead producers	0.50 per metric ton
Lead miners	0.25 per metric ton
Battery producers, equipment and component manufacturers: *	
Turnover > 300 million	60,000
Turnover 250 - 300 million	50,000
Turnover 200 - 250 million	40,000
Turnover 150 - 200 million	30,000
Turnover 100 - 150 million	20,000
Turnover 50 - 100 million	10,000
Turnover 0 - 50 million	5,000
Electric utilities, telecommunications companies, and photovoltaic manufacturers	10, 000
Automotive manufacturers	20,000

***Fees are related to the published battery business turnover of the company in question.**

ALABC 2013 - 2015
MEMBERSHIP RESPONSE FORM - Page 1

My company qualifies for membership as: [Check *one* box]

a) Primary lead producer ☐

b) Secondary lead producer ☐

c) Lead miner ☐

d) Battery producers, battery component manufacturers ☐

Annual Turnover: US$ ________________

e) Electric utilities, telecommunications companies, photovoltaic manufacturers ☐

f) Automobile manufacturer ☐

☐ My company will commit funding to ALABC, at the rate corresponding to the membership category indicated above, for each of the 3 years in the 2013 – 2015 program. (Refer to Table on the previous page for category rates).

☐ My company wishes to be considered as a potential contractor in the ALABC program.

Initial: …………

ALABC

ALABC 2013 - 2015
MEMBERSHIP RESPONSE FORM - Page 2

Please print

COMPANY: ____

____

REPRESENTATIVE NAME: ______________________________

____

ADDRESS: ____

____

CITY: ____

COUNTRY: ____________________ POSTAL CODE: ____________

TELEPHONE: ____________________ FAX: ____________________

____
Signature of Representative

E-mail address: ……………………………………………………

Date: ______________________________

PLEASE RETURN both pages to:

Dr. Boris Monahov
ALABC
International Lead Zinc Research Organization Inc.,
1822 East NC Highway 54, Suite 120
Durham, NC 27713 U.S.A.
bmonahov@ilzro.org FAX: (919) 361-1957

GENERAL OPERATING PROCEDURES

The Advanced Lead-Acid Battery Consortium (ALABC) is a program of the International Lead Zinc Research Organization (ILZRO).

Distribution of Technology

The ALABC is intended to be an "open" Consortium in that all research results will be immediately available to all members, as well as to non-members after a period of time. **The studies have a pre-competitive character** and the results are available for use to all the membership. Those of the members who carry out the particular project work will have the most immediate access to the results. Members are encouraged, but not required, to share and donate relevant technology to further the research goals of the Consortium. Unique technological discoveries may be patented and licensed free of charge by ILZRO to Consortium members, and to non-members for a reasonable fee.

It is the intent of the ALABC members ultimately to make the technology resulting from the research program available to all in order to grow the lead–acid battery industry, which is a principal objective. Consortium members will have the advantages of being involved in the planning of research, as well as having immediate access to the results.

ALABC may support the development of patented technologies. However, ALABC members must have access to the patents for a reasonable, preferential fee, which must be agreed to by ALABC members prior to providing funding, and full access to all information developed with ALABC funding.

Committees

A separate committee, the ALABC Steering Committee, is set up to oversee the activities of the ALABC. All members of the ALABC are entitled to representation on the ALABC Steering Committee and all other committees. Each member of the ALABC will have one vote on the ALABC Steering Committee. Members will also be entitled to representation on all working committees.

Except as noted below under "Approval of Projects and Expenditures," the ALABC Steering Committee shall act by a majority at a properly called meeting with a quorum of at least one- third (1/3) of the Committee members present and/or voting by written proxy. Steering Committee meetings shall be called by the President or Chairman of ALABC by written notice to each Committee member e-mailed at least ten (10) days prior to the meeting date.

There are two working committees - the Technical Committee and the Public Affairs Committee. The Technical Committee will advise on the following subjects:

- prioritization of research projects
- selection of research contractors
- oversight of research projects
- coordination of research program

The Technical Committee functions through several regional subcommittees and working groups established for each research project.

The Public Affairs and Marketing Committee will advise on the following subjects:

- government relations
- publicity
- marketing

Chairmen of the various committees will be elected at the meetings of the ALABC Steering Committee.

Management

ILZRO provides day-to-day administration and research management for the ALABC. The ILZRO Board of Directors has agreed to limit ILZRO's charges to actual costs associated with the management of ALABC and its programs. Non-members of ILZRO are eligible to join the ALABC.

Approval of Projects and Expenditures

All proposed projects will be reviewed by one or more of the Committees (in which each member has a representative).

First, the proposals will be evaluated by the Technical Committee. Five criteria (Relevance to defined overall program objectives, Level of advance likely from successful achievement of project objectives, Probability of success, Quality of people and organization, and Value for the money) will be evaluated on a scale of 0 to 20 points – 100 maximum possible.

If the average total score of the proposal exceeds 80 points it is considered as acceptable and can be sent for voting to the Steering committee. The latter will vote on final approval.

Funding recommendations will be made to the ALABC Steering Committee by the ALABC Technical Committee. Projects requiring funding of up to $100,000 may be approved by the Chairman of ALABC upon advice by the chairs of the Technical Committee and Public Affairs and Marketing Committee. Projects requiring funding in excess of $100,000 will be approved only by the ALABC Steering Committee, which will, in general, vote by e-mail or fax ballot. Approval will require a two-third (2/3) affirmative vote of those responding by the due date indicated on the ballot.

Meetings

Meetings of the ALABC Steering Committee will be held once per year. For the convenience of members, meetings will be scheduled to coincide with major industry meetings. If necessary, additional meetings will be held. Meetings of the Technical Committee (and its subcommittees) and the Public Affairs and Marketing Committee will be held on an 'as needed' basis.

Amendments

The General Operating Procedures may be amended by the ALABC Steering Committee from time to time; except that each member shall always have one representative and one vote on the ALABC Steering Committee and all amendments must be consistent with the Funding Agreements.