EUROBAT

Association of European Automotive and Industrial Battery Manufacturers

Sustainability Report

By: EUROBAT Committee for Environmental Matters (CEM)

Association of European Automotive and Industrial Battery Manufacturers
Avenue Jules Bordet 142
B-1140 Brussels
Phone: +32 2 761 16 53
Fax: +32 2 761 16 99
Email: eurobat@eurobat.org
Web: www.eurobat.org

Graphic design by Kellen Creative

Table of Contents

EUROBAT
Association of European Automotive and Industrial Battery Manufacturers

1.	Table of Contents	page 3
2.	Executive Summary	page 4
3.	Letter from the President	page 7
4.	Introduction	page 9
5.	About Batteries	page 11
6.	Automotive and Industrial Battery Applications	page 19
7.	Environmental and Social Sustainability	page 25
	a. Raw Materials	page 25
	b. Manufacture	page 28
	c. Use	page 32
	d. End-of-Life	page 33
	e. Workers	page 36
8.	Sustainability Perspectives	page 41
9.	Conclusion	page 43
10.	About EUROBAT	page 45
11.	List of EUROBAT Members	page 47

Executive Summary

The European battery industry is a dynamic and multi-billion euro industry employing thousands of people across the continent and upon which thousands of other jobs in related industries depend. The industry is committed to producing sustainable batteries in Europe for European and world markets, from the safe and controlled manufacture of batteries to ensuring effective treatment at end-of-life. Furthermore, the European battery industry makes great use of recycled materials sourced from end-of-life batteries in the production of new batteries.

Batteries play numerous important roles in everyday life, from providing the initial power needed to start the engines of cars to acting as a backup source of electricity in telecommunications, public transportation and medical procedures. Batteries also have the potential to help reduce greenhouse gas emissions by efficiently storing electricity generated from both conventional and renewable energy sources and as a source of power for electric vehicles. Batteries also help to meet the CO_2 targets set by the European Commission by contributing to more efficient energy use in the automotive industry and as a means of mass energy storage for renewable energy sources.

The raw materials used in batteries all come from sustainable sources and much come from recycling, including recycled end-of-life batteries. For this reason, the production of batteries does not create a scarcity in these materials.

The European battery industry ensures that battery manufacturing operations are conducted in a safe and responsible manner and aim to continually reduce their impact on human health and the natural environment. Complying with the applicable laws is just the baseline and the adoption of best available techniques and best practice is encouraged. Special precautions, both industry initiated and through legislation in the form of the REACH Regulation (European Regulation (EC) No 1907/2006) and CLP Regulation (European Regulation (EC) No 1272/2008), are also taken to ensure that substances are handled in a responsible manner and limiting their impact on the environment. The waste from batteries is also tightly controlled both by the industry and legislation to ensure minimal impact on the environment.

Similar safeguards are taken for batteries once they have been completed, including special standards for their safe transport and storage.

A number of valuable metals and substances can be extracted from used batteries. The extraction of these materials is performed by recycling professionals who meet the same high standards as the rest of the industry and this process is covered by specific legislation. These materials are reused either in new batteries or other industries. Thousands of tons of metals such as silver, cobalt, nickel and lead can be recovered for these purposes. This ensures environmentally sustainable and responsible production of these materials which are often scarce and of high economic value. Other battery components are likewise recycled, either being used in the production of new batteries or by other industries (Sodium Nickel Chloride batteries' waste can be used in existing industries such as in the production of stainless steel and road pavement, for example). End-of-life batteries' materials are often extracted directly by battery manufacturers or their subsidiaries which allows them to safely feed back into the battery production process directly.

Numerous safeguards exist to ensure that waste from batteries is properly controlled. Legislation, industry standards and guidelines dictate how used automotive and industrial batteries are handled and their waste carefully dealt with. These high standards follow batteries through their life cycle to ensure that there is minimal impact to the environment with the entire supply chain regulated to maintain strict controls.

Executive Summary

It has long been recognized that workers involved in the manufacture of batteries have a potential exposure to various chemical and physical hazards. The large variety of different battery chemistries means that workers in the industry can be potentially exposed to such chemical hazards as lead, cadmium, nickel, sulphuric acid, potassium hydroxide, organic solvents etc whilst the physical hazards include risks associated with noise, electricity and manual handling.

Because of the potential health risks in the battery manufacturing processes, health surveillance of workers is widespread throughout the industry. All battery plants employ occupational health staff to carry out regular health checks of the workers and to advise company management on effective ways of controlling worker exposures to hazardous substances.

The European battery industry represented in EUROBAT is continuously developing new ways to ensure that batteries remain a sustainable resource for the economy and the environment. Batteries will continue to contribute to sustainability through the development of new applications for electric vehicles and renewable energy storage. In addition, battery manufacturers continue to ensure that proper developments are undertaken to ensure that battery production remains sustainable and has a minimal impact on the environment and the health of humans.

Letter from the President

Dear reader

Rechargeable batteries are increasingly present in our lives, from starter batteries used in cars to ihybrid and electric vehicle batteries, to industrial batteries used as a source of back-up power in hospitals, server rooms and for communication. In addition, new applications abound, such as in storage of renewable energy and with the price of solar panels coming down this area, and the number of industrial batteries connected with it, is expected to grow.

Because batteries are so prevalent in modern society, it is of the utmost importance that they are produced, collected and recycled in a responsible manner. You will see from this report that the European battery industry represented by EUROBAT holds itself to high standards in sustainability, ensuring that the manufacturing of batteries has a minimal impact on the environment and special steps are taken both by individual companies and by the industry as a whole to protect the health and safety of workers.

In addition, industry is bound to comply with both EU and national rules for the protection of the environment from the initial sourcing of raw materials through production and at end-of-life when batteries' materials are recycled for use in the production of new batteries and in other industries.

Not only are batteries highly sustainable but industrial and automotive batteries are increasingly contributing positively to sustainability in other areas as well. Batteries play an important role in solutions for e-mobility including start-stop, hybrid electric and electric vehicles which help to reduce CO_2 emissions.

Harder working batteries, thanks to continuing research and development endeavours, are also leading to a more efficient use of limited fossil fuels in hybrid automotive and industrial applications. And as mentioned earlier, the use of renewable energy sources is expected to grow dramatically in coming years with batteries playing a key role as a cost effective means of storing renewable energy and decreasing CO_2 and other emissions.

I hope that you all find this report informative

Yours Sincerely

Ray Kubis
President EUROBAT

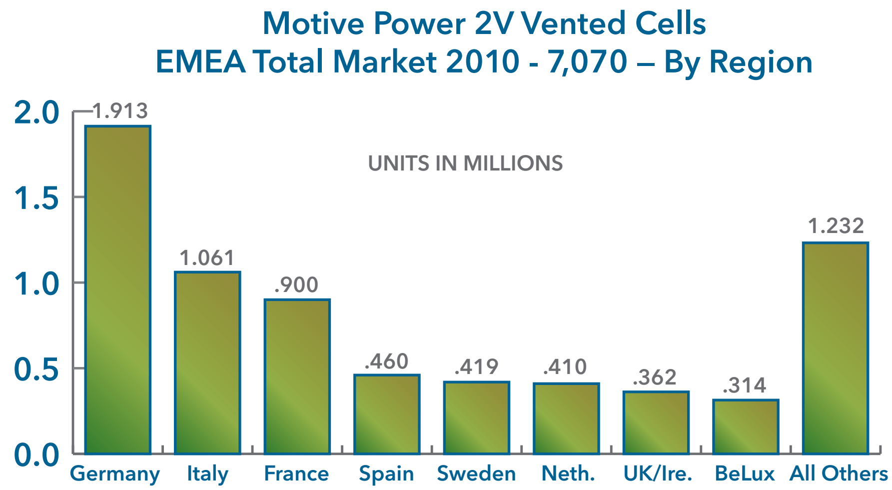
EUROBAT
Association of European Automotive and Industrial Battery Manufacturers

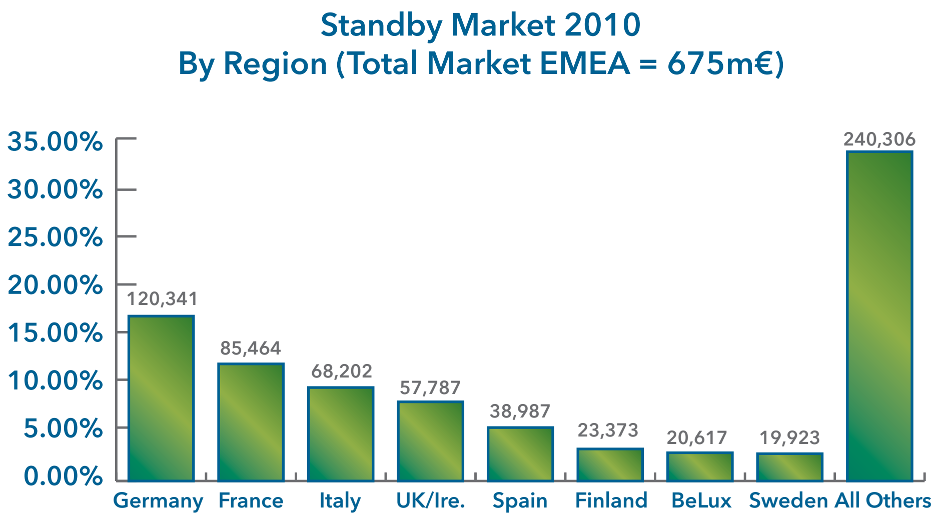
The European Battery Industry

The European battery industry is a dynamic and multi-billion euro industry employing thousands of people across the continent and upon which thousands of other jobs in related industries depend, be they customers and users like the automotive industry, suppliers or surrounding industries. In this way the production of batteries in Europe has further positive effects on economic growth.

