



**Report on the**  
**Joint EC/EPoSS/ERTRAC Expert Workshop 2009**  
**Batteries and Storage Systems for the Fully Electric Vehicle**  
Version 7 / 25 September 2009

**1.) Objective**

Aiming to understand the research needs in the domain of batteries and storage systems which play the most crucial role in the development of fully electric vehicles (FEV), the Commission jointly with the European Technology Platform on Smart Systems Integration (EPoSS) and the European Road Transport Research Advisory Council (ERTRAC) on 19 June 2009 held an expert workshop in Brussels. Following an opening statement given by MEP Erika Mann, who pointed out the importance of innovation in the field of batteries for the strength of the European automotive industry, an intensive exchange of information took place, and a list of shortcomings to be tackled and actions to be undertaken at European level e.g. as part of the European Green Cars Initiative was drawn up. The discussion included more than 50 invited participants of a multitude of European companies from the new automotive battery and energy storage system value chain as well as selected research institutions and relevant DGs of the European Commission. The results of the workshop are summarized in the document at hand.

**2.) Background**

In its European Economic Recovery Plan<sup>1</sup> the European Commission proposes to establish three public private partnerships to leverage innovations in the manufacturing, construction and automotive sectors, which as a result of the crisis have recently seen a demand plummet and which face significant challenges in the transition to a green economy. For the automotive sector, the 'Green Cars' initiative was launched, putting emphasis on research for a broad range of technologies and smart energy infrastructures that are essential to achieve a breakthrough in the use of renewable and non-polluting energy sources, safety and traffic fluidity (EUR 1 billion total mobilised for research). Research on electro mobility, particularly fully electric vehicles (FEV) has been defined as an essential component in this research package.

Batteries and energy storage systems are the key components of the FEV and at the same time their most expensive parts. Despite major breakthroughs made in the last decades, further improvements of energy density, cycle life and product safety together with cost reductions will be crucial for the deployment of FEV and for meeting the particular requirements of future vehicle-to-grid concepts and for use as stationary storage of renewable

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<sup>1</sup> Commission of the European Communities, A European Economic Recovery Plan, 26 November 2008, endorsed by the European Council on 11-12 December 2008.

energies. Significant R&D efforts are required at all steps of the related value chain, ranging from materials research via cell chemistry, battery pack development including ICT solutions for management and control to the integration into the vehicle.

Recognizing the impact of established battery and storage system manufacturing for the competitiveness of their automotive industries, major economies around the world are currently competing in announcing ambitious goals and support measures:

### **Japan:**

The Japanese Ministry of Economy, Trade and Industry (METI) is referring to the unique growth of performance of small-size Lithium ion batteries for the consumer electronics market in last 15-20 years (their energy density has increased by a factor of more than 5 since 1990<sup>2</sup>), and projects that protecting the dominant market share of Japanese companies requires a further increase in performance by a factor of three, and a drop of cost to 20% of today's values for the next ten years<sup>3</sup>. This shall be accomplished by a close cooperation of industry, academia and government in setting R&D targets for three phases (improvement, advancement and innovation), and the building of infrastructures, standards and regulations.

### **U.S.:**

The United States Department of Energy (DOE) is providing a combined \$2.4 billion in federal funding from the American Recovery and Reinvestment Act of 2009 (ARRA)<sup>4</sup> in support of the development of advanced electric drive vehicles in 2009. It published a battery roadmap for the next five years that indicates a rise of energy density by a factor of two, an increase of lifetime by a factor of three, and a drop of cost to 30% of today's values<sup>5</sup>. In early August 2009, the DOE announced funding through the American Recovery and Reinvestment Act for 48 advanced battery and electric vehicle projects spanning the supply chain – from auto parts manufacturers to battery manufacturers to automakers. The recipients range from established companies to small businesses to start-ups<sup>6</sup>. \$1.5 billion in grants will go to US-based manufacturers to produce batteries and their components and to expand battery recycling capacity. Among others A123Systems and Johnson Controls will receive a total of approximately \$550 million to establish a manufacturing base in the state of Michigan for advanced batteries, and two others, Compact Power and Dow Kokam, will receive a total of more than \$300 million for manufacturing battery cells and materials.

### **China:**

The Peoples Republic of China according to a recent report published by the Argonne National Laboratory<sup>7</sup> is making vast progress in manufacturing lithium ion battery technology. The government has a national program in place to attract foreign companies to set up joint ventures and/or partnerships with Chinese companies. It also gives Chinese-owned companies additional incentives for research and provides capital for manufacturing lithium-ion batteries for all application fields. More than 40 companies have already started production. Government-supported projects focus on R&D on LiMn<sub>2</sub>O<sub>4</sub>, LiCoO<sub>2</sub> and LiFePO<sub>4</sub>

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<sup>2</sup> Matsushita Battery Industrial Co., Ltd. (2006).

<sup>3</sup> Japanese Ministry of Economics, Trade and Industry (METI) and New Energy and Industrial Technology Development Organization (NEDO), Research Program "Next Generation Batteries for the Commercialization of Plug-in HVs, FCVs, and EVs - FY2007-2011 (2007).

