ALABC

The Advanced Lead-Acid Battery Consortium

PROSPECTUS

2010-2012

ALABC

Executive Summary

The purpose of the Advanced Lead–Acid Battery Consortium (ALABC) program is to take lead–acid battery technology forward to levels of performance in appropriate duty cycles that will ensure that lead–acid will remain a battery of choice in future electrical energy storage markets. To date the program has begun to show that certain designs of lead–acid battery are able to perform the high-rate partial-state-of-charge (HRPSoC) function that is required in hybrid electric vehicles (HEVs) and thus have the potential to displace more expensive types of battery. The initial, very successful, demonstrations need to be backed up by further confirmations of performance in different models of medium hybrid, and to be followed by tests in full hybrids and by the establishment of the mechanism(s) by which the, rather inexpensive, battery modifications enable lead–acid to succeed in HRPSoC operation.

This prospectus outlines the state of the art as the ALABC program for 2007 – 2009 approaches completion, and outlines a program for 2010 – 2012 designed to confirm, beyond all reasonable doubt, the feasibility of using carbon-modified lead–acid batteries in a range of HEV types. Continued work on HRPSoC duty will also show benefits in the optimization of batteries that can be rapidly recharged 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

Lead is a commodity that is becoming ever more exposed as a product with a single market. The fraction of world lead production that is absorbed in the manufacture of secondary batteries has been increasing progressively over many years (Fig. 1) and today some 80% of lead goes into batteries.

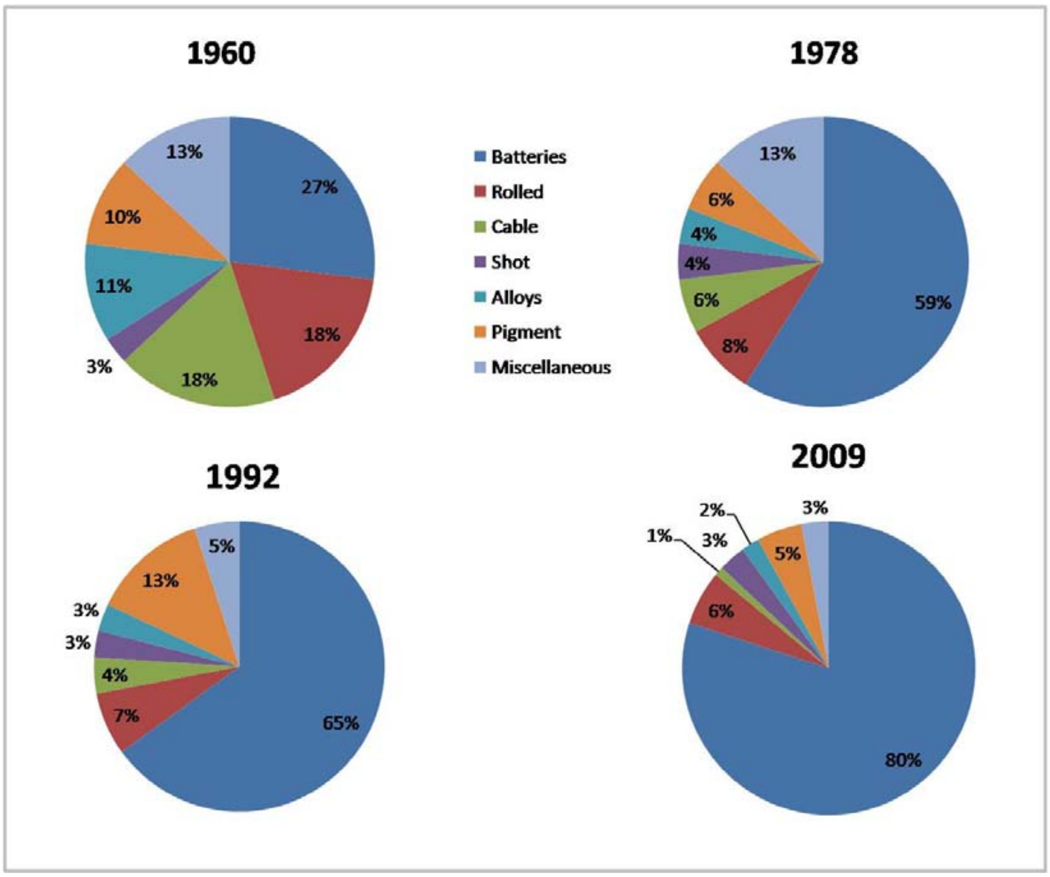

Figure 1 End uses of lead.