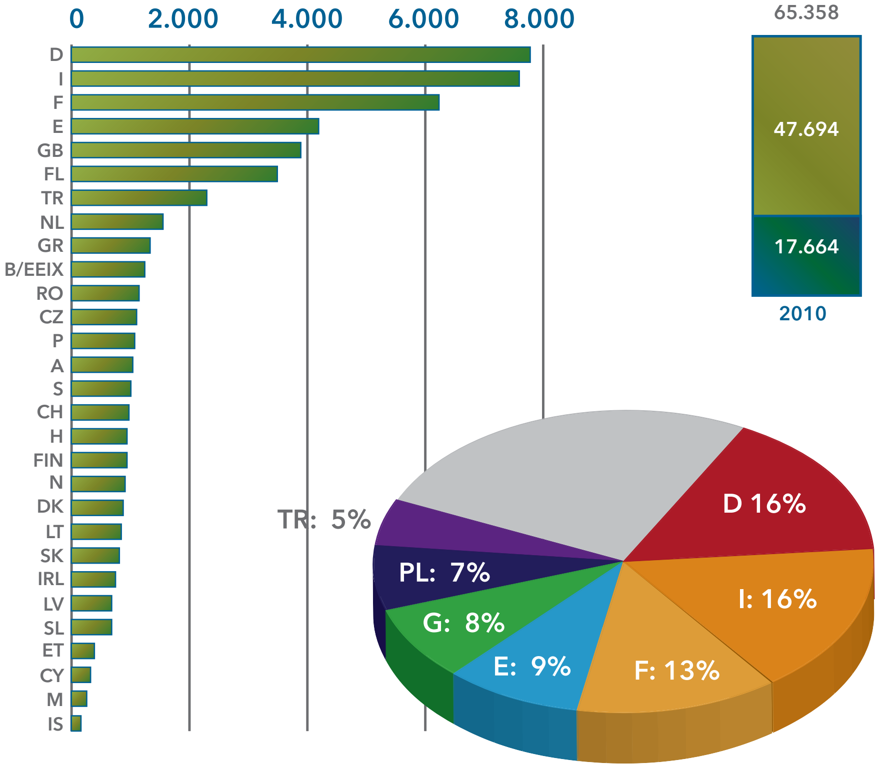
EUROBAT represents manufacturers of automotive batteries, batteries used for starter, lighting or ignition power, and industrial batteries, batteries designed for exclusively industrial or professional uses or used in any type of electric vehicle.

A Few Facts and Figures

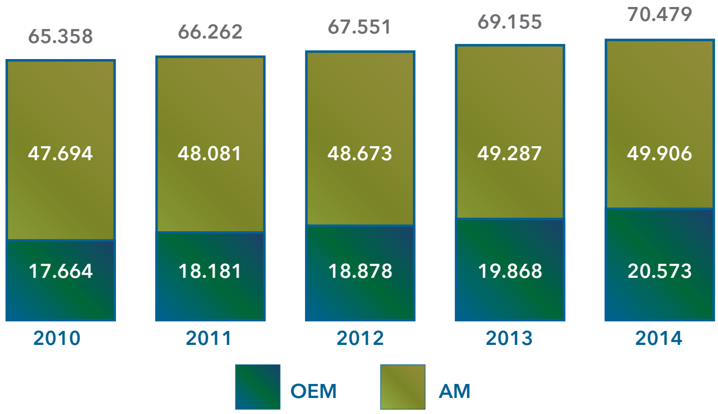




Automotive Battery Aftermarket 2010 in m units (EU 27 + EEA + Turkey)



Automotive Battery Market Volumes 2010 –2014 (in m units)



EEA: Norway, Switzerland, Central Eastern EU

How Can Batteries Help Sustainable Development Worldwide?

Batteries contribute to sustainability not only in their production but also in their use. The European Commission's "Green sustainable development strategies" have made significant changes compulsory to policies in several sectors directly related to the battery/energy storage industry such as energy and transport. Batteries are part of the solution to energy storage needs in a wide number of applications, from facilitating environmentally friendly transport to enabling security of (renewable) power supply and storage.

Within the target of promoting clean urban transport, all battery technologies have made considerable contributions to the further electrification of the drive train of the vehicle, from conventional internal combustion engines (ICE) to start & stop systems, plug-in hybrid electric vehicles (HEV) and full electric vehicles (EV). In addition to this, batteries already make an important contribution to the integration of renewable energy in existing grids and are expected to play a key role in the development of smart grids.

The History of the Battery

Although there is evidence of electrochemical cells dating back to 2000 years ago, the story of the first true battery starts with an Italian physicist by the name of Alessandro Volta. In 1800 Volta created the first battery based on pairs of copper and zinc discs, the Voltaic Pile.

It was with the invention in 1836 of the Daniell Cell, which consisted of a copper pot filled with a copper sulphate solution, that batteries would be made that could deliver a reliable current and be put to industrial use. The first rechargeable battery, or secondary cell, was a lead-acid cell battery invented in 1859 by the French inventor Gaston Planté, whose work laid the foundation for the modern lead-based battery industry. The first practical lead-acid battery was developed by Henri Tudor in 1886 and was manufactured first in Luxembourg and then in Belgium, France, Germany and the United Kingdom.

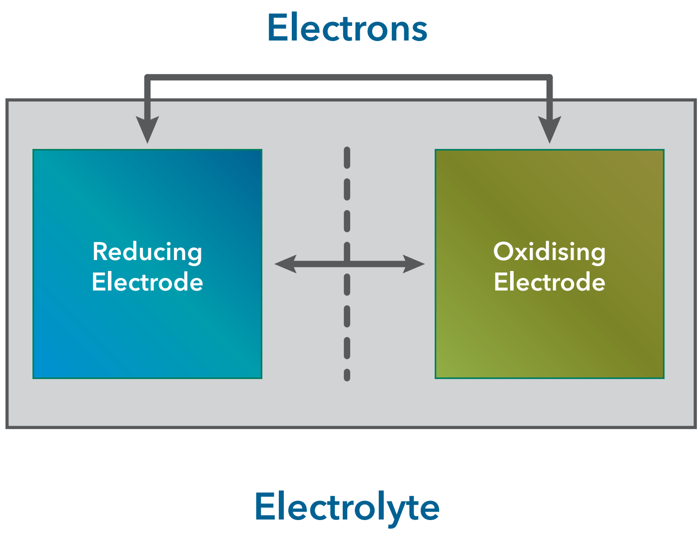
Since then there has been steady improvement of this battery technology in parallel with other technologies such as the first dry cell (a battery with a non-liquid electrolyte), the zinc-carbon battery, in 1887, the nickel-cadmium battery in 1899, the nickel-iron battery in 1903, the nickel hydrogen battery in the early 1970s, nickel-metalhydride batteries in the late 1970s, and lithium and lithium-ion batteries since the late 1980s.

Batteries Today

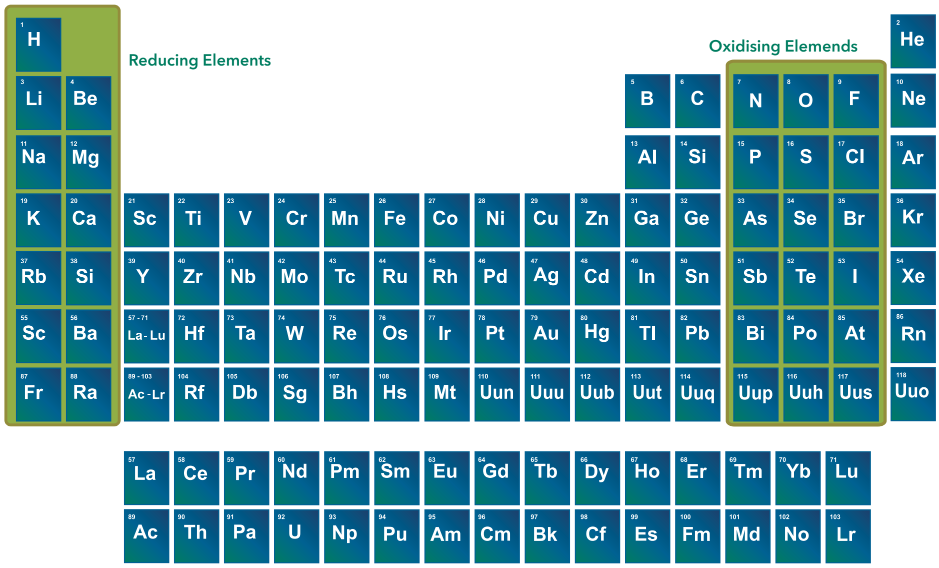
Batteries come in all sizes, from personal batteries used to power MP3 players, toys, radios and smoke detectors, and rechargeable batteries in mobile phones, laptops and portable DVD players, to industrial and automotive batteries used to crank internal combustion engines in cars (starting, lighting and ignition, or SLI, batteries), power electrical vehicles and as support for renewable energy generation. Batteries are also widely used in motive (trucks, trains, ships, aviation, space) and stationary applications, such as providing back-up power for UPS (uninterruptible power supply) and telecommunication systems. As such, batteries are an ever present part of our day to day life from work and leisure, to communications and travel.

How Batteries Work

A battery is an energy storing system based on electrochemical charge/discharge reactions. During discharge the chemical energy is converted into electrical energy and during charge the electrical energy is reconverted into chemical energy. In a primary battery system only the discharge reaction can be used, and the battery's components must be recycled. A secondary or rechargeable battery system is characterized by a charge/discharge reaction that



is reversible, allowing for repeated use.



The higher the reversibility of the reaction the more often a battery can be charged/discharged. The process of a full charge to full discharge and back to full charge is known as a cycle. A battery's cycle life is how many cycles the battery can go through before the battery must be replaced. The electrical energy stored in a battery is directly related to the chemical energy being stored. The cathode incorporates an oxidizing material, the anode a reducing component. The laws of nature have fixed specific energy limits to electrochemical systems from the periodic table of elements (see above). However, most chemical reactions cannot be used in a battery system because they are not reversible in an electrochemical cell.

Batteries in Everyday Use

Batteries play numerous important roles in everyday life, from providing the initial power needed to start the engines of cars to acting as a backup source of electricity in telecommunications, public transportation and medical procedures. Batteries also have the potential to help reduce greenhouse gas emissions by efficiently storing electricity generated from both conventional and renewable energy sources and as a source of power for electric vehicles.

Applications of Industrial and Automotive Batteries

Automotive Applications (including Cars, Trucks, Buses, Agriculture, Construction)

- Starting, lighting and ignition (SLI) batteries
- Start-Stop systems
- Mild, full and plug in Hybrid Electric Vehicles (HEV)
- Electric Vehicles (EV)

Motive Applications

- Lift trucks and handling
- Trains, ships and aircraft

Stationary Applications

- Uninterruptable Power Supply (UPS)
- Telecommunications
- Renewable Energy Systems (RES)
- Grid support

Battery Technologies

A broad range of different electrochemical systems and battery technologies exist today. There are currently four battery families dominating the automotive and industrial battery market

- Lead-based battery technology
- Nickel-based battery technology
- Lithium-based battery technology
- Sodium-based battery technology

The selection of one of these technologies depends on application requirements regarding performance, life, safety and cost.