<sup>4</sup> U.S. Government, Public Law 111-5, American Recovery and Reinvestment Act (2009)

<sup>5</sup> David Howell, United States Department of Energy, EVS-24 Conference (2009).

<sup>6</sup> List of funded projects: [www1.eere.energy.gov/recovery/pdfs/battery\\_awardee\\_list.pdf](http://www1.eere.energy.gov/recovery/pdfs/battery_awardee_list.pdf)

<sup>7</sup> Pandit G. Patil (2008), Developments in Lithium-Ion Battery Technology in The People's Republic of China, Argonne National Laboratory (2008).

cathodes with the latter already at energy densities of 130 Wh/kg (module) and selling price levels in the range of 290 US\$/Wh, i.e. less than 1/3 of the cost levels achieved in Europe and the US today. It should be noted that Lithium is abundant in China which is the second largest producer of Lithium in the world.

In view of this situation the question arose whether an automotive battery and energy storage value chain had already been established in Europe, what would be a pan-European strategy specific to this topic and what comprehensive issues could be facilitated by joint actions of industry, member states and European Commission in the Green Cars PPP.

### 3.) Workshop Structure

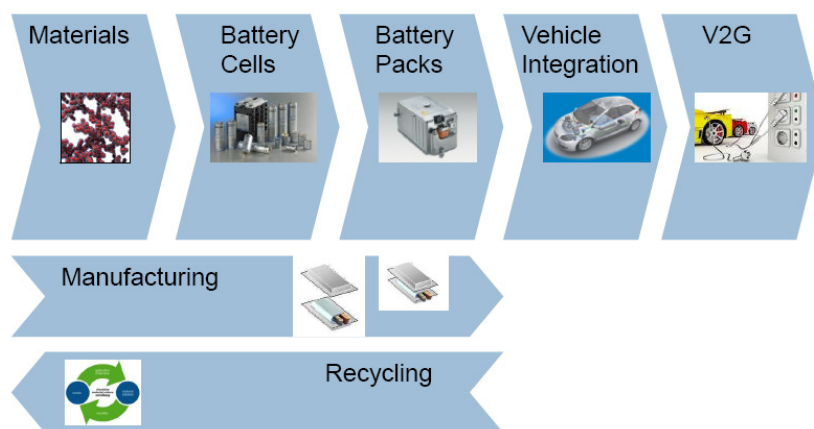
The invitation to this workshop had been signed jointly by the European Commission’s DGs Information Society & Media and Research and the European Technology Platforms (ETP) ERTRAC and EPoSS. The programme was opened by a presentation<sup>8</sup> on the European Green Cars Initiative given by Thierry Van der Pyl, Director Components and Systems of DG Information Society and Media, on behalf of all involved DGs of the European Commission, followed by a talk on the European Industry Roadmap on Electrification given by Guenter Lugert, Siemens, Chairman of the EPoSS Executive Committee, as a representative of the ETps. Also, detailed descriptions were given of content of the 2010 Work Programmes related to the Green Cars Initiative, and the results of a survey on milestones of a European Industry Battery Roadmap were presented.

In light of the complexity of the topic, the expert discussions on actions to be taken were clustered around five topics representing the major steps of the battery and energy storage value chain (see Fig. 1):

- Basic principles and materials
- Advanced battery and supercapacitor cell technologies
- Integration and management of battery packs
- Integration into the vehicle
- Vehicle-to-Grid (V2G) and stationary storage applications

Furthermore, issues of production and recycling were considered by two further topics:

- Cell manufacturing process
- Life cycle of electrodes and electrolyte materials



**Figure 1:** Workshop Structure

<sup>8</sup> The agenda, presentations, and all related documents are ready for download from the EPoSS website at: <http://www.smart-systems-integration.org/public/electric-vehicle/battery-workshop-documents>

Short introductions were given by representatives of major European companies or research organizations active in the respective field followed by discussions on R&D priorities and further needs. Finally, the future role and strategy of Europe in light of the global R&D activities in the field of battery and energy storage systems was discussed and recommendations for the implementation of the Green Cars Initiative were made.

#### 4.) Participants

Participants in the workshop were invited senior technical experts from major European companies and research institutions of the automotive, energy, ICT and battery sectors. Furthermore, representatives of each of the ETPs EPoSS, ERTRAC, and SmartGrids and DGs involved in the research part of Green Cars Initiative attended the workshop. Altogether more than 50 persons from ten European countries took part.

#### 5.) European Battery Roadmap

Prior to the workshop all experts had been asked to provide some information for a European battery roadmap indicating what energy density, calendar life and cost can be achieved for battery cells by 2012, 2016, and 2020 from their organization's point of view.