Further, although the lead–acid battery currently occupies the top position in the table of rechargeable applications that require the storage of at least 5 Ah, batteries based on alternative chemistries are increasingly being promoted as competition.

It follows, therefore, that changes that are taking place in the manner in which electrical energy is stored, and used, can be of major significance for the strength of future markets for both lead and lead–acid batteries.

In a more general sense energy issues are beginning to become a serious preoccupation of governments around the world. In the U. S. A., for example, on May 19th 2009, President Obama declared

"For what everyone here believes, even as views differ on many important issues, is that the status quo is no longer acceptable. While the United States makes up less than 5 percent of the world's population, we create roughly a quarter of the world's demand for oil. …… And that's why, in the next five years, we're seeking to raise fuel-economy standards to an industry average of 35.5 miles per gallon in 2016, an increase of more than eight miles per gallon per vehicle. "

Governments around the world are committing themselves to reducing their dependence on oil imports and to reducing harmful greenhouse gas emissions.

This commitment requires decisions to be made about the efficiency of use of oil-based fuels in transport and leads directly to the introduction of an increase in electrical function of vehicles; to hybrid electric and perhaps to full electrics. The potential benefits of such a move, in terms of increased fuel economy and reduced emissions, are clear but the strategy will only have a significant outcome if the measures are adopted on a very wide-scale, and for this they must be affordable.

There is also a change looming in the generation and use of electrical power for stationary applications as renewable sources of energy begin to be exploited. Renewable sources are distinguished from the more traditional forms of electric power generation (coal, oil, nuclear) in that the former cannot be controlled to produce power exactly in synchronism with demand. Wherever the fraction of total power that derives from renewable sources reaches more than a few percent of the total power generated the transmission system is not able to accommodate it and energy (power) must be stored.

In summary, within the next few years there will be radical changes in the storage of electrical energy, both in vehicles and in stationary applications, and these changes can represent either an opportunity or a threat depending on whether or not the lead–acid industry is able to respond to the demands of the new applications.

Automotive

Far and away the largest market for secondary batteries is that for supplying energy storage in vehicles and this has been the main focus for the Advanced Lead–Acid Battery Consortium (ALABC) right from the start.

ALABC was launched in 1992 at the time when the California Air Resources Board (CARB) was proposing to introduce legislation to require the manufacturers of automobiles to offer up to 10% of their sales as emission-free (battery electric). It was immediately recognized that there were no batteries available at the time that would allow the introduction of electric vehicles with a performance that would be acceptable to the purchasing public. The U.S. Advanced Battery Consortium (USABC) was formed, with major funding from the General Motors, Ford, Chrysler and the U.S. Government, with the aim of developing such batteries. USABC took the decision to exclude work on lead–acid batteries from their program and the lead, and lead–acid, communities responded by founding ALABC in order to show that a valve-regulated lead–acid (VRLA) battery (the only battery capable of meeting the USABC cost target) would be able to perform well in the deep-cycle environment that was needed. This aim was successfully achieved but the CARB mandates were progressively withdrawn and the large-scale demand for electric automobiles did not materialize - largely because the driving range available before a journey had to be interrupted by a lengthy battery charging event was too limited.

By contrast, in the late 1990s, Toyota introduced the Prius hybrid electric vehicle (HEV), which offered some improved fuel economy without any range restriction. The arrival of the HEV proved to be timely and, ten years on, sales of hybrids worldwide have now reached around 2 million units. The duty of the battery in the HEV is radically different from anything that a secondary battery had previously been required to perform. It transpired that the nickel metal hydride battery was able to cope with operating in the necessary high-rate pulses from a partial-state-of-charge baseline but the lead–acid batteries that were available at that time (designed either for normal starting, lighting and ignition or for deep cycling) could not. Nickel metal hydride batteries were designed-in for the first generation of HEVs and have performed well, but they have brought with them a large cost supplement for HEVs which has served to limit customer acceptance of the technology to some degree.