Lead-Based Batteries

Lead-acid technology is the most widely used electrochemical system, used in numerous applications from back-up for uninterruptible power supplies and grid energy storage, to traction in battery electric vehicles and for starting, lighting and ignition (SLI) in conventional combustion engine vehicles.

The lead-acid battery is based on:

- Lead dioxide as the active material of the positive electrode,
- Metallic lead, in a high-surface-area porous structure, as the negative active material,
- Sulphuric acid solution as the electrolyte.

Lead-acid technology is composed of several sub-technologies distinguished by battery design and manufacturing process:

- Flooded lead-acid batteries,
- Valve-Regulated lead-acid (VRLA) batteries with electrolyte immobilized by a gel,
- VRLA batteries with the electrolyte immobilized in an absorptive glass mat (AGM)
- Vented lead acid batteries for industrial applications

Flooded Lead-Acid Batteries

In flooded lead-acid batteries, the positive plate (electrode) is comprised of lead dioxide and the negative of finely divided lead. Both of these active materials react with a sulphuric acid electrolyte to form lead sulphate on discharge and the reactions are reversed on recharge. Batteries are constructed with lead grids to support the active material and individual cells are connected to produce a battery in a plastic case. There are, however, major differences in battery construction depending on the duty cycle and application. The typical application of these batteries is the automotive industry; millions of these batteries are used to start and support the electrical system in today´s cars and trucks.

Valve-Regulated Lead Acid Batteries (VRLA) with Electrolyte Immobilized by a Gel or an Absorptive Glass Mat (AGM)

A secondary battery in which the cells are closed but have a valve that allows the escape of gas if the internal pressure exceeds a predetermined value, valve-regulated lead acid batteries (VRLA) have a starved electrolyte either on glass fibres (Absorptive Glass Mat, or AGM) or as a gel (Gel technology) which allows for internal gas circulation. Water loss from overcharge is reduced to less than 10% through recombination. VRLA batteries can be installed in a free orientation and there are no leakages because of the absence of liquids. The construction of these batteries means that they do not require maintenance, making them especially advantageous for remote area installations.

Today, AGM batteries are typically used in vehicles which are very well equipped and therefore have a correspondingly high cycling demand and cycling depth. A new booming market for AGM batteries is for their use in start-stop vehicles and this segment is expected to grow strongly over the coming years. Other applications include use in motorcycles and motor car racing due to their safety in the event of an accident and Gel VRLAs can also be found in electric wheelchairs due to their suitability for use indoors.

Vented Lead-Acid Industrial Batteries

Vented lead-acid batteries are covered secondary cells with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells. Vented lead-acid batteries have a liquid electrolyte. The battery is closed by a vent plug and has a gassing rate more than 4 times higher than valve regulated batteries. Water loss by electrolysis during overcharge results in the production of hydrogen and oxygen gases. Vented lead-acid batteries are a well-established technology and are economical to produce. Maintenance of water refill depends on design features and application (reduction of refill by recombination plugs or custom refilling systems). The state of charge and age can be checked very easily in vented lead-acid batteries.

Vented lead-acid batteries are commonly found in various traction applications.

Nickel-Based Battery Technology

Rechargeable alkaline batteries employ a nickel hydroxide-based cathode, with either a metallic anode (nickel-cadmium (Ni-Cd), nickel-iron (Ni-Fe), nickel-zinc (Ni-Zn) or a hydrogen storing anode (Ni-H_2, nickel-metal hydride (Ni-MeH)). Due to technical limitations on maintenance and long term cycling performance, Ni-Fe and Ni-Zn batteries cannot be used for automotive or stationary applications.

The construction of the battery differs for particular applications but there are three basic types; the pocket-plate type, the fibre-structured type and types using a sintered or bonded electrode structure. For pocket-plate types, a perforated nickel-plated steel pocket is used to contain the active material. The fibre-structured type is made out of a plastic nickel fibre compound material and therefore has very good contact between the conductive fibres and the active material. For sintered or bonded types, a porous partially sintered nickel substrate may be used but various plastic bonded structures and fibrous constructions are also offered. The pocket-plate construction is highly reliable and offers moderate performance but the other types offer higher levels of electrical performance. Nickel-based batteries may also be constructed in a fully sealed form similar to VRLA batteries, but without any gas emission. Ni-MeH is technically equivalent to Ni-Cd in a number of technical aspects and it can be used in many applications, but its main drawback is the need for an electronic battery management system to ensure proper operations. This adds costs and limits the reliability of this technology, which for the most part has disappeared from the industrial market.

Both Nickel/Hydrogen (Ni-H) and Ni-MeH batteries are, in principle, the same battery system, utilizing nickel hydroxide (NiOOH) as positive and hydrogen (H_2) as negative electrode materials. In Ni-MeH batteries a hydrogen storage alloy is used. Both systems have an excellent cycle life. However, due to several performance limitations, Ni-H batteries, as is the case with Ni-Fe and Ni-Zn, are now limited to very narrow niches of the industrial market.

Ni-Cd batteries have a positive electrode of nickel hydroxide and a negative electrode of cadmium. On discharge the nickel hydroxide is reduced to a different form of nickel hydroxide with a lower oxidation state and the cadmium is oxidised to cadmium hydroxide. The reverse reactions take place on recharge. The electrolyte is a potassium hydroxide solution.

Ni-Cd based batteries offer good resistance to electrical use as they can be left in a discharged condition for long periods without permanent damage, they are recognized for their superior reliability and also offer good performance in higher, lower ambient and extreme temperatures.

Due to their superior reliability, Ni-Cd based batteries are essentially used for the back-up of aircraft and rolling stock (train) electronic systems, as back-up for several mission critical industrial processes where the safety of humans or assets is at stake, as well as in electrically or mechanically arduous applications.

Lithium-Based Battery Technologies

Lithium-ion (Li-Ion) is currently the dominant battery system for portable applications and was introduced to the market in 1991. Due to the high capacity of the active materials and a single cell voltage of 3.6V, Li-Ion provides the highest energy density of all rechargeable systems operating at room temperature. Li-Ion batteries are also available as lithium polymer batteries using a lithium metal electrode in conjunction with a solid or gel-type electrolyte.

The Li-Ion battery employs a Lithium metal oxide cathode and a carbon anode with an organic electrolyte. Over the last years tremendous improvements on battery parameters have been achieved. Both the high level of energy and power makes the Li-Ion system very suitable for various applications, ranging from high energy to high power. The high single cell voltage not only results in high performance, but also allows the use of fewer cells, compared to other battery systems.

In lithium-based batteries, the anode is made of carbon, while the cathode is a lithiated metal oxide ($LiCoO_2$, $LiMO_2$, etc.). The electrolyte is made up of lithium salts (such as $LiPF_6$) dissolved in organic carbonates. When the battery is being charged, the lithium atoms in the cathode become ions and migrate through the electrolyte toward the carbon anode where they combine with external electrons and are deposited between carbon layers as lithium atoms. This process is reversed during discharge. Because lithium reacts with water, non-aqueous solutions are used.

Lithium-based batteries can be found in a range of consumer applications such as portable devices, as well as in several industrial applications in which their unique features of superior cycling ability and high energy density sets them apart from other technologies. This makes them particularly well suited for electric and hybrid vehicles and aerospace applications.

Sodium-Based Battery Technologies

Sodium-based batteries have a high energy density, long cycle life and can operate in harsh environments such as temperatures of -40°C to +60°C. For these reasons they can be found in application in energy grid storage, such as storing energy from intermittent energy sources such as wind- and solar-power. Unlike many batteries, sodium-based batteries consist of a solid or solid and molten electrolyte with liquid sodium acting as the negative electrode. These batteries are usually constructed in a cylindrical form, encased in a container which acts as the positive electrode. The chemistry is quite simple with no side reactions and roundtrip efficiency (charge/discharge) of up to 85%.

Sodium-Nickel Chloride Technology

The cathode in these batteries is nickel chloride ($NiCl_2$) while the anode is made of sodium (Na). The electrolyte is made up of tetrachloraluminate of sodium (such as $NaAlCl_4$), and is liquid at the operating temperature of the cells (and battery) in between 270°C and 350°C. When the battery is being charged the sodium atoms in the cathode become ions and migrate through the ceramic electrolyte. Available free electrons can flow as current to an external load. This process is reversed during discharge.

Commercialized since the middle of the 1990's, sodium-nickel chloride batteries have found application in Electric Vehicles (usually cars) and Hybrid Electric Vehicles (usually buses, trucks, vans). The use of sodium-nickel chloride batteries in the stationary field is in its starting phase. Demonstration systems combined with distributed renewable generators (large photovoltaic plants and micro wind turbine) as well as for grid support with voltages up to 600V have been designed and are now in field test phase.

The end-of-life battery is fully recyclable within existing industries for the production of stainless steel and road paving.

Sodium-Sulphur Technology

This battery has a solid electrolyte membrane between the molten anode and cathode, compared to liquid metal batteries where the anode, the cathode and also the membrane are liquids. The cell is usually made in a tall cylindrical configuration. The entire cell is enclosed by a steel casing that is protected, usually by chromium and molybdenum, from corrosion on the inside. This outside container serves as the positive electrode, while the liquid sodium serves as the negative electrode. The container is sealed at the top with an airtight alumina lid. An essential part of the cell is the presence of a BASE (beta-alumina solid electrolyte) membrane, which selectively conducts Na^+. The cell becomes more economical with increasing size. In commercial applications the cells are arranged in blocks for better conservation of heat and are encased in a vacuum-insulated box.

During the discharge phase, molten elemental sodium at the core serves as the anode, meaning that the Na donates electrons to the external circuit. The sodium is separated by a beta-alumina solid electrolyte (BASE) cylinder from a container of molten sulphur, which is fabricated from an inert metal serving as the cathode. The sulphur is absorbed in a carbon sponge. BASE is a good conductor of sodium ions, but a poor conductor of electrons, and thus avoids self-discharge. As the cell discharges, the sodium level drops. During the charging phase the reverse process takes place. Once running, the heat produced by charging and discharging cycles is sufficient to maintain operating temperatures and usually no external source is required.

The Na-S battery is used in pilot projects to develop a durable utility power storage device due to its efficiency of 70% or better and a lifetime of over 1,500 cycles.