According to the results of this survey (refer to Tab. 1 for a summary), by 2020 the energy density of battery cells can be expected to increase by a factor of two (for current Li ion battery technology) to three or above (for next generation batteries). It is foreseen that by then the lifetime of the battery will increase by a factor of up to three such that it matches the lifetime of the car, and the cost will be dropping to at least 1/3 of today's values, and to even far less if mass volume production is achieved where the minimum cost eventually will be given by the cost of the raw materials.

| Batteries for EVs         | today                                    | 2012                   | 2016                   | 2020  |
|---------------------------|--|------------------------|------------------------|---|
| Energy Density (cells)    | 140 Wh/kg<br>(200 for laptop batteries)  | 220 Wh/kg<br>(140-300) | 300 Wh/kg<br>(150-500) | 450 Wh/kg<br>(250-700)<br>>1000 (LiO <sub>2</sub> ) |
| Life time (calendar life) | 7 yrs.<br>(lack of reliable data for EV) | 9 yrs<br>(8-10)        | 11 yrs.<br>(10-12)     | 17 yrs.<br>(10-20 yrs)                              |

**Table 1.** Milestones of a European Battery Roadmap<sup>9</sup>

The experts noted that for their projections they had to take into consideration safety and power requirements, and that in practical terms both cell and pack levels should be considered. It was also pointed out that battery technology before becoming fully mature will rather represent trade-off paths of the energy-power density, lifetime and cost aspects: E.g., lifetime requirements would be less strict for cheap (thus replaceable) batteries, or thermal management which increases the lifetime would reduce the energy density. An agreement on common cost targets turned out to be complicated because these depend on the assessment of a multitude of parameters of comparable impact, e.g. electrode materials, cell design, production process and total volume of production.

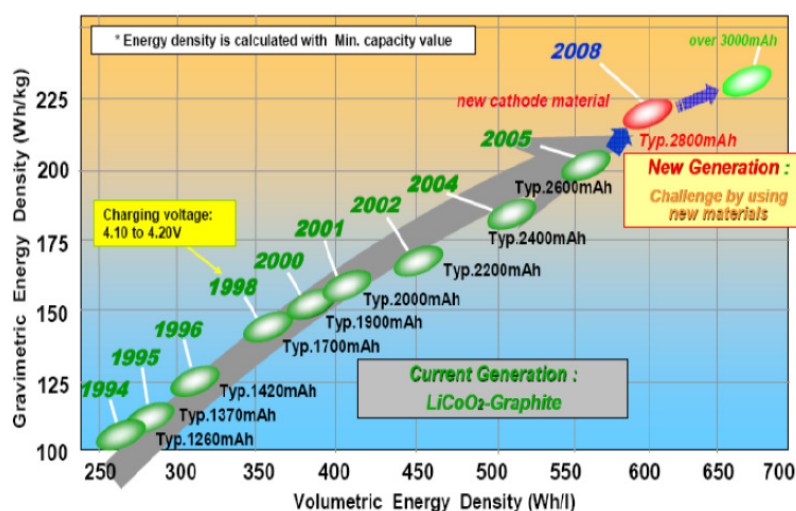
<sup>9</sup> Average of the indications given by the experts, numbers in brackets indicate range of estimates.

## 6.) Results of Workshop Discussions

In the following, abstracts of all talks are given as well as summaries of the experts discussions on foremost R&D needs and actions to be taken for achieving the milestones set in the roadmap. The order of this paragraph is a match of the workshop structure as described above.

### Basic Principles and Materials

Results and future directions of fundamental research related to the basic electrochemistry and the choice of materials for battery cells was introduced to the workshop by Mathieu Morcrette from the University of Picardie (France) which is heading the ALISTORE European Research Institute<sup>10</sup>, a network of 23 research laboratories from eight European countries dealing with fundamentals of energy storage and a focus on Lithium ion battery cell technology.



**Figure 2.** Recent achievements in energy density of Lithium ion battery cells

Lithium ion batteries are a type of rechargeable battery in which a lithium metal ion extracted from the anode moves to the cathode and intercalates with it during discharge (and vice versa during charging). Due to their high energy density, absence of memory effect and limited loss of charge, Lithium ion batteries are widely used in consumer electronics. Voltage, capacity, lifetime, and safety of a lithium ion battery are critically dependent on the choice of materials for cathode, anode and electrolyte. For batteries used in portable devices the anode is typically made from carbon (graphite), the cathode is a metal oxide (e.g.  $\text{LiCoO}_2$ ), and the electrolyte is a lithium salt. This way, energy densities of more than 200 Wh/kg can be achieved (see Fig. 2) today.