In the future, growing concerns over both oil supplies and green-house gas emissions will feed the pressure for the widespread adoption of more fuel-efficient automobiles. Car manufacturers are tackling this challenge with different strategies in different parts of the world (see Table 3). In Europe the first major move, largely driven by the prospect of legislation aimed at limiting fleet emissions of CO_2, is for the early introduction of the stop/start function (as in micro hybrids) on a grand scale (see Figure 2). Later, if CO_2 legislation becomes tighter, there may well be a move to medium or full hybrids.

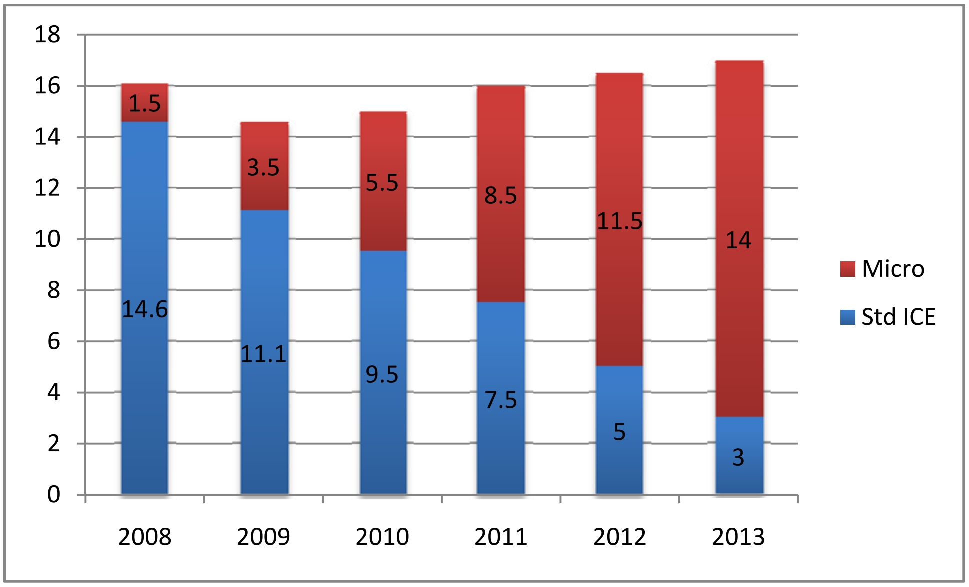

Fig. 2 OEM conversion to micro HEVs in Europe, millions of units (From G. Fraser-Bell 11 ELBC Warsaw).