Automotive and Industrial Battery Applications

Batteries represent the main solution to the power needs of a widespread number of applications; from vehicles and portable devices to renewable energy systems, through a variety of industrial uses such as ensuring energy supply in cases of power failure (uninterruptible power supply or UPS, telecommunications), as well as in strategic defence applications. In this way batteries play numerous important roles in everyday life, contributing to social welfare.

Batteries are also beneficial to European employees and consumers by guaranteeing job growth and ensuring the introduction of energy efficient and quality products on the market at reasonable costs as well as contributing to energy independence and security of energy supply.

Batteries also have the potential to help reduce greenhouse gas (GHG) emissions as they have the ability to continue or further increase the deployment of new technologies in wider sectors, namely those that incorporate batteries as essential parts of their electronics. As such, new market opportunities for batteries are developing.

Automotive Applications

Batteries are making a key contribution to energy efficient, cleaner and more environmentally friendly transportation. They are not only essential for road but also for rail, maritime and air transportation. Cars contribute around 12% of total man-made CO_2 (a common GHG) emissions in Europe, the EU overall transport produces 26%.

Automotive batteries initially provided SLI (starting, lighting and ignition) functions to conventional internal combustion engine (ICE) powered vehicles. However, due to the further electrification of road transportation the battery has many additional functions to fulfil, including direct electric propulsion. Depending on the vehicle concept (start-stop micro, mild, full, plug-in hybrid electric vehicles and full electric vehicles) and driving profile of users, batteries can have a significant impact on fuel savings and lowering greenhouse gas emissions.

Micro-Hybrid Electric Vehicles (Micro HEVs) –Start-Stop System

In a micro-hybrid electric vehicle the internal combustion engine automatically shuts down when braking and at rest. Some systems also provide a certain degree of regenerative braking. Fuel savings and lowered greenhouse gas emissions can reach up to 8% and more, depending on type of duty cycle. When the engine is shut off while the vehicle is in motion, GHG savings can be even higher.

Mild Hybrid Electric vehicles (Mild HEVs)

In mild hybrid electric vehicles, electrical operation is used mainly during vehicle start and acceleration phases. The positive features such as regenerative braking and engine shut-off in motion mentioned in the micro-hybrid section could and will be applied to this technology as well. Pure electrical driving is not provided for in this technology but fuel saving and lowered GHG emissions have been measured at 15-20%.

Full Hybrid Electric Vehicles (HEVs)

In full hybrid electric vehicles electric propulsion is used for relatively short periods, specifically during starting to substitute a thermal engine which has a very poor efficiency at low rpm. Regenerative braking is a key feature of this technology and pure electric driving is possible for short distances. Fuel and GHG reductions can reach up to 40%.

Plug-In Hybrid Electric Vehicles (plug-in HEVs)

If plug-in hybrid electric vehicles are regularly connected to the grid, the battery energy storage can be used for longer periods. Concerns about range limitation have been solved with the battery system supported by an internal combustion engine.

Electric Vehicles (EVs)

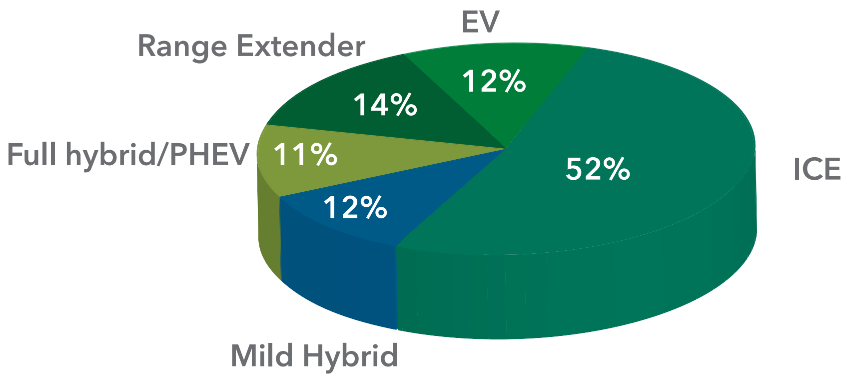
Electric vehicles operate with electrical power only. The battery is the crucial factor for the driving range, mostly up to 150 km. Some of these vehicles have a fuel-operated generator on board, the so called Range-Extender.

While no greenhouse gas emissions are directly released as a result of the pure electric drive of the plug-in HEV and EV, the amount of CO_2 savings depends on the power mix and its share of fossil, nuclear and renewable energy used to feed the grid from which the energy is sourced.

Currently, the main markets for road transportation are passenger cars, light commercial vehicles (delivery vans) and heavy commercial vehicles (buses and trucks). But light vehicle market segments (motorcycles, E-bikes, Segway-type vehicles) are also developing significantly in terms of market size and their contribution to greener transportation.

Today, Start-Stop micro-HEVs have already entered the mass market in Europe. Further evolution of the different vehicle architectures will depend on incentives and technological evolutions but reputable consulting companies and major stakeholders such as ERTRAC (European Road Transport Research Advisory Council) and ACEA (European Automobile Manufacturers Association) are all predicting that different vehicles architectures will co-exist, with the internal combustion engine becoming more and more electrified and remaining important in the next decades and up to 2050.

Automotive Landscape EU in 2025
Source: Roland Berger 2011



(ICE: Mainly Start-Stop Micro HEV)

The European Commission plans to set targets to cut by half the urban usage of internal combustion vehicles by 2030 and to phase them out by 2050, according to an EU road map on transport (March 2011). The objective of internal combustion engine vehicle-free cities by the middle of the century is to be pursued through fiscal measures, promotion of alternative transport systems and building of the necessary infrastructure to move to a widespread use of more electric and clean cars.

Automotive and Industrial Battery Applications

EUROBAT
Association of European Automotive and Industrial Battery Manufacturers

The battery technology for plug-in HEVs and EVs (both fixed and removable) has evolved tremendously over the last decade with the introduction of lithium-based batteries complementing lead-, nickel- and sodium-based technologies. These technologies will all continue to have a significant impact on electro-mobility as they may give cost and/or performance advantages for specific applications, for example as start-stop and hybrid solutions.

The selection of a technology depends on the requirements for performance, life and cost for a given application. Given the diversity of possible operating modes, there is no one battery system or technology that covers the entire range of application needs sufficiently. On the contrary, different battery energy storage technologies exist and each of them has a role to play in the future as the best solution to the needs of a system depending on their specific attributes:

- Lead-based: for start-stop micro application, up to mild HEVs
- Nickel-based: for HEV applications only
- Lithium-based: for HEV, plug-in HEV and full EVs
- Sodium-based: for Plug-in HEV and full EVs

For more information on the contribution of batteries to e-mobility, please consult the EUROBAT position paper on "Battery Energy Storage Solutions for Electro-mobility".

Industrial applications

Batteries are essential in numerous industrial applications. Typical stand-by applications include telecommunication systems, data communication, cabling and DC power systems, switching and security lights. Typical industrial motive applications include use in forklifts, cleaning machines, access equipment, golf carts, wheel chairs etc.

Batteries are essential in a number of areas as a source of back-up power. They contribute to the effective functioning of communications, IT, oil and gas networks and for the storage of data in uninterruptible power supply as well as other industrial systems. Batteries also support several other activities such as medical procedures for which uninterruptable power is essential in performing operations and other important treatments. Back-up power supplied by batteries provides back-up lighting in the event of black-outs and they are also essential in defence applications.

Battery energy storage (BES) can assist in achieving an EU low carbon economy. Renewable energies are a good way to reach this goal, but there are still a number of technical challenges to overcome, notably their integration into the grid, synchronisation between supply and demand, stabilisation of voltage and frequency control. BES has proved to be a valuable option in overcoming these issues and allows for optimised integration and use of the electricity produced via renewable energy sources.

Batteries can therefore contribute to all three objectives of the EC-20-20-20 targets in the EU Climate Change Package:

- Reducing EU emissions by 20% by 2020
- 20% of the EU's overall energy consumption coming from renewables by 2020
- Achieving 20% savings in energy consumption

Battery storage is also a key component for optimizing grid integration of renewable energy sources. The functions of batteries are widespread, from "energy time-shifting" to "capacity firming". These battery uses can be adapted to any size wherever renewable energy generation is included in the system, from a few kilowatts in residential or small commercial installations, up to megawatts sizes in power generation plants. Battery energy storage is a valuable and sustainable way of increasing the integration of renewable energies in the energy mix of off-grid, mini-grid and grid-connected configurations.

In addition to the environmental advantages related to renewable energy generation, integration and distribution, BES has also been shown to be beneficial to end-users and to electricity providers.

For the end-user (households and industry) the value of BES is generated from three main streams:

- Enhanced availability, quality and security of electrical power
- Enhanced value of (renewable) energy in periods of high demand
- Remuneration of services from utilities or savings on utility charges

The key functions that the batteries can fulfill for the households and industry are:

- "Backup power" to provide continuity in case of grid power outage
- "Time-shift" to store & shift energy from off-peak periods to on-peak (trading)
- "Peak Shaving" to reduce loads during peak demands
- "Power Quality" to protect sensitive electronics
- "Demand Response" to allow customers to turn off loads with financial compensation in return
- "Renewable Energy Supply Capacity Firming" to take up and supplement 100% of a generator's nominal power

For electricity utility providers (generators and grid operators, Transmission System Operators, or TSOs, and Distribution System Operators, or DSOs) the value of energy storage is generated from three main streams:

- Cost-effective provision of grid support services
- More efficient use of existing generation/transmission assets
- Avoiding / postponement of investment in grid / generation upgrades

The key functions that batteries can fulfil for electricity providers are:

- "Primary Reserve Power" to respond to immediate generation loss or load increase, necessary for frequency stability
- "Secondary Reserve Power" to substitute CO_2-emitting spinning units, combining primary and secondary regulations at the same time
- "Reserve Capacity" in case normal electricity supply resources become unavailable, BES can substitute fuel powered spinning-reserves
- "Grid Stability & Performance" to ensure ancillary services to compensate electric anomalies during transmission
- "Peak Shaving" to reduce peak-loads (e.g. postpone investments for grid upgrades)
- "Voltage Support" to compensate voltage drops at end of feeding lines

An EU Smart Grid will allow operators to keep track of electricity generation and flows with more precise information about the electricity that is generated and operators will be able to monitor the energy savings and therefore reduce costs. BES will contribute even more to grid services to the benefit of the concerned stakeholders by allowing operators to effectively control the electricity flows.