Lithium ion batteries are currently also considered the best option for transportation batteries to be used in plugin hybrid and full electrical vehicles. However for this application a new generation of battery system will be required providing higher energy density, lower cost and use of abundant materials. The cathode material of choice (as it is providing higher safety) may be  $\text{LiFePO}_4$ , which in its natural form is a mineral with poor electronic and ionic conductivity, however if synthetically shaped on the nanoscale it may provide appropriate properties<sup>11</sup>. Also for the anode, nanostructured materials are considered, e.g. hard carbon or Si-C nano-composites which can be expected to increase the energy density by 20-30 percent. Technology paths towards even higher energy densities (as desired for fully electric traction)

<sup>10</sup> [www.u-picardie.fr/alistore](http://www.u-picardie.fr/alistore)

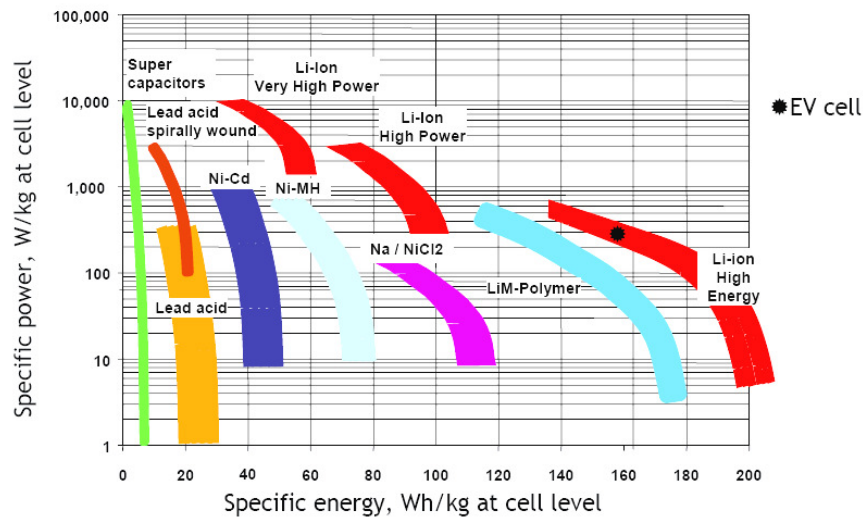
<sup>11</sup> N. Recham, M. Armand and J.M. Tarascon Chem. Mater. 21 (6), 1096 (2009).

may include Lithium air batteries, whereas higher power densities (required for hybrid power trains) may be expected from Lithium ion batteries using nano-sized titanate electrodes.

The experts agreed that two paths should be followed to advance the basic principles of batteries for EV, (a) research in even more advanced, next generation (not necessarily Li) battery systems, and (b) improvement of the available Li ion battery by development of new or newly structured electrode materials, novel electrolytes and other components.

### Advanced battery and supercapacitor cell technologies

Subsequent to the discussion of fundamental research approaches, the perspective of a company manufacturing Lithium ion battery cells was presented by Anne de Guibert, Saft (France). Besides Saft several other companies have plans to manufacture Lithium ion traction batteries in Europe, e.g. Li-Tec(Germany), European Batteries (Finland), Nissan (U.K. and Portugal), Bollorè (France). Furthermore, several European companies have agreements with Asian or U.S. based manufacturers to integrate imported battery cells into their battery systems. Also there are manufacturers of supercapacitors in Europe, e.g. Maxwell (Switzerland) and Batscap (France).



**Figure 3.** Ragone chart<sup>12</sup> of various battery cell technologies indicating the maturity of Lithium ion batteries for application in the electric vehicle

From the battery cell manufacturer’s point of view, requirements to be fulfilled by energy storage systems that shall be used in a fully electric vehicle include:

- Size of battery: 10 kWh (plug-in) up to 20-25 kWh (pure electric)
- Safety: at battery cell level
- Life duration: 8-10 years
- Specific energy: as high as possible
- Cost: as low as possible

These requirements can mainly be achieved by Lithium ion technology as it provides high energy densities (as mentioned above), excellent cycleability, good calendar life, and high power if required. However, the downsides are: the global cost of the technology, the need for sophisticated control electronics, limited safety of large cells and batteries under abuse conditions, and weak chargeability at low temperatures. The variety of cathode materials has

<sup>12</sup> A Ragone chart plotting energy density versus power density is used for performance comparison of various energy storage devices.

an enormous impact on key performance parameters of Lithium ion batteries such as energy and power density, calendar and cycle life, safety, cost, maturity and low temperature chargeability. Also, other components of the battery determine its properties: separator, binder, electrolyte, current collector and the mechanic behaviour of the cell. The complex interrelations of the various parameters are calling for tradeoffs in many cases, e.g.

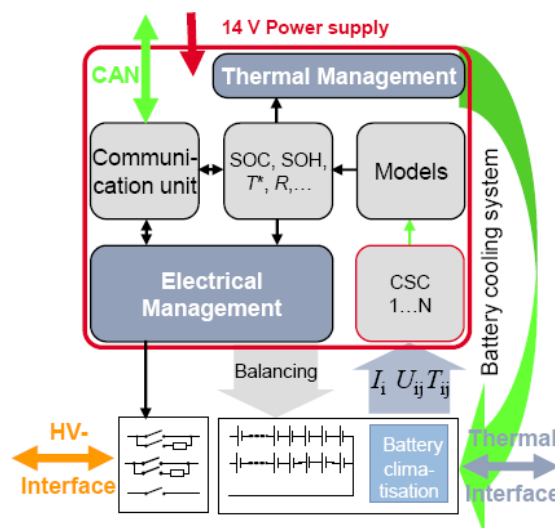
- Specific energy increase decreases power (always), safety (often) or life (in relation with other parameters)
- High temperature exposure increases power but decreases life (divided by a factor of 2 every 10°C increase above 25-30°C)
- It is detrimental to life to charge high energy cell at low temperature
- A high cumulative capacity cycled by the battery means to limit the depth of discharge at each cycle

Aiming at high power, supercapacitors are considered an integrated storage option. They provide fast charge and discharge, excellent performance at low temperatures, high safety and most probably a very long lifetime under extreme working conditions.