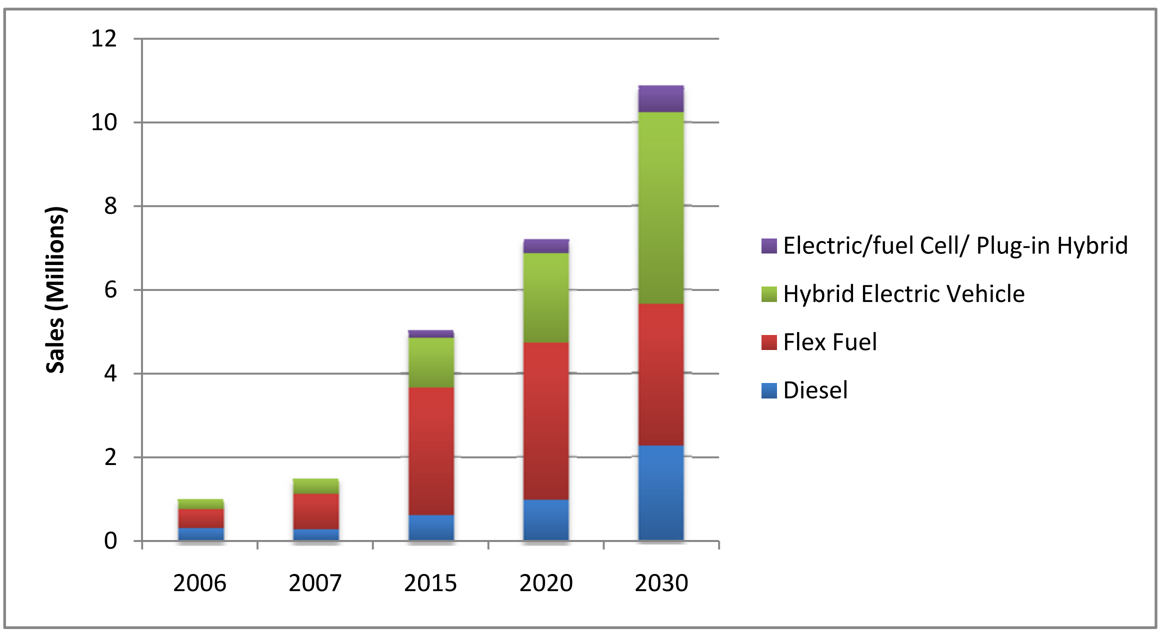

Fig. 3 Predictions of sales of alternative technology vehicles through 2030 - US DOE Energy Information Administration Annual Energy Outlook 2009 Reference Case.

In the U. S. A. the picture is somewhat different. There are already large numbers of medium and full hybrids and future predictions (Fig. 3) anticipate further strong growth of hybrids alongside flex-fuel vehicles and diesels.

There are three broad categories of HEV (Table 1). Micro hybrids involve the least modification over a conventional internal combustion engined vehicle and offer the smallest energy savings benefit but attract the least cost supplement. Indeed one car company has launched its first stop/start offering with no additional cost over that of the conventional model. Mild hybrids are configured to provide some 15 – 20% of energy savings but the cost supplement ($3,500) is substantial, largely because the battery is a nickel metal hydride type. The full hybrid provides the maximum energy savings but the cost supplement is greater still (not shown here because the only established comparison – that of the Ford Escape, is for a large vehicle and also uses nickel metal hydride).

Table 1 Characteristics of the three broad categories of hybrid electric vehicle.

	Micro-	Mild	Full
EV Drive			*
Motor assist		**	***
Regen. braking	*	**	***
Engine stop	*	*	*
Energy savings	8%	15 – 20%	40%
Supplementary cost	$ 0 - 600	$3,500	$6,000*
Battery voltage	12	144	>200
Battery capacity (Ah)	50 - 90	6 - 8	5

* Supplement for the Ford Escape.

The ALABC program has, for a number of years, focused on the new application demands posed by HEV duty and this work is now bearing fruit. Designs of VRLA battery with relatively inexpensive modifications to the negative plate have proved very successful in operating the HEV duty cycle, not only in the laboratory but also in vehicle tests on the road. The new designs of battery that have been shown to cope with the HEV task are early prototypes but have achieved large mileage in the road tests without failure and the life limit of such designs has yet to be reached.

The original reason for lead–acid to be overlooked in HEV duty - that the system could not perform the function - appears no longer to be valid. Lead–acid batteries do have a poorer specific energy than the competing systems but batteries in HEVs are rather small (about 1kWh) so the weight penalty of adopting lead–acid rather than nickel metal hydride (NiMH) or lithium ion is modest – especially when it is recognized that lead–acid does not need the supplementary battery and 12 V starter motor that covers NiMH against low temperatures, nor the cell-by-cell battery management that lithium ion must have to ensure safety. Thus there may not be anything standing in the way of the adoption of lead-acid variants in HEVs, which would enable the price supplement of HEVs to be minimized. The cost advantages of using a lead–acid battery rather than nickel metal hydride or lithium ion, in a medium hybrid, are clear (Table 2).

Table 2 Comparison of the costs of lead–acid batteries with those for nickel metal hydride and lithium ion for HEVs (cost figures for non-lead batteries are from AABC 2008).

	Battery type	Battery Cost ($)	Hybrid Cost ($)	Total Cost of Hybridization ($)	Time to Payback (years)	Time to Payback ($)
USABC Freedom Car	USABC Ultimate Goal	500	1500	2000	3.1	0.8
AABC 2008	NiMH German (Honda)	2000	1500	3500	5.1	3.1
AABC 2008	Li Ion Future cost (Takashita)	1000	1500	2500	3.9	1.6
	Ultra Battery	260	1500	1760	2.7	0.4

Automobile manufacturers will be more comfortable with the notion of including VRLA designs in future models of HEV once they are armed with the following:

(i) The demonstration that more than one design of ‘high-carbon’ VRLA battery is capable of performing the duty cycle for an acceptable life.

(ii) The capability to perform the HEV duty is demonstrated in several different models of HEV.