In addition to centralised storage units, several BES systems could be combined with up to hundreds of megawatt hour (MWh) capacity in various locations on the electric power grid and be used as an almost universally applicable method of utility electricity storage/regulation to prioritize renewable energy generation and fully integrate up to 100% (i.e. Renewable Grid Initiative). In this sense, BES will be a major path to a fully decarbonised EU power system by supporting renewable energy sources at different levels and a variety of applications and maximising the benefits of electricity supply (transmission & distribution).

Different BES technologies exist and each of them has a role to play in the future as best solutions to the needs of a system depending on their specific attributes.

For more information on the contribution of batteries to renewable energy storage, please consult the EUROBAT white paper on "The importance of Battery Energy Storage for Renewable Energy Supply".

Raw Materials

Different battery technologies vary in their complexity. For example, lead-based batteries contain relatively few components. Several other battery technologies, on the other hand, consist of dozens of substances. The battery constituents and electronics can be and are widely recycled. Nonetheless, the raw materials used in batteries come from a number of sustainable sources and the European battery industry ensures that these substances are safely delivered to their factories.

Lead[1]

Lead, the principal component of the lead-based battery, is obtained initially by the mining of lead ores. The most common lead ore is galena (lead sulphide) although there are a very small number of deposits of cerussite (lead carbonate). Most mines are underground since those outcropping near the surface have mainly been exhausted a long time ago as lead has been mined and used for various applications for literally thousands of years. The lead industry aims to ensure the safe production and use of lead whilst safeguarding human health and minimising impact on the natural environment. The process of mining lead ores is largely mechanised, minimising any risks to the health of miners. The lead industry has also initiated a number of programmes to promote the principles of sustainable development throughout the industry and they invest heavily in the development of programmes guaranteeing high sustainability standards in countries without comprehensive regulatory safeguards. Independent research projects have also been funded to identify the health and environment impacts of lead.

After mining the ore is ground into fine particles and the lead and zinc fractions are separated by flotation to give lead-rich and zinc-rich concentrates. The lead concentrate is then smelted by adding reductants such as carbon and iron. During this process the sulphur is driven off leaving pure metallic lead. A variety of smelting technologies are employed, all of which are operated to very strict standards to limit emissions to air and water and to control human exposure.

At the end of their useful life batteries are invariably collected for recycling because of the intrinsic value of the materials they contain. Indeed the lead-acid battery is one of the most recycled products in use throughout the world and Europe has an extensive system for collecting, recycling and re-using lead from these sources. For more information on the use of recycled lead see the section on end-of-life batteries.

1. International Lead Association, www.ldaint.org

Nickel[2]

Nickel is the 5th most common naturally occurring substance and is mined throughout the world, including in Europe. Nickel is used in a variety of applications, particularly as an alloy. Reserves of nickel are sufficient to satisfy demands for the element for decades and exploration is finding additional deposits for possible future development.

Nickel is also easily recycled from many of its applications. Nickel's recyclability is supportive of the needs of sustainability. The stock of nickel is constantly increasing due to the joint recovery of nickel through recycling and new production of nickel and it can therefore be described as a sustainable resource, not diminishing as it is used in various applications including the production of batteries. Due to this high recyclability, only about 1.4 million tonnes of new or primary nickel are produced and used annually in a wide range of industries around the world.

Cadmium[3]

Cadmium is found principally in association with zinc sulfide based ores and, to a lesser degree, as an impurity in lead and copper ores. It is also found in sedimentary rocks at higher levels than in igneous or metamorphic rocks, with the exception of course of the nonferrous metallic ores of zinc, lead and copper. Most cadmium metal today is produced as a by-product of the extraction, smelting and refining of these nonferrous metals – zinc, lead and copper.

As such, the mining of cadmium has no additional impact on the environment as these materials are mined for their own value and use in various other industries, including the battery industry. Although pure cadmium veins exist, these have not been tapped into as there is sufficient supply of cadmium as a by-product of zinc refining to meet global demand for the metal[4].

Most recycled cadmium comes from end-of-life nickel-cadmium batteries which can then be reused in the battery industry.

2. Nickel Institute, www.nickelinstitute.org
3. International Cadmium Association, www.cadmium.org
4. Mineral Information Institute, www.mii.org

Lithium[5]

Lithium does not occur naturally in its elemental form due to its high reactivity with fresh water so lithium metal is either mined and separated from other elements or found in brine pools (salt water) and it is from brine pools that most of the lithium for lithium-based batteries comes from. Lithium is most commonly produced in Nevada, USA, Chile and Argentina, where salt rich brines are pumped from beneath the desert and fed into a series of large, shallow ponds on the desert floor. While some ponds are lined with stable PVC plastic and natural materials, these cause no contamination in the surrounding soil and other ponds do not use PVC at all. The brine evaporates over an 18-24 month period until it has a sufficient concentration of lithium salts, at which point the concentrate is shipped by truck or pipeline to processing plants where it is converted to usable salt products.

The primary substances used to produce lithium are lime and soda ash. Both substances are natural materials, commonly used in many processes and have no detrimental effect when used properly. The energy consumption from the production is relatively small; a small amount is used for pumping the brine from the ground, while the energy used for the evaporation is solar.

The desirable salts of lithium or potassium chloride and the by-products such as magnesium or sodium chloride are substances that are already present in the soil and not carcinogenic or dangerous to the environment, and are often used in fertilizer production[6]. There is no adverse impact on the water supplies as the water extracted as part of the process of producing lithium has high concentrations of salts and other minerals and is therefore undrinkable.

Chemical Regulation in Europe

Europe now has comprehensive and far reaching legislation regulating the use, production and labelling of chemicals in Europe. REACH (European Regulation (EC) No 1907/2006) is the European Regulation on the registration, evaluation, authorisation and restriction of chemical substances. EUROBAT members have participated in the registration of the most important substances used in batteries, namely nickel, lithium, lead and lead compounds and sulphuric acid. Battery industry suppliers are responsible for registration in respect to the majority of substances used in batteries, and in many cases the battery industry has aided in these registrations.

EUROBAT Guidance on CLP Regulation

In an aim to ensure the battery industries strict adherence to the CLP Regulation, EUROBAT has prepared guidance to battery manufacturers on how to implement and respect this legislation. The guidance can be found at www.eurobat.org.

The CLP Regulation (European Regulation (EC) No 1272/2008) governs the classification, labeling and packaging of chemicals. Many of the chemicals used by the battery industry are governed by this piece of legislation ensuring that the risks and properties of these chemicals are easily identifiable.

5. International Lithium Alliance, www.lithiumalliance.org
6. Life Cycle Assessment LCA of Li-Ion batteries for electric vehicles , EMPA, www.cars21.com/files/news/LCApresenation.pdf last accessed 1 September 2011

Manufacture

The European Battery industry ensures that battery manufacturing operations are conducted in a safe and responsible manner and aims to continually reduce its impact on human health and the natural environment. Complying with the applicable laws is just baseline and the adoption of Best Available Techniques and Best Practice is encouraged. Special precautions, both industry initiated and from legislation in the form of the REACH Regulation and CLP Directive, are also taken to ensure that substances are handled in a responsible manner and limiting their impact on the environment. The waste from batteries is also tightly controlled both by the industry and legislation to ensure minimal impact on the environment.

Water

Clean drinkable water is a key element for human survival. Not only that, but we use water on a daily basis for numerous different tasks from cooking food to cleaning clothes and even in industry. For these reasons, it is important to ensure that bodies of water which could feed back into the water cycle are kept unpolluted. The European battery industry, guided by legislation, makes sure that the manufacturing process of batteries does not contaminate water. During the manufacture of batteries strict controls are implemented and all water flows from battery plants undergo rigorous decontamination processes. Special care is taken to ensure that the water that emerges from this process is not only clean, but also drinkable. Water emerging from battery manufacturing processes is closely monitored to ensure these high standards are met.

Furthermore, water is increasingly becoming a scarce resource. Battery manufacturers are taking special care in ensuring that only essential amounts of water are used in the production of batteries.

A case study from Exide Technologies

Within a period of four years the Industrial battery plants of Exide Technologies were able to reduce the specific water consumption by 28% - in absolute figures by 271,000 m³.
That equals the water consumption of a small town with 5,800 inhabitants.

CO_2 Emissions

The European battery industry is committed to continuously developing and presenting new viable technical solutions, which helps combat climate change and reduce CO_2 emissions in the fields of transportation and energy supply. This does not only apply for the wide field of the applications of our products – we commit to reduce our footprint even while producing our batteries. New technologies in manufacturing and new processes have been implemented in factories throughout Europe to ensure a minimal impact on the environment. Battery manufacturing plants are continuously being upgraded with the latest low carbon technologies.

A case study from Exide Technologies

Within 4 years, targeted projects resulted in a reduction of the specific energy consumption of 16.6% - in absolute figures a saving of 7,013 MWh. At first glance that figure does not tell so much – the climate protection efforts becomes more obvious if you see that this equals a CO_2 reduction of 4,534 t. That again equals the annual millage of 2,115 average sized cars.

Safe Use of Substances

A number of different chemistries are used in the various battery types that are available on today's market. Batteries, by their very nature, are a source of energy and therefore contain substances which are chemically reactive. These chemicals have the potential to cause harm both to humans and to the environment unless they are handled in a carefully controlled manner.

Protection of workers

A wide range of measures are in place to minimise worker exposure to harmful substances. These include the following:

- Complete enclosure of processes. Wherever possible, processes are completely enclosed to prevent the spread of contamination through the workplace e.g. in the transfer of battery lead oxide from the Oxide Mill area to the Pasting area.
- Local exhaust ventilation. For any operation in which there is likely to be worker exposure to harmful dusts e.g. lead, cadmium or nickel, local exhaust ventilation is installed to capture the dust.
- Respirators. It is common practice for workers in battery plants to wear respiratory protection to a standard of FFP2 (CEN Standard EN 149:2001) or better even though local exhaust ventilation is in place.
- Workwear. Uniforms, which are provided to the workforce, are cleaned in specially equipped laundries. In addition personal protective equipment, which is job-specific, is issued free of charge.
- Cleaning. The floors of 'wet' processes in a lead acid plant such as Pasting and Formation are kept permanently hosed down to prevent the generation of air borne dusts. In 'dry' areas, regular cleaning of the floors and workplaces is carried out using vacuum cleaners equipped with high efficiency particulate (HEPA) filters.
- Shower facilities. Locker rooms are a requirement in battery plants. These comprise two locker rooms (one for work clothes and one for civilian clothes) separated by a shower area. End-of-shift showering is mandatory to ensure that any contamination is not spread to the workers' homes.