According to the advice given by the experts, the tradeoffs of life, cost and performance of lithium ion batteries need to be further optimized. Also, from the manufacturers' point of view the overall battery system needs to be simplified, and improved by compromises between already established and slightly changed materials. First of all considering that the battery pack will become more and more a structural element of a vehicle, the experts pointed out that rather than cost and performance issues a lack of manufacturing and integration of Lithium ion batteries in needed quantities may put the European automotive industry in a disadvantage. Therefore the gap between results of academic research and the scaling up of production needs to be closed.

### Integration and management of battery packs

Beyond the creation of high performance, cheap and intrinsically safe battery cells, the integration of a multitude of them into manageable modules and packs is a major R&D issue. Vast progress has been made in terms of the design of the EVs lightweight chassis, powerful and efficient drive trains, aerodynamic shapes, and sophisticated computer controllers, but the same cannot be said for battery technology.



**Figure 4:** Battery management system of the fully electric vehicle

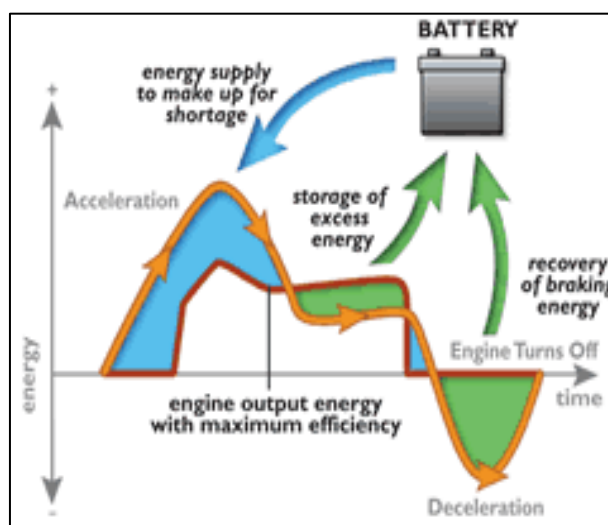
Several automotive suppliers have recently started activities in this direction. Their approaches were summarized by Heiko Weller, Bosch (Germany) for the audience of this workshop

The integration and management of battery cells into packs is predominantly aiming at the optimization of two aspects being the thermal and the electrical management. Thermal management is meant to regulate the pack to a desired temperature range and to reduce uneven temperature distributions within it. This helps to increase its energy efficiency and protects the cells from damage and premature end of life, which should be avoided for warranty reasons. It also prevents the battery pack from thermal runaway that in adverse situations may cause explosions. Electrical management stands for the control of the electrical interconnections between the battery cells and the interface of the battery pack to the vehicle. Aiming at maximising the state of charge, state of health, power and capacity of the battery pack, as well as its safety the electrical management is monitoring the voltage, current and temperature of each battery cell. One of the strategies applied is to keep the peak voltage of each individual battery or cell below its maximum value so to allow weaker batteries to be fully charged, bringing the whole pack back into balance. Another typical approach is to avoid state of charge mismatch, e.g. by switching off bad cells, since otherwise the pack capacity is limited to the capacity of the weakest cell. The functionality of a battery management system is summarized in Fig. 4.

According to the advice given by the experts, R&D efforts in the domain of smart battery cell management should be further increased. Also, there is consensus that the development of appropriate microsystems and ICT solutions, i.e. distributed networks of sensors and controls as well as the means of their mutual communication has to be supported and complemented by modelling and simulation of the cells, the thermal and electrical networks as well as the vehicle environment, and that validation has to be performed at multiple stages from the cell and the battery management system to the entire battery.

### Integration into the vehicle

Eventually, the performance requirements for transportation batteries will be set by the manufacturers of the vehicle. At the workshop, their point of view was presented by Alessandro Coda, European Council on Automotive Research (EUCAR) which represents the major European vehicle manufacturers.