(iii) A full understanding of the mechanism by which the addition of certain carbons enables the battery to perform the required duty.

Future ALABC project work must ensure that such factors are fully covered.

Stationary Energy Storage.

Although the amount of energy generated from renewable sources is currently a small fraction of the total amount of energy used by Western nations, the deployment of wind and solar generation capacity is growing world-wide and governments have declared plans to continue this process. Distribution grids can only accommodate a relatively small fraction of energy input from renewable sources before problems of power quality arise. As more renewable energy comes on stream therefore, it can be anticipated that there will be a major requirement to store it. Battery energy storage appears to be one of the least-cost options for this application and facilities have been built based on lead–acid, nickel-cadmium, sodium-sulfur and various flow batteries. These latter are well suited to large-scale energy storage as the liquids involved can be stored in tanks to cope with large amounts of energy.

A system based on conventional lead–acid batteries is the cheapest option based on first-cost, but there is a need for the life of such batteries in this application to be extended. There have also been reports of a soluble lead–acid flow battery that could be effective in the stationary storage of energy (D. Pletcher et al., Journal of Power Sources 149 (2004) 103 and 149 (2004) 96 and 180 (2008) 621 and 180 (2008) 630).

Status of the ALABC Program during the second half of 2009

During the latter part of 2009 ALABC still has program areas active, and results in prospect, in the following three general areas:

1. The role of carbon in high-rate partial-state-of-charge operation.
   (i) Empirical search for an optimum formulation (projects C1.1/2.1A, C1.2A, GD 1.1).

(ii) Study of the mechanism(s) by which the carbon provides its benefit (C1.1/2.1B,C2.3A).

2. Hybrid Electric Vehicle demonstrations using lead–acid batteries.
   (i) In the U.S.A. – Honda Civic hybrid with an Ultra battery (6.7 Ah, project DP1.8) and hybrid electric bus with a homogeneous high-carbon negative plate battery (50Ah project DP1.9).
   (ii) Honda Civic hybrid with a bipolar battery (7 Ah DP1.7).

In addition there is a preliminary evaluation of the PbO_2/C asymmetric super-capacitor (project USP2) and a preliminary evaluation of small, flat-plate, high-carbon cells (project GD1.2). Both of these could lead to vehicle demonstrations but are not yet fully-funded for that stage.

3. Storage of energy from renewable sources – exploiting the partial-state-of-charge technology that has been developed for HEVs (project SPSoC1).

Public Affairs and Marketing

The ALABC has taken steps to increase the awareness of advancements in lead–acid among key policymakers throughout the world. For the past several years, the ALABC has published an online newsletter, Keeping Pace, to promote developments. An improved ALABC website for members also has been launched. Promotional "one-pagers" were produced and distributed highlighting the Ultrabattery, bi-polar technology and recycling.

A highlight during this period was the achievement of a 100,000 mile performance test of a Honda Insight equipped with an Ultrabattery unit in place of the nickel-metal hydride unit originally installed in the vehicle. This 100,000 mile barrier was broken on January 15, 2008 at the Millbrook Proving Ground in England. Among those attending the milestone were two senior staff members of the U.S. Senate Energy and Natural Resources Committee, who, in turn, invited the ALABC leadership to brief committee staff in the spring of 2008. This milestone attracted worldwide attention.