Protection of the environment

Emissions to Air

Air emissions of particulate materials from the manufacturing process e.g. lead, cadmium and nickel dusts are abated by the use of a bag filter, often in conjunction with an additional safety (HEPA) filter. The emission of other substances to atmosphere is also controlled by the relevant abatement equipment e.g. sulphuric acid mist, which is produced during the electrical formation of lead acid batteries, is treated by passing through a scrubber system.

End-of-life bag filters, which are contaminated with heavy metals, are sent for recycling, thus ensuring a closed loop in the use of the metal.

Emissions to Water

The emission of harmful substances to sewers or rivers from the production of batteries is minimised by the treatment of process wastewater at an on-site WWTP (Wastewater Treatment Plant). In lead-acid plants, the untreated wastewater is generally acidic (i.e. low pH) and contains lead compounds in solution and in suspension. There are a number of different WWTP technologies available which utilise different chemistries. In general, however, the wastewater treatment process comprises filtration, neutralisation, precipitation and settlement prior to discharging the purified and pH-neutral water to sewer or river.

In a lead-acid plant, the solids from the settlement process are often high in lead content. These solids are de-watered in a filter press and sent to a lead smelter for recycling.

Monitoring of emissions

Battery plants in Europe are generally regulated under the Integrated Pollution Prevention and Control (IPPC) Directive (European Directive 2008/1/EC) which sets strict limits for the emission of hazardous substances to air, water and land. Air emissions have to be measured according to accepted protocols, usually by an accredited third party. Emission reports have to be provided to the authorities in accord with the conditions of the IPPC permit.

In addition, there is an air quality standard (AQS) in place for ambient lead of 0.5 $\mu g/m^3$ throughout the EU. The regulator has to be satisfied that the ambient lead concentration in the vicinity of a battery plant is below the AQS otherwise the plant must further abate the air emissions.

In accordance with IPPC requirements, emissions of wastewater have also to be analysed by an accredited third party and the results provided to the regulator.

Waste from Manufacture

In common with most industrial processes, the manufacture of batteries generates by-products, which are considered to be waste by the battery company but which can be further processed at a recycling plant. In lead-acid plants, the main waste products are the dross from the lead casting process, lead battery plates from the pasting and assembly processes and lead solids from the wastewater treatment process. These wastes all have a high lead content and are sent to the lead smelter for re-cycling.

The storage of lead-bearing wastes at the battery plants is strictly controlled, in accord with the conditions of the IPPC permit, to ensure that there is no likelihood of contamination spreading into the environment.

Waste is transported to recycling facilities, usually by road, under strictly controlled conditions. It is a requirement in Europe to use a registered waste carrier for the transport of the hazardous waste from the plant to the recycling facility. The waste has to be placed in covered containers to prevent any spread of contamination.

Use

Batteries are widely used in various devices seen on a daily basis as well as in less visible devices which are nonetheless of great importance for the sustainability of current social and economic standards, as listed in Chapter 5. Batteries have been developed to meet the varied needs for power and on the market you can find a wide range of products able to operate in the most diverse conditions and environments.

The battery is an article containing a preparation as an integral part and not an article with an intended release as defined by REACH (the European regulation on registration and authorization of chemicals) so under normal conditions the chemicals do not leave the battery and therefore do not enter into contact with users.

In flooded batteries, i.e. wet batteries having a liquid electrolyte, oxygen and hydrogen might develop during charging due to the electrolysis of water that occurs; the areas of the battery in which this occurs are well ventilated to prevent accumulation of gases, neither of which have an adverse effect on the environment or the health of humans.

In advanced technology batteries (VRLA or Valve Regulated Lead Acid batteries), the electrolyte is absorbed in the separator (AGM or Absorptive Glass Mat) or gelled (GEL), where the recombination of internal gases occurs and results in these batteries emitting only negligible amounts of gas, allowing use in all areas. They can also operate in any orientation without leaking.

The substances and materials that batteries are composed of can deteriorate prematurely due to improper use or incorrect storage conditions. Each type of battery is in fact designed to be used in a specific application to ensure the optimal power return and length of life. Storage in a cool and ventilated area will help to increase the life of batteries, whereas storage at high temperatures should be avoided as this could enhance the self-discharge phenomena, shortening the batteries' life.

It should be kept in mind that the batteries contain a considerable amount of energy and in case of short circuit they can develop a high-intensity current and cause electrical shocks. For this reason, it is important for all users to know the characteristics of batteries and EUROBAT's Committee for Environmental Matters has drawn up "Instructions for the safe use of lead-acid batteries" as part of its Customer Care Program.

A case study from EUROBAT

EUROBAT's Committee for Environmental Matter has produced a document called "Explanatory Notes for the internal and cross-border transportation of new and used batteries and other battery-specific dangerous goods by road", complete and regularly updated guidelines on the safe transport of batteries so that operators can safely arrange the transport of batteries and waste components.

The nature of the substances taking part in the chemical oxidation-reduction process, converting chemical energy into electrical energy, either due to the corrosive nature of electrolyte, acidic in the case of lead-acid or alkaline in nickel-cadmium batteries, or the reactivity of sodium and lithium in other technologies, constitutes a risk factor which needs to be controlled during transport. The classification of batteries as dangerous goods requires compliance with specific provisions which vary depending on mode of transport (road, rail, sea and air) but have a common origin in a UN model regulation updated and discussed by a committee of experts which meets regularly. The regulation takes into account new and used batteries, the electrolyte, batteries collected by homogeneous type or mixed with other types, as well as waste generated in the production of new batteries and battery recycling at the end-of-life.

End-of-Life

A number of valuable metals and substances can be extracted from used batteries. The extraction of these materials is performed by recycling professionals who meet the same high standards as the rest of the industry and this process is covered by specific legislation. These materials are reused either in new batteries or other industries. Thousands of tons of metals such as silver, cobalt, nickel, lead and cadmium can be recovered for these purposes. This ensures environmentally sustainable and responsible production of these materials which are often scarce and of high economic value. Other battery components are likewise recycled, either being used in the production of new batteries or by other industries. Sodium-nickel chloride batteries' waste can be used in existing industries such as in the production of stainless steel and road pavement, for example. End-of-life batteries' materials are often extracted directly by battery manufacturers or their subsidiaries which allows them to safely feed back into the battery production process directly.

Numerous safeguards exist to ensure that waste from batteries is properly controlled. Legislation, industry standards and guidelines dictate how used automotive and industrial batteries are handled and their waste carefully dealt with. These high standards follow batteries through their life cycle to ensure that there is minimal impact to the environment with the entire supply chain regulated to maintain strict controls.

The Collection of Spent Automotive and Industrial Batteries

Spent lead-based automotive and industrial batteries have been recycled for decades in European lead smelting plants, thus saving resources at an early stage and assuring environmentally compatible, state-of-the-art recycling and lead acquired in this way is reused in the manufacture of batteries.

Return points for all industrial batteries are predominantly industrial and commercial companies which use industrial batteries. This ensures that the valuable materials contained within can easily be accessed by recycling professionals who have the expertise and training to deal with their recovery and handling. It also ensures that end-of-life industrial batteries are stored by professionals up until they are collected and economies of scale as these batteries are not dispersed into the wider community, allowing for ease of collection.

Return points for automotive batteries include car accessory dealerships, automobile workshops and recycling businesses, DIY and consumer markets, filling stations, local communities and metal dealerships. Collection points include metal dealerships, freight forwarders and branches of the battery industry. The batteries are picked up from the collection points by specialized companies, who ensure the safe transport of the end-of-life batteries, and are delivered to secondary smelting plants either directly or via specialised interim storage points. In this way, professionals are engaged from start to finish in ensuring the safe collection of used batteries. This infrastructure of battery collection is expected to continue in the future as the battery market for automotive batteries diversifies further.

Manufacturers of industrial Ni-Cd batteries have set up Bring Back Points (BBPs) in the EU as well as in its different geographical markets so that end users of such batteries can easily return them free of charge for the purpose of recycling. From these BBPs, spent Ni-Cd batteries are returned to fully recognised recycling facilities located in compliance with Regulation 1013/2006/EC or the Basel Convention which regulate trans-boundary shipments of hazardous waste.

The Recycling of spent Automotive and Industrial Batteries
Lead-based battery recycling

The lead from batteries in Europe operates in a closed-loop, i.e. the lead in batteries does not enter into free circulation but is collected and recycled by the battery industry and other smelters resulting in no direct environmental impact from the lead in these waste batteries.[7] More than one type of recycling process exists for lead-based automotive and industrial batteries and they fall into two broad categories of furnace for lead-based batteries: the rotary and the blast furnaces according to BAT (Best Available Technology).

The recycling efficiency of lead-based batteries without taking plastics as a reducing agent into account is in the range of 68 – 83%.[8]

Recycling results in detail regarding Lead Automotive and Industrial Batteries[9]:
The recycling results for spent Lead Automotive and Industrial Batteries fluctuate depending on the process used at each recycling plant. In general, it can be said that:

- The lead content (approximately 60% of the battery weight) enters the recycling process and approximately 97% of the total material is recovered as secondary lead.
- The plastic content[10] (approximately 7% of the weight) is usually separated before the lead is recycled, depending on the method used, and reprocessed and reused in the automobile industry, for example in bumpers, wheel arches and other parts. With another recycling method, lead batteries are reprocessed completely, including their plastic casing. The pyrolysis gas produced in the shaft furnace by the pyrolysis of the plastics is then utilized as energy in the afterburning of thermal exhaust air as a substitute for natural gas.
- The slag produced in the recycling process has as low a lead content as can be achieved and is, in some countries, usable as a construction material. However, in many instances it has to be disposed of to landfill because it is unsuitable for use due to its chemical/physical properties.
- The waste acid (approximately 30% of the weight) is treated in a variety of ways. Some companies separate and filter it to make it suitable for regenerating fresh acid for a variety of applications. Others convert the waste acid into calcium sulphate (gypsum) or sodium sulphate (soda) which can be used for various applications such as building products or detergents. Some companies simply neutralize the acid before disposal.
- The drosses removed during the refining process contain small amounts of metals other than lead. Sometimes these are recovered by the company itself, in other cases they may be sold as waste to specialist recyclers of these metals.
- The matte of lead is sold to companies which produce sulphuric acid from it through roasting. The residual lead is recycled during the further processing of the roasted material.
- Filter dusts from air purification plants contain significant amounts of lead and other metals. These dusts are normally blended back into the smelter for recovery of the metals contained. Residues from wastewater treatment plants which contain lead and other metals can be dewatered and returned to the furnaces to remove lead and other metals. In one externally conducted hydrometallurgical pre-treatment, the lead contained in the filter dust is converted into lead carbonate which is reintroduced to the recycling process as a raw material.