**Figure 5:** Use of a battery in the hybrid powertrain

The vehicle manufacturers consider electrification of mobility to be one of the components of the future transport system while pointing out that challenges in urban mobility are more generally calling for collaborative transport solutions for people and goods that need an integrated approach. They consider electric traction to be one of the possibilities for passenger cars in urban or inter-urban use and for goods delivery in specific environments. Electrification of the power train according to EUCAR does include all modes of hybridization: start/stop, mild and full hybrids, plugin hybrids and fuel cell vehicles, each of them with particular requirements for the battery (see Fig. 5). Regarding the full electric vehicle, EUCAR considers it a frugal vehicle that requires low energy through the application of an energy efficient electric powertrain, efficient auxiliaries for heating, cooling, steering etc., appropriate managing of brake energy and smart navigation systems. It should provide additional autonomy based on new range extender concepts that are clean, efficient, compact and affordable. EUCAR together with the European Association of Automotive Suppliers (CLEPA) recently published a strategy paper providing input to the European Green Cars Initiative<sup>13</sup>. According to this document, for energy storage systems of the electrical vehicle two major technology paths should be followed: (a) Battery systems for vehicle applications based on further improvement of Li ion cell chemistry and technology; (b) Basic research on new open cell systems technology (post Li ion) for highest energy density focusing on electrochemistry of battery cells and storage capacitors (packaging, crashworthiness, durability, reliability, adoption to different vehicle concepts) with an appropriate level of safety.

The experts agreed on goals in terms of battery performance following suggestions by EUCAR for enabling sellable vehicles and matching realistic requirements in 2020: Enhancing the energy density to above 200 Wh/kg, increasing the durability to above 5000 cycles, and cell cost below 150 Euro/kWh. They also agreed that requirements of various modes / missions (bikes, passenger cars, vans) short vs. long distance should be considered. The first area to be focus on is the development of battery packs for application in vehicles for urban mobility.

### **Vehicle-to-Grid (V2G) and stationary storage applications**

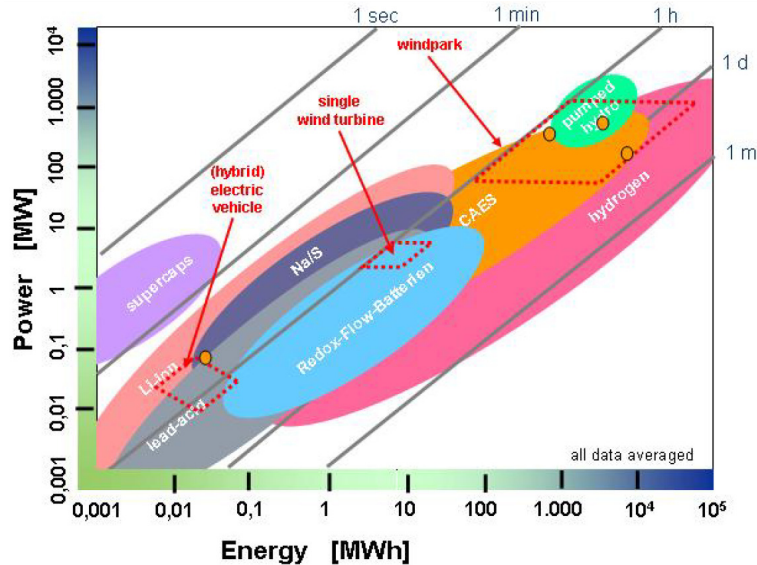
The battery of the electric vehicle may have additional functionality beyond storing traction energy: the transient buffering of energy from renewable sources like wind and solar. This so called vehicle-to-grid (V2G) concept was presented to the participants of the expert workshop by Manfred Waidhas, Siemens (Germany).

The increasing integration of volatile renewable energy in the energy mix requires matching storage solutions. Various solutions for transient energy storage can be considered: super-capacitors, flywheels, batteries (Pb, Li, NaS, redox-flow), pumped hydro, CAES (Compressed Air Energy Storage) and hydrogen. Batteries on board of an electric vehicle that is connected to the power grid are one option. There are two concepts: plug in cars with unidirectional charge flow where the batteries are charged in times of peak supply, and V2G, with bidirectional charge flow, where the battery also is discharged at times, e.g. when there is a need to balance grid instabilities or to cover of peak demand. V2G implies some specific implications in terms of basic requirements for the battery: costs below 200 €/kWh, lifetime above 6000 cycles under all application-relevant conditions ( $T > 40^{\circ}\text{C}$ , high power), charging capability at temperatures as high as  $60^{\circ}\text{C}$ , approved safety concepts, green chemistry and recycling concepts, standardization (e.g. voltage range), smart communication & control, metering, billing, and smart battery management and power electronics. It should be noted,

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<sup>13</sup> EUCAR and CLEPA, R&D Priorities for the Greening of Vehicles and Road Transport, May 2009.

that there is indeed no universal solution for energy storage, but Li ion batteries in many cases are the more efficient, easily installable and cheaper solution than others. Another main criterion for choosing the storage technology is the required discharge time (see Fig. 6). Battery-type storage can meet requirements up to approximately 30 MW / MWh as well as provide discharge in the range of tens of minutes up to some hours which make it an option for storage of energy from e.g. single wind turbines.