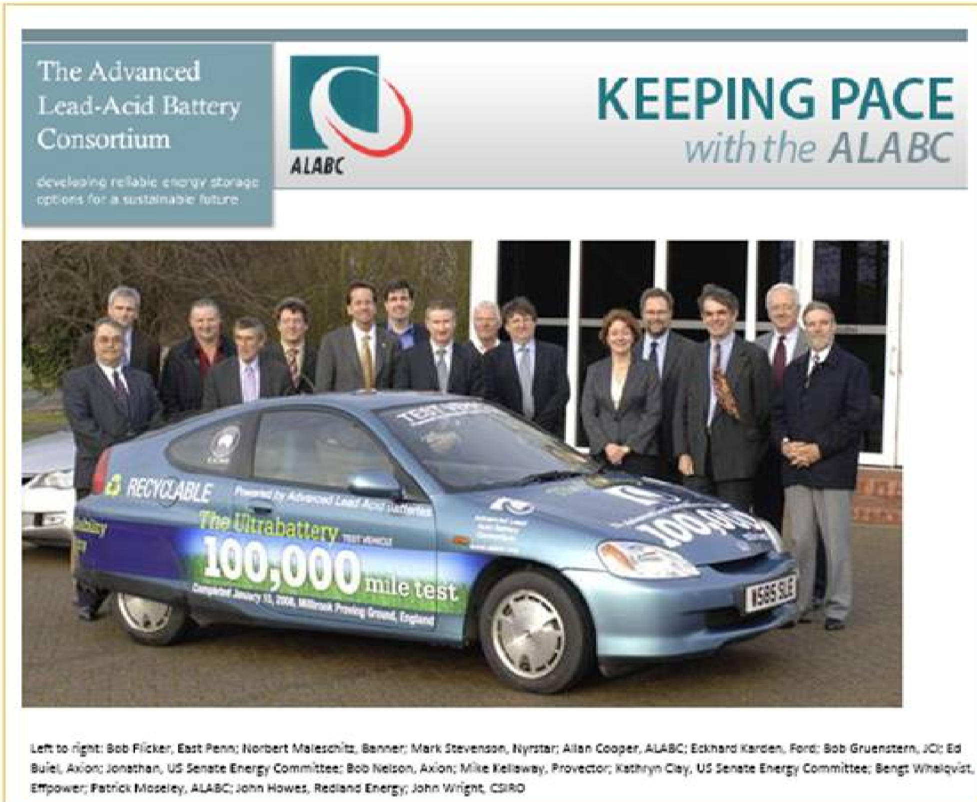

Fig. 4 Completion of 100,000 miles with a Honda Insight Hybrid employing an Ultrabattery.

The ALABC also conducted briefings on the Ultrabattery achievement for staff of the U.S. House Science and Technology Committee, the U.S. Senate Armed Services Committee and the U.S. Department of Defense. The ALABC also was invited to participate in a symposium on advanced battery development conducted by the National Automotive Center of the U.S. Army's Tank Automotive Research, Development and Engineering Center (TARDEC).

Earlier this year, as the Obama Administration was preparing to issue requests for proposals from battery manufacturers for more than $2 billion in federal stimulus funding, the ALABC met with program managers of the U.S. Department of Energy to be briefed on the department's areas of interest. This was followed by an on-line seminar for ALABC members in preparation for the submission of proposals.

In the coming months, the ALABC plans to continue working with U.S. DOE on programs for the continued research and development of lead-acid products for both vehicle and stationary applications.

Potential Development Areas

The ALABC program is, to a large degree, driven by the major changes that are taking place in the electrical component of automobile design. Many automobile manufacturers appear to be on course to switch the major part of their fleets to stop/start operation over the next few years. Some are initially planning to deploy the stop/start function alone while others are seeking to access the extra fuel and pollution savings that regenerative braking can provide. Stop/start without regenerative braking can be launched with the aid of fairly conventional lead–acid batteries. Whenever regenerative braking is added, however, conventional lead–acid batteries will suffer from negative plate sulfation and will need built-in conditioning in order to survive. The ALABC program has shown that the extra cost of the conditioning system can be avoided through the use of batteries with high-carbon negative plates and such batteries are likely to be adopted as manufacturers seek to cost-reduce their stop/start/regenerative braking offerings.
Later still, it can be anticipated that pressure will grow for even greater fuel economies and CO_2 reductions (see figure for Europe 2020 in Table 3), driving car-makers to look to the extra benefits of low-cost medium hybrids (with power-assist).

Table 3 Carbon Dioxide Emission Targets

Europe	130 g CO_2 per km by 2015 (95 g per km by 2020)
USA	160 g CO_2 per km by 2020 (presently 204 g per km)
Japan	138 g CO_2 per km by 2015

During the past 12 months ALABC has accepted half a dozen invitations to present progress to automobile manufacturers and opportunities now exist to share projects with some of them.

The continuing demonstration that various lead–acid battery designs are able to perform the medium HEV function will be helpful as the lead and lead–acid battery industries seek to ensure a continuing hold on their major market.

There may also be important opportunities for the local storage of energy as the proportion of electrical energy that is garnered from renewable sources increases in future years.