Under the Battery Directive (European Directive 2006/66/EC), all existing secondary lead smelters in the EU will achieve the statutory recycling efficiency of 65% by average weight of lead-based batteries, including recycling of the lead content to the highest degree that is technically feasible while avoiding excessive costs in compliance.

7. Adaptation to scientific and technical progress of Annex II ELV & RoHS Annex, Oeko-Institut e.v., pp. 57
8. Study on the calculation of recycling efficiencies and implementation of export article (Art. 15) of the Batteries Directive 2006/66/EC, BiPRO, pp. 153
9. Ibid., pp. 183
10. The plastic content of batteries varies from product to product.

Nickel-based battery recycling

Nickel[11] is a substance which can easily be recycled from numerous applications, including end-of-life batteries and given its high economic value, nickel is among the most highly recycled metals in the world today. Most recycled nickel from nickel-based batteries ends up in the manufacture of stainless steel.

Industrial Ni-Cd batteries are collected at the end of their life by the network of Bring Back Points which has been set up by producers in the EU and in other markets, and most consumer Ni-Cd batteries are collected in accordance with the requirements and targets of Battery Directive. The landfilling and incineration of industrial batteries is prohibited. Once these batteries reach a fully permitted recycling facility, all the cadmium is extracted by means of distillation and it is returned to battery manufacturers for the purpose of new battery manufacturing.

Ni-Cd battery recycling is conducted by a limited number of facilities in the EU. They all operate under the oversight of national authorities, under a permitting regime. However, these facilities offer sufficient capacity to deal with the existing and foreseen volume of spent batteries.

Apart from nickel and cadmium, the main components of a Ni-Cd battery are the alkaline electrolyte which is used for acid neutralization by hazardous waste processors, contact parts which are steel or copper and are therefore recycled, as well as plastic containers which are either recycled or with energy recovery. Reuse of plastic is not always possible due to the high number of customer specific plastic variations that were specified by customers at the time of manufacture.

Lithium-based battery recycling[12]

Recycling of lithium-based industrial and automotive batteries is still in its infancy in Europe. Due to an estimated life time of 10 years for a typical car battery, intensive battery recycling of lithium batteries used in electric vehicles will start after that period, and an increase in the lithium supplied from recycling after 2030. Lithium batteries are expected to reach an expected recycling rate of 50% of the incorporated Lithium (75 - 80% from chemical pulping plus some extra losses from battery disassembling).

End-of-life Batteries' Environmental Impact

The Battery Directive (2006/66/EC) was published in 2006 and has now been transposed into national law in all EU Member States. The Directive introduced a range of environmental and product design requirements, including restrictions on the use of certain potentially dangerous substances, the labelling of batteries containing lead, mercury or cadmium, and the collection and recycling of those batteries, when spent. Also, importantly, the Directive banned the incineration or landfill of batteries containing lead, nickel or cadmium. Thus there should be no landfill of any lead-acid or nickel-cadmium batteries and any 'scrap' batteries which are produced during the manufacturing process are sent to a recycling facility for processing. For end-of-life batteries, obligations are placed upon battery producers to ensure that they collect the batteries from the end users, thus ensuring that a high degree of recycling is carried out.

11. Nickel Institute, www.nickelinstitute.org
12. Source: http://www.chemetalllithium.com/en/lithium-resources/lithium-resources.html

Workers

It has long been recognized that workers involved in the manufacture of batteries have a potential exposure to various chemical and physical hazards. The large variety of different battery chemistries means that workers in the industry can be potentially exposed to such chemical hazards as lead, cadmium, nickel, sulphuric acid, potassium hydroxide, organic solvents etc whilst the physical hazards include risks associated with noise, electricity and manual handling.

Because of the potential health risks in the battery manufacturing processes, health surveillance of workers is widespread throughout the industry. Lead-acid and nickel-cadmium plants employ occupational health staff to carry out regular health checks of the workers and to advise company management on effective ways of controlling worker exposures to hazardous substances.

Occupational Exposure Levels

Strict regulations are in place within the EU to protect the health of employees involved in the battery making processes.

For workers involved in the manufacture of lead-based batteries, the accepted method of assessing the lead exposure of an individual is through the measurement of the lead concentration in the person's blood. A maximum allowable blood lead concentration of 70 µg/dl for males was originally stipulated in a 1982 European Directive 82/605/EEC. Although there has been no change since then for the European limit, most EU Member States have introduced their own stricter blood lead limits. For instance, the blood lead suspension level in Italy and the UK is 60 µg/dl; in Poland it is 50 µg/dl whilst in both Germany and France it is 40 µg/dl.

A case study from EUROBAT

In 2001 EUROBAT introduced a Blood Lead Reduction Programme. Following its success, the programme was revised in 2006 with aiming to further reduce Blood Lead levels in the battery manufacturing industry. Since the launch of this programme and its associated guidelines, Europe has seen a sharp decline in the Blood Lead levels of battery manufacturer employees.

EUROBAT members continue to introduce workplace measures in order to reduce the lead exposure of the workers. In 2006 the members agreed on a voluntary initiative to reduce blood lead levels to below 40 µg/dl for all employees and to below 30 µg/dl for female employees. The blood lead reduction programme was based in the main on revisions and improvements to workplace procedures, counselling on personal hygiene, personal protective equipment selection and use and worker training.

EUROBAT
Association of European Accumulator Manufacturers
Association des Fabricants Européens d'Accumulateurs
Vereinigung Europäischer Akkumulatoren-Hersteller

BLOOD LEAD REDUCTION INITIATIVES

(Update 2006)

The European Lead Battery Manufacturers, represented by:

E U R O B A T

have agreed to update the national and industry specific programs to continue the significant reduction in employee blood leads. Under this program we'll continue to minimise potential health effects to our workers.

The target of our programme is to reduce our employees blood lead levels to:

below 40 µg/dl for all employees

below 30 µg/dl for female employees

Our blood lead reduction initiatives are based on revisions where appropriate to:

- technical controls and work place procedures;
- personal hygiene;
- personal protection equipment;
- training and counselling.

The boundary conditions are described in:

BLOOD LEAD REDUCTION GUIDELINES 2006

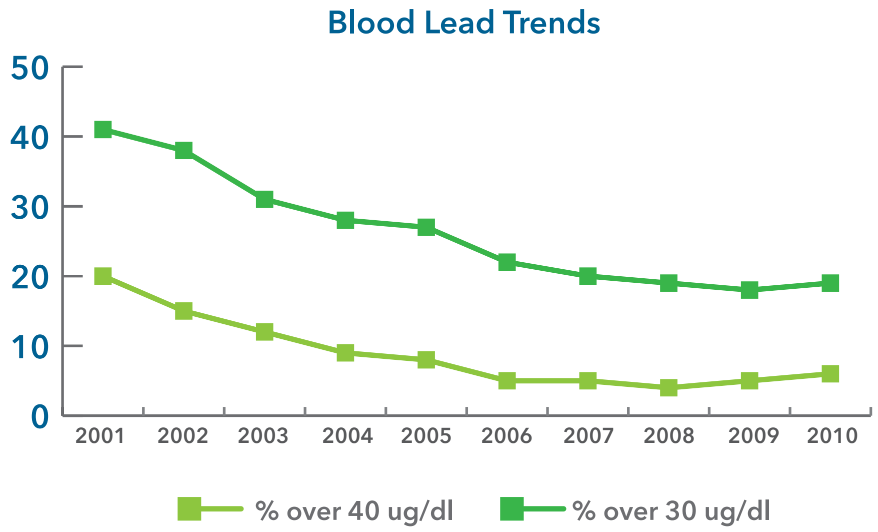
GUIDE TO LOWER BLOOD LEADS IN LEAD BATTERY INDUSTRY

Each of the single Battery manufacturers organized in EUROBAT will develop their own blood lead reduction programs based on these guidelines. The program and the insight generated in the process will be shared with interested third parties.

Signed Alfons Westgeest — December, 2006

Secretary General of EUROBAT

The progress that the industry has made in reducing exposures can be demonstrated by the graph shown below.



The percentage of workers above 40 µg/dl has been reduced from 19.4% in 2001 to 5.1% by the end of 2010. A similar marked improvement can be seen for the percentage of workers above 30 µg/dl which has more than halved since 2001.

A case study from EUROBAT

Due to the fact that workers engaged in the production of nickel are exposed to a variety of nickel minerals and compounds, in 1993 the Nickel Producers Environmental Research Association (NiPERA) in collaboration with the Nickel Development Institute (now the Nickel Institute), prepared a guide to the safe use of Nickel in the workplace[14], an updated version of which is now available online. The guide contains such useful information as guidelines for monitoring nickel exposure, control options whenever conditions suggest high exposures (including engineering, administrative and work practice controls), information on reports produced by international organisations such as the International Labour Organization (ILO) to be used as reference sources for hazard communication.

Legislative pressure to reduce lead exposure of workers is increasing and the battery industry is continuing to work hard to reduce blood lead levels.

There are also strict controls in place for the manufacture of nickel-cadmium batteries. Although the mechanism of nickel carcinogenicity is still unknown and the precise health risks, if any, of exposures to low levels of nickel are uncertain, governmental authorities have adopted recommended or mandated maximum exposure levels designed to protect the worker adequately. These OELs apply to a typical worker whose shift operates eight hours per day, five days per week. In addition to the eight-hour, time-weighted average (TWA), several countries have limits or guidelines for short-term exposures as well. Some countries allow exposures up to a specified concentration for a short time period; others specify "ceiling" concentrations that should never be exceeded. A number of standards apply to specialized operations. Some OELs are strictly health-based; others may take both health and feasibility into consideration.[13]

13. Nickel Institute, www.nickelinstitute.org
14. www.nickelinstitute.org/NiPERA/HealthScience

There are similar OELs in place for cadmium. In the past (1960s) elevated exposure levels of cadmium in the air were detected in some workplaces, sometimes as high as 1 mg/m³. Due to improved standards and control measures, these levels have dropped considerably so that most occupational exposure limits (OELs) today are in the range from 2 to 50 µg/m³. The result has been that occupational exposures today are generally below 5 µg/m³, and most cadmium workers are exposed at levels which are considered to be safe by the SCOEL (European Scientific Committee for Occupational Exposure Levels). In rare cases where cadmium air levels are higher (some very specific maintenance operations), the use of personal protective equipment is mandatory. [15]

Comprehensive hygiene and protective measures are in place for all workers who may come into contact with these substances and monitoring is in place to ensure that any employees in the battery industry who reach a certain threshold of exposure receive adequate medical attention. More importantly than this, special administrative and work practices ensure that such drastic steps are rarely needed.