**Figure 6.** Energy, power and discharge time characteristics of energy storage systems.

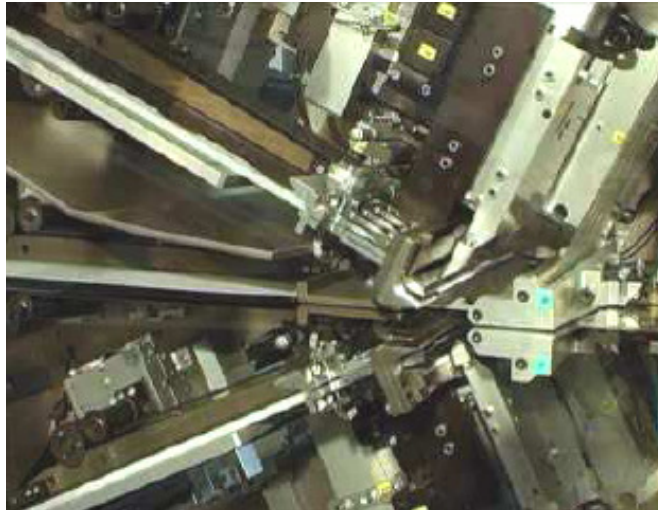
The experts expressed the opinion that V2G is one concept among others (e.g. stationary storage) for covering peak demand. They considered it questionable whether utility providers will prefer to use and pay for the combination of hundreds or thousands of vehicle batteries or will rather install Lithium ion batteries for reliable, stationary energy storage. Moreover, the experts agreed that more research is required to assess the potentials of batteries for the stability of the grid at integration of renewable energy in general. Also, some fundamental R&D related to batteries for the V2G concept is required, including the development of the communication and control interfaces, and solutions for standardization and safety issues. This will require modeling, simulation, demonstration and real time testing efforts. Access rights to vehicle batteries and the related business models have also to be investigated in parallel to R&D activities.

### Cell manufacturing process

As part of the battery value chain, the manufacturing process of battery cells has to be considered. Claudio Lanciotti, Arcotronics (Italy) explained the details of the process

The making of Li ion battery cells starts with the preparation of the electrodes, i.e. coating of metal films by the active materials (e.g.  $\text{LiFeO}_4$  for the cathode, carbon for the anode) followed by notching of tabs out of the active layers. It furthermore comprises steps of assembly of the electrodes (stacking or winding and insertion of separator films), packaging (cylindrical resp. prismatic cans or softpacks) and eventually the filling with the electrolyte. The process, even though it is straight forward requires sophisticated machinery in terms of accuracy, cleanliness and speed (Fig. 7).

The experts agreed that the production processes should be further developed and accelerated where ever possible as this is regarded essential for mass manufacturing of cheap batteries.

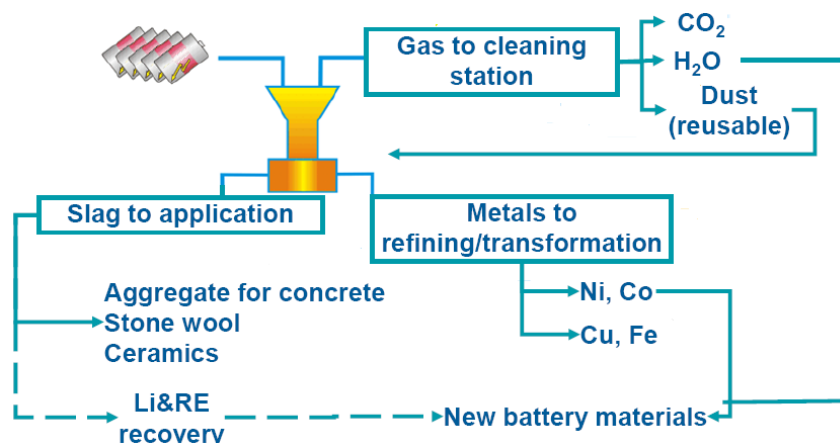


**Figure 7.** Machine for the assembly of Li ion bicells

### Life cycle of electrodes and electrolyte materials

Besides manufacturing also the reverse process, i.e. recycling, has to be considered when talking about batteries. Jan Tytgat, Umicore (Belgium) in his talk presented the environmental, financial, and social impacts of battery recycling to the audience of this workshop.

Two major approaches are considered: (a) the early stage standardization and volume driven unit process aiming at recovery of metals, e.g. Li or rare earth metals to the level that they can be transformed into new battery material and (b) dedicated processes for each battery chemistry which is a value driven process aiming at the recovery of compounds, e.g. electrolyte, separator, or active cathode material. Process (a) is based on proven technology (see Fig. 8) and has shown a huge CO<sub>2</sub> benefit<sup>14</sup>, whereas process (b) lacks maturity due to quality and quantity requirements set by the OEMs.



**Figure 8.** Pyro-metallurgical recycling process of Li-ion batteries

The participants of this workshop in the discussion on R&D needs pointed out that it is required to advance standardization of batteries and their components to enable the reuse of battery components and the 2<sup>nd</sup> use of batteries, e.g. for stationary energy storage.