An ALABC program beyond 2009, therefore, might include at least the following components:

A. Development of a full mechanistic model of the function of carbon in the negative plates on lead–acid batteries that are exposed to high-rate charging.
B. A completion of the range of demonstrations of medium hybrids with several lead–acid battery variants. These might include Ultra, 2 designs of Bipolar (ideal grid configuration), Hybrid super capacitor and conventional design (flat or spiral) with high-carbon negative).
C. Extension of the demonstration work into full hybrids.
D. Exploration of the facility of high-carbon batteries to be able to cope with some deeper cycling – as in PHEVs. In this connection, earlier ALABC work showed the 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 the ultimate failure mode seemed to be shifting from the positive plate to the negative. Thus there are prospects that additional carbon may assist the performance of VRLA batteries in a PHEV duty also. Candidate designs would not to be exposed to a combination duty cycle that combines HRPSoC operation with some significant depth-of-discharge cycling.
E. Stationary applications
    - Small to medium scale – test of HRPSoC modules
    - Large-scale soluble lead–acid flow battery.

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.

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 Fig. 5.

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.

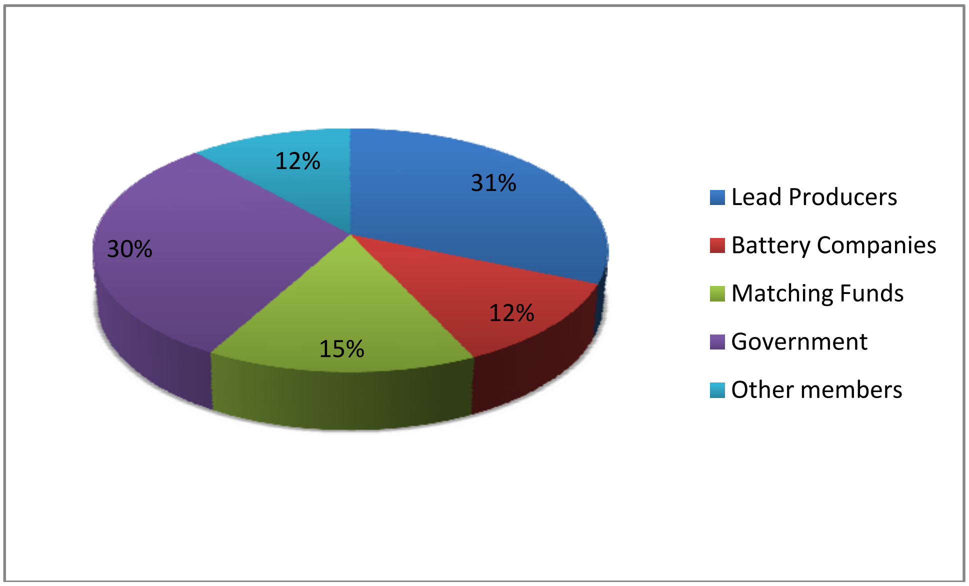

Figure 5. Composition of ALABC financial support in 2007 - 2009.

Conclusions

The twin pressures of the cost-at-the-pump of oil-based fuels and a progressive tightening of the legislation on CO_2 emissions may force world car manufacturers to produce ever more fuel-efficient vehicles in the next few years. 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 may then be reached when only medium or full hybrids are acceptable. Such a situation must be anticipated early enough for lead–acid to be developed and offered as the affordable alternative to be designed into such vehicles. The ALABC program outlined in this prospectus constitutes an essential further step along the road to achieving this goal.

Membership Forms

Membership Categories and Fees - ALABC Program 2010 - 2012

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.**

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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 for 2010-12 at the rate corresponding to the membership category indicated above. (Refer to Table on Page 15 for category rates).

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

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MEMBERSHIP RESPONSE FORM - Page 2

Please print.

COMPANY: ____

____

REPRESENTATIVE NAME: ______________________________

EMAIL: ____

ADDRESS: ____

____

CITY: ____

COUNTRY: ____________________ POSTAL CODE: ____________

TELEPHONE: ____________________ FAX: ____________________

____
Signature of Representative

Date: ______________________________

PLEASE RETURN both pages to:

Patrick T. Moseley, President
ALABC
International Lead Zinc Research Organization Inc.,
1822 East NC Highway 54, Suite 120
Durham, NC 27713 U.S.A.
pmoseley@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. 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. 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 Executive Vice President of ILZRO and 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.