Safety

Safety training is of paramount importance in the battery industry.

In general, new workers undergo an induction programme which educates the workers on the health hazards associated with the processes and stresses the importance of hygiene procedures, use of respiratory equipment, fire protection measures, safety equipment of machinery, emergency procedures etc. In addition, medical testing (e.g. lead in blood for lead workers, cadmium in urine for nickel cadmium workers) is carried out prior to the workers commencing employment.

Refresher training of workers is carried out an annual basis.

Other measures such as cleaning of machinery and workplaces, daily changes in work wear, end of shift showering, examination and testing of ventilation and fire-fighting equipment are carried out on a regular basis.

15. Cadmium Association, www.cadmium.org

Sustainability Perspectives

The European Battery industry represented in EUROBAT is continuously developing new ways to ensure that batteries remain a sustainable resource for the economy and the environment. Batteries will continue to contribute to sustainability through the development of new applications for electric vehicles and renewable energy storage. In addition, battery manufacturers continue to ensure that proper developments are undertaken to ensure that battery production remains sustainable and has a minimal impact on the environment and the health of humans.

Battery integration into existing grids will contribute to environmental sustainability by enabling the development of a European smart grid allowing for greater energy efficiencies and the creation of a common electricity market. Similarly, technologies are continuously being developed that will further enhance the capabilities of batteries in ensuring the integration of renewable energy into existing grids and allowing for improved efficiencies in energy storage. New developments in battery technologies and chemistries are continuously being looked into and will directly help in improving energy efficiency in vehicles and facilitating the introduction of full-electric vehicles including in public transport applications.

Innovations in carbon capture are also being made to ensure reduced carbon emissions from factories and these will see continuous improvements in the future. Water treatment technologies are also being developed and both these advancements will contribute significantly to continuously cleaner emissions from the production of batteries.

Improved recycling methods are also being introduced, resulting in a greater amount of materials being recovered from end-of-life batteries ensuring a further decrease on the demand for untapped resources which will ensure their continued availability in the future.

EUROBAT and its members will continue to directly contribute to the sustainability of batteries through the continued implementation of EUROBAT guidelines, monitoring of blood-lead levels in Europe and the formulation of further guidelines for the battery industry in areas such as respect of workers health and safety and the safe transport of batteries.

A case study from Johnson Controls

Improved smelting and refining processes by using oxygen to optimize the furnace processes in lead-based battery recycling will increase fuel efficiency, reduce off-gas volume and CO_2 emissions. For lead refining, intensified oxidation processes through high turbulence mixers and fine dispersed gas bubbles injectors will reduce the batch treatment times, saving energy and reducing the amount of drosses produced. The selectivity of refining steps is expected to improve, allowing enriching and concentrating valuable alloying elements, such as Tin and Antimony in separate phases and thus enabling an easier reuse.

Conclusion

EUROBAT
Association of European Automotive and Industrial Battery Manufacturers

This overview illustrates how batteries are an essential element of everyday life. They are used in a variety of applications on which we rely and are necessary for meeting the standard of living we expect today. Furthermore, the European battery industry creates numerous jobs in Europe and has positive economic implications, either directly through the production and export of batteries, but also through their activities in recycling end-of-life batteries and returning valuable resources to the market.

It should now also be clear that special precautions are taken at every step in the manufacture, use and end-of-life batteries and that that there are numerous legislative and industry led safeguards in place to ensure that there is the least impact on the environment and human health from the production, use and recycling of batteries.

Battery production is not only sustainable but batteries are also a key enabler to ensure a cleaner and more environmentally friendly use of energy in all other industries. Batteries are an integral part of the solution to global goals for reducing CO_2 emissions either by facilitating the use of renewably sourced energy, the introduction of electric vehicles or improving the design of batteries to more effectively use and recover energy. From start to finish, batteries are a truly sustainable industry.

About EUROBAT

EUROBAT
Association of European Automotive and Industrial Battery Manufacturers

EUROBAT is the association of automotive and industrial battery manufacturers. It acts as a unified voice in promoting the interests of the European automotive, industrial and special battery industries to the EU institutions, national governments, customers and the media. With over 30 members from across the continent comprising more than 85% of the battery industry in Europe, EUROBAT works with stakeholders to help develop new battery solutions to issues of common concern in areas like e-mobility and renewable energy storage. In addition to this, EUROBAT coordinates the exchange of information on European battery issues and serves as an advisor on all information related to the starter and industrial battery domain.

Structure of EUROBAT

General Assembly

The General Assembly is the main decision body of EUROBAT and meets once per year alongside the EUROBAT Forum. All Members (Regular and Associate) may attend the General Assembly. However, only Regular Members have full voting rights. The General Assembly decides on all matters concerning the internal organization of the Association, financial obligations of the Members towards the Association and the incurred liabilities towards third parties, which are not delegated to other organs.

Board

The Board is responsible for implementing the resolutions of the General Assembly and managing the business of EUROBAT. The Board's members are elected by the General Assembly for a period of 2 years.

EUROBAT Board:

- Ray Kubis, EnerSys EMEA, EH Europe GmbH; Chairman
- Andreas Bawart, Banner GmbH; Vice-Chairman
- John Searle, SAFT; Vice-Chairman
- Michael Ostermann, Exide Technologies
- Federico Vitali, FAAM S.p.A
- Nicola Cosciani, FIAMM SpA
- Marc Zoellner, Hoppecke Batterien GmbH & Co KG
- Johann-Friedrich Dempwolff, Johnson Controls Power Solutions Europe
- Meir Arnon, Vulcan Automotive Industries
- Charles-Louis Ackermann, Accumalux S.A
- Marcus Ulrich, Entek International

EUROBAT Committees

Three committees provide the platform for the majority of EUROBAT's activities and are formed according to the needs and the objectives of the Association. In addition to this, EUROBAT maintains a number of task forces on specific issues who report to the committees.

Committee for Environmental Matters

The Committee for Environmental Matters ensures that the European battery industry operates to the highest standards of environmental legislation, safeguarding the interest of those who work in the industry as well as its consumers. The committee achieves this by monitoring EU legislation in the fields of safety and the environment and regularly issues guidance to members on a number of topics to ensure that the industry operates in accordance with these rules. It also engages with European decision-makers to provide them with the information they require on the battery industry to ensure better policy making.

Automotive Batteries Committee

The Committee for Automotive Batteries handles all kinds of automotive application issues. Europe's major automotive market is the Starting, Lighting and Ignition battery (SLI-battery). The ABC deals with statistics, standardisation issues and on expanding marketing initiatives to develop new demand for automotive batteries. The committee has set up two task forces: *ABC TF1 on Start-Stop Micro Hybrid Battery Labelling* covers the issue of warning labelling and investigates the minimum technical requirements for Start-Stop micro hybrid battery labelling.

ABC TF2 on Mild, Full and HEV/EV Batteries covers Hybrid Electric Vehicles/Electric Vehicle statistics and EU strategic monitoring in relation to legislation, standardisation activities, deployment activities and Research & Technical Development support schemes.

Industrial Batteries Committee

The Committee for Industrial Batteries monitors activities in relation to motive and stand-by battery markets. The IBC is elaborating accurate statistical information for Europe, Middle- East and Africa to identify markets and trends. The committee also deals with European and worldwide standardisation and the pre-standardisation phase. To define and promote new market opportunities in relation to renewable energy integration, the IBC has recently set up two new task forces: IBC Task Force on Rural Electrification and IBC Task Force on Smart Grids.

Communications Task Force

The Communications Task Force is responsible for ensuring that EUROBAT's positions are communicated to the public and media through its website, newsletters and the EUROBAT Forum, an annual meeting of members to address battery industry issues which occurs alongside the General Assembly.

For more on EUROBAT, go to our website www.eurobat.org.

List of EUROBAT Members

EUROBAT
Association of European Automotive and Industrial Battery Manufacturers

Members

There are two different categories of membership in EUROBAT. Regular members are companies who manufacture and sell storage batteries in Europe and have full rights and obligations. Associate members are companies that are sub-contractors of raw material or of equipment to storage battery manufacturers and have limited rights and obligations.

Regular Members

Accumulatorenwerke Hoppecke Carl Zoellner & Sohn

Akkumulatorenfabrik Moll

ASSAD

Banner GmbH

EnerSys EMEA EH Europe

Exide Technologies

FAAM

FIAMM

FIAMM Sonick

INCI AKÜ SANAYI VE TIC.

Johnson Controls

Koncern ''Farmakom MB'' ŠABAC Fabrika Akumulatora Sombor

Mutlu Akü ve Malzemeleri Sanayi

S.C. ROMBAT

SAFT

Systems Sunlight

TAB tovarna akumulatorskih Baterij

Vulcan-Volta Batteries

Yuasa Battery Europe

Associate Members

Abertax Group

Accuma SpA

Accumalux S.A

Amer-Sil S.A.

Berzelius Metall GmbH

BM Rosendahl

Daramic, Inc

DEKRA Certification B.V.

Entek International Ltd

Evonik Litarion GmbH

Froetek Kunststofftechnik GmbH

Glatfelter Gernsbach GmbH

Hollingsworth & Vose Company

MECONDOR

MTH Metalltechnik Halsbrücke GmbH & Co KG

NISSAN Motor

Recylex SA

SOVEMA S.p.A

T.B.S Enginieering Ltd.

Water Gremlin Aquila Company S.p.A.

EUROBAT

Association of European Automotive and Industrial Battery Manufacturers

Avenue Jules Bordet, 142 • B-1140 Brussels, Belgium
Tel: +32 2 761 1653 • Fax: +32 2 761 1699 • E-mail: eurobat@eurobat.org • www.eurobat.org