<sup>14</sup> According to Saft, making LiCoO<sub>2</sub> based Li-ion cells from recycled Co saves 70% in energy and CO<sub>2</sub> emissions

## 7.) Recommendations for a Pan-European Battery Strategy

The workshop closed by a discussion involving all participants on what could be considered a pan-European strategy for batteries.

As a trigger for this discussion, Stefano Saguatti from Arcotronics Industries (Italy) gave a talk describing the activities of the U.S. National Alliance for Advanced Transportation Battery Cell Manufacture (NAATBatt)<sup>15</sup> which Arcotronics is part of. NAATBatt, founded in December 2008 as a public-private partnership, is aiming at building one or several state of the art lithium ion battery facilities that shall be shared by the member companies for prototyping, assembling and testing of batteries. The Alliance has more than 50 members and is supported by the U.S. Department of Energy's Argonne National Laboratory. It is modeled after Sematech, formed by the US computer-chip industry in 1987 to compete globally.

In the following discussion, experts agreed that for Europe's automotive sector to remain globally competitive when technology preferences move towards plugin-hybrid and electric vehicles it is necessary to create competence centers for all steps of the battery value chain ranging from materials, cell technologies, energy and thermal management and power electronics to vehicle integration. In particular for cell technologies, it is considered important to bring the excellent research conducted by universities and research institutes throughout Europe closer to application. Moreover, the experts pointed to the safety issues related to the transport of batteries that make it essential to have battery cell manufacturing close to the location of the end user. Even though several companies have started or announced starting manufacturing of Li ion batteries in many European countries very soon, the experts foresee that the annual output of Lithium ion batteries by these facilities may be far too small to meet the demand of the emerging EV industry and may thus put the European automotive industry in a disadvantage in the next few years. Therefore in general supporting the establishment of a diverse European transportation battery industry is regarded highly desirable.

Some experts also emphasized that the development of novel battery and energy storage technologies and their translation into innovative, marketable products requires companies to have access to advanced equipment for research, prototyping, safety testing, validation and small batch manufacturing. According to this position, in order to provide business opportunities for a multitude of technologies and to various companies from all around Europe, world-class pilot facilities should be established, jointly funded as public-private partnerships.

Contrary to this position, it was argued that establishing pilot facilities would mean to basically create an industry which may have several problematic side effects like e.g. the danger of supply not being controlled by market demand and jobs sensitively dependent on subsidies and funding.

The experts agreed that any 'close to market' support activities by the European Commission should be aimed at gaining competitiveness over Asia and the U.S. Therefore, a clear focus shall be put on enhancing and accelerating the creation of a strong European battery industry. One option could be that the EU Member States promote actions in the direction of (a very few or even no more than one) national pilot plants while the European Commission encourages the pan-European coordination and linkage of these facilities and supports the submission of R&D proposals to these "facilities of reference".

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<sup>15</sup> [www.naatbatt.org](http://www.naatbatt.org)

## 8.) Conclusions

Summarizing the Joint EC/EPoSS/ERTRAC Expert Workshop 2009 ‘Batteries and Energy Storage Systems for the Full Electrical Vehicle’ the following three conclusions can be drawn:

- The discussion made clear that there is a need for better interlinking the steps of the new automotive battery and energy storage value chain, predominantly to bring the cost down. Initial acceptance issues may be solved by incentives or leasing concepts. In general, however, the gap between fundamental research and manufacturing needs to be bridged. Therefore, the establishment of a small number of pilot facilities for energy-power storage systems was suggested by some experts. This would call for a well balanced and coordinated approach that involves companies, organisations and administrative entities related to all steps of the value chain, all relevant European member states and all Directorates General in charge of the topic. Given the strategic importance of the battery topic for the competitiveness of the European automotive industry the nucleus for such activity, e.g. a dedicated advisory board, should be created as shortly as possible.
- In order to achieve the ambitious milestones of the European battery roadmap substantial R&D is still needed at all levels of the technology, starting from the fundamental electrochemistry of the battery systems, including the advancement of cell technology, the smart integration of battery cells into a pack or module and the requirements for integration into the vehicle or the grid. Significant cost reduction may also come from completely new advanced (or post) Li cell technologies. Therefore, it can be concluded that batteries and energy storage systems should continuously be the topic of industrial R&D and hence the joint calls of all involved DGs of the European Commission for the duration of the PPP Green Cars Initiative.
- It should also be emphasized that batteries and energy storage systems is not a matter for the auto industry alone. Given the importance of batteries as buffer storage for the integration of fluctuating renewable sources into the energy mix, stationary energy storage may be at least as important an application as V2G in the future. Therefore utilities and providers of renewable energies should be considered another real mass customer for Li ion batteries besides OEMs and thus be more strongly involved in debate about energy storage systems.

## 9.) Rapporteur

Dr. Gereon Meyer

VDIVDE Innovation + Technik GmbH, Steinplatz 1, 10623 Berlin, Germany

Tel. +49 30 310078 134, [gmeyer@vdivde-it.de](mailto:gmeyer@vdivde-it.de)